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Assessment of banana genotypes for physico-chemical fruit quality and post-harvest characteristics

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Abstract

Banana (*Musa* spp.) is one of the world's most important fruit crops, serving as a vital source of nutrition, income, and livelihood security in tropical and subtropical regions. India leads global banana production, contributing significantly to fruit availability and rural employment. However, the quality and post-harvest behaviour of banana fruits vary widely across genotypes due to their diverse genetic makeup and ecological adaptation. The present study entitled "Assessment of banana genotypes for physico-chemical fruit quality and post-harvest characteristics" was carried out during 2024-25 at ICAR-AICRP on Fruits, Kittur Rani Channamma College of Horticulture, Arabhavi, under the University of Horticultural Sciences, Bagalkot, Karnataka. Sixty-four banana genotypes were evaluated in a Complete Block Design (CBD) with two replications to assess variation in fruit quality and storage potential. Significant differences were observed among genotypes for total soluble solids (TSS), titratable acidity, TSS:acid ratio, ascorbic acid content, shelf life, and physiological loss in weight (PLW). The genotype 'Sakkarebale' recorded the highest TSS (26.15 °B) and lowest acidity (0.24%), resulting in a superior TSS:acid ratio (109.15), while 'Poovan' exhibited the highest ascorbic acid content (7.13 mg/100 g). 'Popoulu' showed the longest shelf life (11.62 days), and 'Red Banana' recorded the least PLW (5.23%). The variability observed highlights the rich genetic diversity within *Musa* germplasm, providing valuable opportunities for selecting superior parental lines for quality improvement and post-harvest resilience. The findings underline the potential of specific genotypes for commercial cultivation and utilization in banana breeding programs targeting enhanced fruit quality and storability.

Keywords: *Musa* spp., genotype evaluation, fruit quality, shelf life, genetic diversity

Introduction

Banana (*Musa* spp.) is an ancient, widely cultivated fruit crop belonging to the family Musaceae and thrives in humid tropical and subtropical regions. Originating from South-East Asia (Sardos *et al.*, 2016) ^[11], this herbaceous perennial monocot of the order Scitamineae is one of the most produced and consumed fruits in India. Globally, it ranks as the fourth most important food crop after rice, wheat, and potato, being cultivated in about 130 countries. In India, banana occupies a premier position among fruit crops, with 9.94 lakh hectares under cultivation, 366.14 lakh metric tonnes of production, and a productivity of 36.83 MT ha⁻¹, making it the largest producer worldwide (Indiastat, 2023) ^[2]. In Karnataka alone, banana is grown in 1.08 lakh hectares with a productivity of 27.45 MT ha⁻¹, significantly contributing to the state's fruit economy.

Banana holds immense socio-economic importance, providing nutrition and livelihood support across tropical and subtropical regions (Singh *et al.*, 2016) ^[13]. The term 'banana' entered English from the Guinea coast of West Africa via Portuguese, while 'plantain'-referring to cooking types-comes from the Spanish 'plantano' (Karamura and Karamura, 1995) ^[7]. While dessert bananas are sweet and consumed ripe, plantains are starchier and mainly used in cooking, serving as a staple food in Central and West Africa, the Caribbean and Latin America due to their high nutritional value and easy digestibility. Millions of people worldwide depend on banana cultivation for livelihood and food security. In the face of global hunger, malnutrition, and climate change, sustainable banana production is considered a crucial pillar of a resilient food system with minimal environmental impact (Tutwiler *et al.*, 2017) ^[15].

