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Sushma Sharma
Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu and Kashmir, India

Mahital Jamwal
Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu and Kashmir, India

Nirmal Sharma
Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu and Kashmir, India

Amit Jasrotia
Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu and Kashmir, India

Zahid A Bhat
Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu and Kashmir, India

Kamakshi Sharma
Division of Post Harvest Management, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Main Campus, Chatha, Jammu and Kashmir, India

Ayushi Sambyal
Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu and Kashmir, India

Nikhil Thakur
Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu and Kashmir, India

Corresponding Author:
Sushma Sharma
Division of Fruit Science, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu and Kashmir, India

Characterization of apple germplasm: Insight to trait variability and selection

Sushma Sharma, Mahital Jamwal, Nirmal Sharma, Amit Jasrotia, Zahid A Bhat, Kamakshi Sharma, Ayushi Sambyal and Nikhil Thakur

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Abstract
The investigation entitled on "Characterization of Apple (*Malus* x *domestica* Borkh.) Germplasm" was carried out in order to document and characterize the apple germplasm growing at Bhaderwah region of J&K. The germplasm under study comprised of forty-eight apple genotypes to analyse biochemical variability. Among the biochemical characters, Wide range of variation was observed for various biochemical attributes. Range of total soluble solids, titratable acidity, total sugars, pectin content, anthocyanin and total phenols ranged between 9.95 ^{o}B in BA-18 to 13.12 ^{o}B in BA-1, 0.21 percent in BA-15 to 0.80 percent in BA-4, 9.55 percent (BA-19) to 12.23 percent (BA-1), 9.62 percent (BA-44) to 13.75 percent (BA-1) and 44.21 percent (BA-40) to 84.67 percent (BA-10) respectively. Based on the findings of the investigation, it is concluded that high diversity existed for biochemical characters among the apple germplasm growing at Bhaderwah region of J&K. The seedling origin plants were distinct from the commercial cultivars of apple. The identified promising seedling strains can be used for further breeding programme in order to enhance the production and quality of apple in J&K in general and Bhaderwah region, in particular.

Keywords: Apple, germplasm, diversity, biochemical, breeding

Introduction
The apple (*Malus* × *domestica* Borkh.) is one of the most widely cultivated and consumed fruits globally. In India, apple is cultivated on 315 thousand hectares area with annual production of 2506 thousand metric tonnes (Anonymous, 2023a) [1]. In India, apple is mainly grown in Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Arunachal Pradesh and Nagaland. In Union Territory of Jammu and Kashmir, The total area under apple is around 1,64,744 hectares with a production of 18,82,320 MT and productivity of 11.42 metric tonnes/hectare. However, in Jammu division, the area under apple is around 18,416 hectares with a production of 30,596 MT (Anonymous, 2023b) [2]. Apple fruit is known for its rich taste, crisp texture, and nutritional value. This fruit is not only an important dietary component but also an excellent source of bioactive compounds with potential health benefits. Biochemical characterization of apple fruit involves the systematic analysis of its chemical composition, focusing on various nutrients, antioxidants, vitamins, phenolic compounds, sugars, organic acids, and enzymes that contribute to its unique flavor, texture, and overall quality. Through the biochemical profiling of apples, researchers can uncover the underlying metabolic processes that influence fruit development, ripening, and postharvest quality Dar *et al*., (2015) [3]. Additionally, understanding the biochemical makeup of apples allows for the identification of specific cultivars with superior health-promoting properties, such as enhanced antioxidant activity and reduced susceptibility to diseases. This comprehensive biochemical characterization serves as a foundation for improving apple breeding, storage techniques, and processing methods, thereby enhancing its nutritional and commercial value. There is a growing interest in the characterization of local plant genotypes in order to preserve biodiversity and to search for agronomic and adaptive traits, such as better adaptation to local conditions and resistance/tolerance to pathogens. Apple breeders have been eager to exploit the broad genetic diversity of malus species in order to meet consumer demands for new cultivars.

Materials and Methods

Present study was carried during 2023-2024 at Bhaderwah region of doda district of (J&K), India. It is located at 32^0 53' and 34^0 21' latitude and 75^0 01' and 76^0 47' E longitudes with an altitudinal 1600 m above the mean sea level. The climate is characterized as sub humid temperate region, rainfall restricted mostly to winter months. Snowfalls during December, January and February months are also experienced.

Table 1: Name and code of the genotype of forty-eight apple (*Malus* × *domestica* Borkh.) germplasm

S. No.	Code	Variety
1.	BA-1	Starking delicious
2.	BA-2	Red delicious
3.	BA-3	Oregon spur
4.	BA-4	Red spur
5.	BA-5	Red gold
6.	BA-6	Jona gold
7.	BA-7	Coop-IV
8.	BA-8	Vista Bella
9.	BA-9	Super chief
10.	BA-10	Lodh
11.	BA-11	Vance delicious
12.	BA-12	Silver spur
13.	BA-13	Mollies delicious
14.	BA-14	Red chief
15.	BA-15	Gold spur
16.	BA-16	Royal delicious
17.	BA-17	Well spur
18.	BA-18	Top red
19.	BA-19	Lal Ambri
20.	BA-20	Firdous
21.	BA-21	Golden delicious
22.	BA-22	Hybrid-29
23.	BA-23	Starkrimson
24.	BA-24	Hybrid-60
25.	BA-25	Akbar
26.	BA-26	Shireen
27.	BA-27	Amarican Trail
28.	BA-28	Hard France
29.	BA-29	Ambari
30.	BA-30	Maharaji
31.	BA-31	Local germplasm
32.	BA-32	Local germplasm
33.	BA-33	Local germplasm
34.	BA-34	Local germplasm
35.	BA-35	Local germplasm
36.	BA-36	Local germplasm
37.	BA-37	Local germplasm
38.	BA-38	Local germplasm
39.	BA-39	Local germplasm
40.	BA-40	Local germplasm
41.	BA-41	Local germplasm
42.	BA-42	Local germplasm
43.	BA-43	Local germplasm
44.	BA-44	Local germplasm
45.	BA-45	Local germplasm
46.	BA-46	Local germplasm
47.	BA-47	Local germplasm
48.	BA-48	Local germplasm

Sample Collection: Apple fruits from all the selected genotypes comprising of commercial cultivars and indigenous germplasm were collected with uniform size, maturity, and free from visible damage were sourced from different location of Bhaderwah region. The fruits were harvested at the commercially accepted maturity stage and analysed for various biochemical parameters in the Research Laboratory of Division of Fruit Science, SKUAST-Jammu, Chatha under controlled conditions to prevent any deterioration or degradation of the biochemical properties.

The total soluble solids (TSS) of the fruit juice were recorded by using an Erma hand refractometer (0-32º B), TSS of the fruit juice were measured at room temperature in terms of degree Brix (ºB) in accordance according to the standard procedure as given by Lahamge (2017) [10]. The total titrable acidity was calculated in terms of malic acid on the basis of 1ml of 0.1N NaOH solution equivalent to 0.0067 and expressed in terms of percent acidity. Fruit juice pH was estimated by pH meter by using method suggested by Rangana (1997) [15]. The reducing sugars were estimated by using Lane and Eynon (1923) [11] method with modification suggested by Rangana (1997) [15]. Pectin content was extracted by the method of Ranganna (1997) [15]. The total phenols of apple fruit were measured using the Folin-Ciocalteu's colorimetric assay. This method is based on electron transfer assay (Ahmed and Abozed, 2015) [3]. Anthocyanin is determined by the pH differential spectroscopic method and the results were calculated mg/100 g (Okatan *et al*., 2019) [14].

Results and Discussion

A significant variability was observed in biochemical traits across the genotypes illustrated in table 4.8. The biochemical traits namely TSS, pH, acidity, total sugar, reducing sugar, non-reducing sugar, pectin, phenol and anthocyanin were studied.

The genotypes showed considerable variation in TSS, the minimum TSS recorded in BA-18 with 9.94 ºB and maximum in BA-1 with 13.12. These results are supported by the findings of Karatas (2021) [7] where they observed soluble sugar contents ranged from 8.90-13.00 percent. Among the genotypes a significant variation was found in pH value ranging from 2.62 in BA-9 to 4.51 in BA-12. These results are also supported by finding of Macit *et al.* (2021) where they recorded the pH value varied from 3.72 to 4.18. The acidity percentage across the genotypes expressed considerable variation ranging from 0.20% in (BA-14) to 0.80% (BA-4 and BA-36), similar results were also observed by Kumar *et al.* (2018) [9] where they observed titerable acidity ranged from 0.25% to 0.57%. A significant variation was recorded among the genotypes with regards total sugar content. The genotypes BA-1 showed maximum total sugar 12.23% content whereas the minimum total sugar content in BA-29 with 9.75%. The variability in sugar content might be influenced by genetic factors as well as environmental conditions, as reported by Kader (2008) [6]. A considerable variation was noted across the apple genotypes with regards reducing and non-reducing sugar content. The reducing sugar content was highest in BA-11 with 7.92% while non-reducing sugar was highest in BA-1 with 6.14%. The pectin content among the genotypes was found significantly difference. The maximum pectin content occurred in genotype BA-16 and was minimum content in BA-3. These findings are consistent with the work of Ornelas-Paz *et al.*, (2018) [16] who reported that pectin content in apple varied with maturity time.