Nutritionally, banana is a rich source of carbohydrates, vitamins (riboflavin, folate, vitamin C), carotenoids (β -carotene, α -carotene, lutein, zeaxanthin), and minerals (K, Ca, Mg, Fe, Zn, Cu, B) (Ashokkumar *et al.*, 2018)^[5]. These components not only make it an ideal food for energy and nourishment but also position it as a potential crop to combat hidden hunger and micronutrient malnutrition. Despite its importance, banana production and marketing face challenges due to variations in fruit physico-chemical properties, post-harvest behaviour, and storage stability among genotypes. Hence, evaluating physico-chemical fruit quality and post-harvest characteristics among diverse banana genotypes is crucial for identifying superior types suited for fresh consumption, processing, and long-distance marketing. Such assessments also provide valuable insights into genetic variability, aiding in breeding programs aimed at developing high-quality, nutritionally enriched, and shelf-stable cultivars.

Materials and Methods

Climatic conditions

The experiment was conducted at the ICAR-AICRP on Fruits, Kittur Rani Channamma College of Horticulture (KRCCH), Arabhavi, during the 2024-25 growing season. A total of sixty-four banana genotypes were evaluated under a Complete Block Design (CBD) with two replications, maintaining six plants per treatment. The crop was planted at a spacing of 1.8 m $\times$ 1.8 m, ensuring uniform plant population and growth conditions across treatments. All standard agronomic and management practices recommended for banana cultivation were followed uniformly throughout the experimental period to ensure healthy crop growth and minimize environmental variability. Observations were systematically recorded on physico-chemical and post-harvest fruit quality parameters from selected representative plants in each treatment and replication.

Quality Parameters

Five fully ripened fingers from the third hand of each bunch were selected to record the fruit quality parameters. The average of five observations was computed for each genotype.

Total Soluble Solids ($^{\circ}$ Brix)

The total soluble solids (TSS) content of the pulp was determined using a hand refractometer and expressed in degrees Brix ($^{\circ}$ Brix).

Titrateable Acidity (%)

Titrateable acidity was estimated by the titration method as described by Ranganna (1977)^[9]. A known amount of sample (1.0 g) was reconstituted with distilled water, and 10 ml of the extract was titrated against 0.1 N NaOH using phenolphthalein as an indicator. The light pink color persistence for a few seconds marked the endpoint. The acidity was expressed as citric acid equivalent using the formula:

$$\text{Titrateable acidity (\%)} = \frac{\text{Vol. of NaOH (ml)} \times \text{Normality of NaOH} \times 0.064 \times 100}{\text{ml or g of juice}}$$

Where 0.064 = Equivalent weight of citric acid in grams.

Ascorbic Acid Content (mg/100g)

Ascorbic acid content was determined following the method outlined by AOAC (2000)^[1], based on the reduction of 2,6-dichlorophenol indophenol (2,6-DCPIP) by ascorbate. One gram of sample was macerated in 4% oxalic acid, filtered through

muslin cloth, and made up to 50 ml. Five ml of aliquot was mixed with 5 ml of 4% oxalic acid and titrated against 2,6-DCPIP dye solution until a pink endpoint appeared. The volume of dye used for the sample (TV_2) and standard ascorbic acid (TV_1) was recorded, and the ascorbic acid content was calculated using the formula:

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Ascorbic acid in standard} \times TV_2 \times \text{Vol. made up} \times 100}{\text{Aliquot taken} \times TV_1 \times \text{Weight of sample}}$$

Brix-to-Acid Ratio

The ratio between total soluble solids and titrateable acidity was computed as:

$$\text{Brix:Acid Ratio} = \frac{\text{Total Soluble Solids (}^{\circ}\text{Brix)}}{\text{Titrateable Acidity (\%)}}$$

Post-Harvest Parameters

Shelf Life (days)

Shelf life was recorded as the number of days from the onset of ripening until the fruits reached the last edible stage. The mean shelf life for each genotype was calculated and expressed in days.