The phenolic content, which contributes to antioxidant properties, was highest in BA-10 (84.67 mg/100 g). These results are advocated by the finding of Karatas N. (2021) [7]

where they found total phenolic content 87mg to 164mg/100 g fresh weight. Anthocyanin content ranged from 6.45 mg/100 g (BA-15) to 7.88 mg/100 g (BA-1). The observed variability aligns with the findings of Liu *et al*. (2018), who reported genotype-dependent differences in phenolic and anthocyanin content.

Table 2: Biochemical variability in apple (*Malus* x *domestica* Borkh.) genotypes

Sr. No.	Genotypes	TSS (ºBrix)	pH	Acidity (%)	Total sugar (%)	Reducing sugar (%)	Non reducing sugar (%)	Pectin (%)	Phenol (mg/100 g)	Anthocyanin (mg/100 g)
1.	BA-1	**13.12**	4.22	0.30	**12.23**	6.09	**6.14**	13.75	51.32	**7.88**
2.	BA-2	12.74	4.00	0.39	12.12	6.08	6.04	13.64	52.12	7.75
3.	BA-3	12.94	3.38	0.50	11.94	6.24	5.70	9.45	54.45	7.61
4.	BA-4	12.03	3.04	0.80	11.57	6.22	5.35	11.23	57.43	7.69
5.	BA-5	11.03	3.28	0.70	11.27	7.01	4.26	11.40	56.17	7.41
6.	BA-6	11.46	3.17	0.48	11.26	6.64	4.62	9.67	61.33	6.94
7.	BA-7	11.32	3.04	0.60	10.49	6.05	4.44	12.32	63.23	7.28
8.	BA-8	10.45	3.08	0.67	11.07	6.14	4.93	11.45	58.32	7.43
9.	BA-9	10.22	2.62	0.78	10.33	7.22	3.11	9.89	50.09	6.89
10.	BA-10	11.06	4.26	0.40	10.86	6.87	3.99	10.23	84.67	6.87
11.	BA-11	10.98	4.33	0.30	10.58	7.92	2.66	10.45	53.17	7.43
12.	BA-12	11.05	4.51	0.41	10.20	7.26	2.94	10.67	61.21	7.23
13.	BA-13	10.61	4.40	0.50	10.66	7.84	2.82	10.65	60.32	7.41
14.	BA-14	11.07	4.21	0.20	10.54	6.78	3.76	11.12	58.12	6.96
15.	BA-15	11.26	4.49	0.21	10.21	6.94	3.27	9.34	62.23	6.45
16.	BA-16	10.65	3.08	0.60	10.45	6.80	3.64	14.24	78.43	6.78
17.	BA-17	11.66	3.67	0.52	10.95	7.03	3.92	9.56	58.34	7.32
18.	BA-18	9.94	4.23	0.35	10.37	7.04	3.33	12.21	64.21	7.56
19.	BA-19	10.32	3.11	0.70	9.84	6.56	3.28	9.78	62.13	7.61
20.	BA-20	10.78	4.28	0.28	10.70	6.78	3.92	11.67	56.14	7.34
21.	BA-21	11.02	3.37	0.56	10.38	7.34	3.04	10.21	54.27	6.91
22.	BA-22	11.35	3.74	0.69	10.63	7.45	3.18	10.23	53.76	7.48
23.	BA-23	10.67	3.68	0.50	10.04	7.18	2.86	10.24	56.73	7.32
24.	BA-24	10.56	4.02	0.40	10.17	7.65	2.53	10.32	61.23	7.41
25.	BA-25	11.17	4.24	0.30	9.91	7.48	2.43	10.34	57.42	7.55
26.	BA-26	11.67	4.12	0.41	11.01	7.41	3.60	10.65	55.61	7.34
27.	BA-27	9.95	3.15	0.60	9.93	7.93	2.00	10.67	60.12	6.88
28.	BA-28	11.12	3.19	0.69	10.53	6.91	3.62	9.89	54.09	6.67
29.	BA-29	11.02	3.71	0.41	9.75	7.37	2.38	10.41	55.17	7.44
30.	BA-30	10.09	3.15	0.50	10.51	7.29	3.22	9.62	49.09	7.23
31.	BA-31	12.02	3.05	0.60	9.88	7.65	2.23	11.40	50.48	6.79
32.	BA-32	10.82	3.18	0.50	10.42	7.94	2.48	11.12	48.05	7.33
33.	BA-33	11.79	4.21	0.42	10.35	7.35	2.99	10.98	53.85	7.49
34.	BA-34	10.94	3.82	0.61	9.81	7.76	2.05	10.97	52.12	7.72
35.	BA-35	11.77	3.22	0.69	10.56	7.97	2.59	10.43	56.35	6.96
36.	BA-36	11.69	4.03	0.80	10.71	8.04	2.67	10.56	62.03	7.31
37.	BA-37	11.02	3.54	0.49	9.55	7.36	2.19	10.76	55.42	6.95
38.	BA-38	11.10	2.87	0.52	10.16	7.05	3.11	10.87	51.23	7.01
39.	BA-39	11.38	3.14	0.60	9.57	6.62	2.96	9.88	46.03	6.91
40.	BA-40	10.81	3.32	0.77	10.13	7.31	2.81	10.25	44.21	7.27
41.	BA-41	11.25	3.05	0.60	9.61	7.37	2.24	10.86	45.06	6.98
42.	BA-42	10.35	3.14	0.40	10.73	7.72	3.02	10.94	47.52	7.47
43.	BA-43	11.91	3.39	0.30	11.44	7.81	2.63	9.89	44.38	6.92
44.	BA-44	11.07	3.42	0.60	9.90	7.64	2.26	9.48	49.32	6.86
45.	BA-45	11.37	3.27	0.50	10.43	7.48	2.94	10.34	61.04	7.53
46.	BA-46	10.46	3.13	0.60	10.26	6.54	3.72	10.92	48.93	7.12
47.	BA-47	11.55	3.16	0.30	11.89	6.78	3.11	9.98	57.34	7.04
48.	BA-48	10.97	3.07	0.63	10.16	6.84	3.32	10.31	51.42	7.28
	SE m±	0.44	0.34	0.036	0.47	0.43	0.28	0.41	2.35	0.32
	CV	6.90	16.55	11.93	8.029	10.49	14.66	6.76	7.27	7.78