Physiological Loss in Weight (PLW) (%)

The physiological loss in weight of fruits during storage was determined by recording the initial and final weights of fruits at the end of their shelf life. The percentage loss in weight was calculated using the formula:

$$\text{PLW (\%)} = \frac{\text{Initial weight} - \text{Weight at end of shelf life}}{\text{Initial weight}} \times 100$$

Statistical Analysis

The experimental data were subjected to analysis of variance (ANOVA) using the method outlined by Panse and Sukhatme (1985)^[3]. The level of significance was tested at 5% ($p \leq 0.05$) to determine the variability among genotypes for each trait. The coefficient of variation (CV) and critical difference (CD) values were computed to compare treatment means.

Results and Discussion

The evaluation of sixty-four banana (*Musa* spp.) genotypes for physico-chemical and post-harvest quality traits revealed significant diversity among the genotypes studied, reflecting the broad genetic base and differential adaptation of *Musa* germplasm under the agro-climatic conditions of northern Karnataka. The results are presented and discussed below.

Total Soluble Solids ($^{\circ}$ Brix)

The total soluble solids (TSS) among the genotypes varied significantly, indicating distinct differences in sweetness and ripening behaviour. The maximum TSS was recorded in 'Sakkarebale' (26.15 $^{\circ}$ B), which was statistically on par with 'Ney Poovan' (25.37 $^{\circ}$ B), 'Udayam' (25.35 $^{\circ}$ B), and 'Malaikali' (25.14 $^{\circ}$ B), while the minimum was observed in 'NRCB-7' (13.84 $^{\circ}$ B). High TSS is a desirable trait associated with better flavor, consumer acceptability, and market preference. The higher TSS in 'Sakkarebale' and 'Ney Poovan' could be attributed to enhanced carbohydrate accumulation during ripening and greater efficiency in the conversion of starch to sugars, which is genetically controlled and influenced by ripening physiology. Conversely, lower TSS in 'NRCB-7' may be due to slower starch hydrolysis or incomplete ripening.

Similar variations in TSS content among banana genotypes were also reported by Syamal and Mishra (1989)^[14], Medhi (1994)^[8], and Sagar *et al.* (2018)^[10].

Titrateable Acidity (%)

Significant differences in titrateable acidity were recorded across genotypes. The lowest acidity was observed in 'Sakkarebale' (0.24%), followed by 'Mysore Mitli' (0.25%), 'Nendran', 'NCR-17', 'Karibale', 'Grand Naine', and 'KBS-8' (each 0.28%), whereas the highest acidity was noted in 'Poovan' (0.60%). The inverse relationship between TSS and acidity observed in this study suggests that sweeter fruits generally exhibit lower organic acid content, which enhances palatability and eating quality. Genotypic differences in acid content are largely governed by metabolic activity during ripening, where organic acids serve as intermediates in respiration and sugar metabolism. Similar patterns of variation were observed by Devi *et al.* (2012)^[6] and Sagar *et al.* (2018)^[10], who reported that low-acid cultivars were more desirable for dessert purposes.

TSS to Acid Ratio

The TSS:acid ratio serves as an important indicator of fruit taste

balance, combining sweetness and acidity attributes. Among the genotypes, 'Sakkarebale' recorded the highest ratio (109.15), followed by 'Ney Poovan' (90.60), while the lowest was recorded in 'Yangambi Selection' (31.72). A higher TSS:acid ratio reflects a favourable flavour profile and better consumer acceptance. The superior taste quality in 'Sakkarebale' is attributable to its higher sugar content and lower acidity, making it suitable for table consumption. These results align with the findings of Syamal and Mishra (1989)^[14] and Medhi (1994)^[8], who emphasized that genotypes with high TSS:acid ratios possess enhanced dessert quality.

Ascorbic Acid Content (mg/100 g)

The ascorbic acid (vitamin C) content showed notable variation among genotypes, ranging from 1.49 mg/100 g in 'Sakkarebale' to 7.13 mg/100 g in 'Poovan', which recorded the highest value. The observed differences could be attributed to genotypic variation in biosynthesis and retention of ascorbate during fruit development and ripening. Higher ascorbic acid levels contribute to antioxidant potential and post-harvest quality stability, making such genotypes desirable for both nutritional and industrial purposes. The relatively.

Table 1: Performance of banana genotypes for quality parameters

Sl. No.	Genotypes	TSS (°B)	Titrateable acidity (%)	TSS: Acid ratio	Ascorbic acid (mg/100g)
AAAB					
1	Gold Finger	19.34	0.34	57.74	2.48
2	FHIA-18	20.42	0.36	56.71	2.14
ABB					
3	BCB-I	20.41	0.33	62.82	1.55
4	BCB-II	20.51	0.31	67.27	2.67
5	Karibale	20.18	0.28	73.40	2.34
6	CO-3	19.33	0.32	61.38	2.42
7	Budu Mitka	18.57	0.30	62.96	2.64
8	Budu Bale	20.92	0.32	66.41	1.52
9	Karpurbale	20.76	0.34	61.98	3.64
10	Karpurvalli	20.12	0.41	49.69	4.69
11	Kothia	17.78	0.45	39.53	4.32
12	Kovvur Bontha	17.01	0.44	38.69	3.52
13	NRCB-10	20.13	0.32	63.92	3.06
14	NRCB-8	15.58	0.46	34.31	3.13
15	NRCB-7	13.84	0.43	32.55	3.17
16	Monthan	17.39	0.45	38.64	3.58
17	Pisang Awak	23.85	0.43	56.12	3.25
18	Saba	22.38	0.35	64.87	4.19
19	Udayam	25.35	0.41	62.60	4.51
20	Shanbale	16.67	0.46	36.67	3.85
AAB					
21	Dudhsagar	20.51	0.35	59.44	1.89
22	CO-1	17.42	0.37	47.73	3.25
23	Bargibale	17.07	0.41	42.15	3.56
24	Bangladesh Malbhog	20.50	0.37	56.19	2.47
25	H-531	19.65	0.34	58.67	2.80
26	Krishnavazhai	20.85	0.36	58.73	2.90
27	Malaikali	25.14	0.34	73.94	3.29
28	Manjeri Nendran	15.77	0.39	40.95	5.22
29	Nendran	15.94	0.28	57.95	3.76
30	NCR-17	20.21	0.28	73.51	3.25
31	Mysore Mitli	21.94	0.25	87.93	2.39
32	Martman	18.73	0.41	46.25	5.35
33	Nendrapedati	22.76	0.42	54.84	3.57
34	Palayankondan	22.35	0.35	64.78	2.40
35	Popoulu	16.52	0.32	52.44	2.30
36	Poovan	20.36	0.60	37.88	7.13
37	Vannan	20.09	0.43	46.75	1.49
38	Thiruvananthapuram	18.76	0.39	48.72	2.61

Table 1: contd.

Sl. No.	Genotypes	TSS (°B)	Titrateable acidity (%)	TSS: Acid ratio	Ascorbic acid (mg/100g)
AAB					
39	Rastali	19.50	0.35	56.54	3.08
40	Rajapuri	20.30	0.41	50.13	4.19
41	Sakkarebale	26.15	0.24	109.15	1.49
AAA					
42	Dwarf Cavendish	21.24	0.39	55.17	2.42
43	Gandevi Selection	22.21	0.34	66.31	2.30
44	Grand Naine	21.62	0.28	78.62	1.98
45	Red Banana	23.07	0.32	73.29	3.09
46	Phule Pride	21.07	0.34	62.91	2.34
47	Manoranjitham	23.86	0.33	73.41	3.23
48	KBS-8	21.63	0.28	78.71	1.49
49	Red Banana (Green)	23.54	0.32	74.72	2.01
50	Robusta	24.17	0.37	66.22	1.78
51	TBM-9	19.61	0.29	68.85	1.88
52	Thella Chakkarakeli	19.34	0.36	54.45	2.72
53	Yangambi Selection	15.46	0.48	31.72	5.52
54	Williams	19.32	0.32	61.36	2.23
AB					
55	Kodapanilla	20.00	0.36	56.34	4.18
56	Aktoman	21.00	0.42	50.01	2.79
57	Kunnan	19.12	0.36	53.85	4.89
58	Ney Poovan	25.37	0.36	71.46	1.58
59	Mitli	24.24	0.34	72.37	2.11
AA					
60	Anaikomban	18.27	0.45	41.10	3.70
61	Pisang Lilin	23.30	0.41	57.53	3.39
62	Namarai	22.85	0.42	54.41	4.74
63	Kadali	24.28	0.37	66.53	3.87
64	Cultivar Rose	23.55	0.35	68.27	4.62
	Mean	20.45	0.36	58.60	3.12
	SEm±	0.61	0.02	2.29	0.22
	CD @ 5%	1.73	0.07	6.46	0.62