Table 3: Correlation between biochemical traits in different apple genotypes

	Acidity	pH	TSS	Total sugar	Reducing sugar	Non reducing sugar	Pectin	Phenol	Anthocyanin
Acidity	1.000	-0.486	-0.037	0.089	0.027	-0.061	-0.038	-0.126	-0.036
pH	-0.486**	1.000	0.091	0.065	0.022	0.029	0.227**	-0.011	-0.011
TSS	-0.037	0.091	1.000	0.283**	-0.098	0.367**	0.356**	-0.079	0.043
Total sugar	-0.089	0.107	0.283**	1.000	-0.257**	0.613**	0.364**	0.057	0.106
Reducing sugar	0.027	0.065	-0.098	-0.257**	1.000	-0.577**	-0.301**	-0.126	-0.125
Non reducing sugar	0.061	0.022	0.367**	0.613**	-0.577**	1.000	0.515**	0.131	0.183*
Pectin	-0.038	0.029	0.356**	0.364**	-0.0301**	0.515**	1.000	-0.093	0.164*
Phenol	-0.126	0.227**	-0.079	0.057	-0.126	0.131	-0.093	1.000	-0.074
Anthocyanin	-0.036	-0.011	0.043	0.106	-0.125	0.183*	0.164*	-0.074	1.000

The correlation coefficients among characters in 48 apple genotypes were computed and presented in correlation table 3. The total sugar showed strong positive correlations (r= 0.283) with TSS followed by with reducing sugar (r=0.367), and with non-reducing sugar (r = 0.356). The pectin content was found to have positively correlated with non-reducing sugar (r = 0.515) and with phenol content (r = 0.183).

Conclusion

Based on the findings of the present investigation, it is be concluded that genotypes (BA-43 and BA-47) are diverse at biochemical level and have good fruit attribute like TSS, Sugars, Phenol, Anthocyanin, pectin and acidity content. Both the genotypes found to be more diverse than Red Delicious with respect to different fruit characters. It is further recommended that these promising seedling strains are having the potential for quality apple production and may be used for further multiplication and breeding programmes in order to enhance the production and quality of apple in province of J&K.

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