low vitamin C content in ‘Sakkarebale’ may result from accelerated degradation during advanced ripening stages. Comparable findings were reported by Devi *et al.* (2012)^[6] and

Sagar *et al.* (2018)^[10], emphasizing genotype-dependent differences in ascorbic acid concentration in banana fruits.

Table 2: Performance of banana genotypes for post-harvest parameters

Sl. No.	Genotypes	Shelf life (days)	Physiological loss in weight (%)
AAAB			
1	Gold Finger	7.32	13.22
2	FHIA-18	8.37	14.15
ABB			
3	BCB-I	8.39	14.56
4	BCB-II	8.12	8.59
5	Karibale	8.24	8.10
6	CO-3	9.35	12.67
7	Budu Mitka	7.28	15.27
8	Budu Bale	7.58	18.91
9	Karpurbale	7.28	9.91
10	Karpurvalli	7.74	10.30
11	Kothia	8.33	5.32
12	Kovvur Bontha	9.32	5.37
13	NRCB-10	8.39	15.27
14	NRCB-8	8.63	9.09
15	NRCB-7	9.33	8.79
16	Monthan	8.35	9.74
17	Pisang Awak	7.58	10.63
18	Saba	7.80	8.57
19	Udayam	7.51	10.60
20	Shanbale	8.85	5.63
AAB			
21	Dudhsagar	7.30	11.14

22	CO-1	9.54	15.78
23	Bargibale	8.57	11.58
24	Bangladesh Malbhog	7.48	13.58
25	H-531	7.53	14.36
26	Krishnavazhai	7.65	16.30
27	Malaikali	6.52	9.16
28	Manjeri Nendran	10.60	15.81
29	Nendran	9.46	15.45
30	NCR-17	8.28	15.47
31	Mysore Mitli	9.38	16.75
32	Martman	7.20	10.27
33	Nendrapedati	7.78	8.13
34	Palayankondan	7.49	12.18
35	Popoulu	11.62	12.06
36	Poovan	7.41	13.27
37	Vannan	6.68	12.06
38	Thiruvananthapuram	7.39	11.12
39	Rastali	8.38	8.30
40	Rajapuri	9.50	8.58
41	Sakkarebale	8.42	15.35

Table 2: contd.

Sl. No.	Genotypes	Shelf life (days)	Physiological loss in weight (%)
AAA			
42	Dwarf Cavendish	9.32	13.52
43	Gandevi Selection	9.46	14.42
44	Grand Naine	8.48	10.05
45	Red Banana	10.90	5.23
46	Phule Pride	8.63	16.90
47	Manoranjitham	8.52	11.80
48	KBS-8	8.65	11.47
49	Red Banana (Green)	10.67	5.66
50	Robusta	8.25	7.73
51	TBM-9	7.76	15.26
52	Thella Chakkarakeli	7.48	9.88
53	Yangambi Selection	6.71	8.55
54	Williams	8.16	12.66
AB			
55	Kodapanilla	7.12	11.04
56	Aktoman	5.67	15.25
57	Kunnan	6.54	21.71
58	Ney Poovan	10.58	13.13
59	Mitli	9.96	27.76
AA			
60	Anaikomban	6.75	15.34
61	Pisang Lilin	8.59	22.45
62	Namarai	5.91	18.17
63	Kadali	7.48	12.15
64	Cultivar Rose	7.74	21.77
	Mean	8.24	12.55
	SEm±	0.24	0.48
	CD @ 5%	0.67	1.35

Shelf Life (days)

Post-harvest evaluation revealed significant variation in shelf life among the genotypes. The longest shelf life was observed in 'Popoulu' (11.62 days), followed by 'Red Banana' (10.45 days), while the shortest was recorded in 'Aktoman' (5.67 days). Longer shelf life is associated with slower ripening rates, thicker peels, and lower respiration and transpiration rates. The extended storage duration in 'Popoulu' may be linked to higher starch content and lower soluble solids, which delay physiological ripening. Moreover, genotypes belonging to the *M. balbisiana* (BB) group typically exhibit firmer pulp and thicker peel, contributing to delayed senescence and reduced spoilage. Similar observations were made by Shaun *et al.* (1999)

^[12] and Adeniji *et al.* (2007) ^[4], who reported that genotypes with higher starch content and lower ethylene production showed prolonged shelf life.

Physiological Loss in Weight (PLW) (%)

PLW, an indicator of water loss and metabolic activity during storage, also varied significantly among the genotypes. The minimum PLW was observed in 'Red Banana' (5.23%), which was on par with 'Kothia' (5.32%), 'Kovvur Bontha' (5.37%), 'Shanbale' (5.63%), and 'Red Banana (Green)' (5.66%), while the maximum PLW was recorded in 'Mitli' (27.76%). Lower PLW values in 'Red Banana' and related genotypes may be due to their thicker peel, firmer pulp, and reduced transpiration rates,

which collectively help maintain fruit weight and freshness. In contrast, higher PLW in 'Mitli' could result from thinner peel and higher surface permeability, leading to increased moisture loss. These findings corroborate earlier reports by Adeniji *et al.* (2007)^[4] and Sagar *et al.* (2018)^[10], emphasizing that low PLW is a desirable post-harvest trait for longer marketability and storage.

The significant genotypic variability observed in TSS, acidity, ascorbic acid, TSS:acid ratio, shelf life, and PLW underscores the rich genetic diversity within *Musa* spp. and its potential for fruit quality improvement. The superior performance of 'Sakkarebale' in sweetness parameters, 'Poovan' in vitamin C content, and 'Popoul' in shelf life demonstrates the possibility of combining these traits in breeding programs to develop high-quality, nutrient-rich, and shelf-stable cultivars. The observed variation is a function of genetic makeup, ripening physiology, and environmental influences such as temperature, humidity, and soil fertility during the growing period.

Conclusion

The comparative assessment of sixty-four banana genotypes revealed significant diversity in physico-chemical fruit quality and post-harvest attributes, indicating the vast genetic potential within *Musa* germplasm. Genotype 'Sakkarebale' exhibited superior sweetness with the highest TSS (26.15 °B) and lowest titratable acidity (0.24%), resulting in an excellent TSS:acid ratio (109.15), while 'Poovan' recorded the highest ascorbic acid content (7.13 mg/100 g). Genotypes such as 'Popoul' and 'Red Banana' demonstrated extended shelf life and minimal physiological loss in weight, reflecting better post-harvest performance and storability. The observed variability can be attributed to inherent genetic differences and environmental influences, emphasizing the importance of genotype selection for targeted breeding and commercial utilization. Overall, the study identifies promising genotypes with desirable quality and storage traits that can be effectively used in future banana improvement programmes aimed at enhancing fruit quality, nutritional value, and post-harvest longevity.

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