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Omkar Sadakal
Research Scholar,
Dr. Sharadchandra Pawar
College of Agriculture, Baramati,
Pune, Maharashtra, India

Amrut Morade
Scientist (Fruit Science), ICAR-
National Institute of Abiotic
Stress Management, Malegaon,
Pune, Maharashtra, India

Shubhada Tayade
Assistant Professor,
Dr. Sharadchandra Pawar
College of Agriculture, Baramati,
Pune, Maharashtra, India

Vijay D Kakade
Scientist (Fruit Science), ICAR-
National Institute of Abiotic
Stress Management, Malegaon,
Pune, Maharashtra, India

Swapnil Holkar
Research Scholar,
Dr. Sharadchandra Pawar
College of Agriculture, Baramati,
Pune, Maharashtra, India

Nishigandha Kokani
Research Scholar,
Dr. Sharadchandra Pawar
College of Agriculture, Baramati,
Pune, Maharashtra, India

Macchindra Agale
Assistant Professor,
Dr. Sharadchandra Pawar
College of Agriculture, Baramati,
Pune, Maharashtra, India

Ganesh Shinde
Assistant Professor,
Dr. Sharadchandra Pawar
College of Agriculture, Baramati,
Pune, Maharashtra, India

Pooja Shitole
Assistant Professor,
Dr. Sharadchandra Pawar
College of Agriculture, Baramati,
Pune, Maharashtra, India

Corresponding Author:
Amrut Morade
Scientist (Fruit Science), ICAR-
National Institute of Abiotic
Stress Management, Malegaon,
Pune, Maharashtra, India

Evaluation of fruit physical and biochemical characteristics in local mango germplasm from semi-arid region of Maharashtra

Omkar Sadakal, Amrut Morade, Shubhada Tayade, Vijay D Kakade, Swapnil Holkar, Nishigandha Kokani, Macchindra Agale, Ganesh Shinde and Pooja Shitole

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Abstract

This study examined the physical and biochemical traits of local mango (*Mangifera indica* L.) germplasms collected from the semi-arid agro-climatic zones of Maharashtra. Fruits of ten local germplasms were collected in summer-2023 to assess variations in fruit weight, dimensions, pulp, peel, and stone percentage. Significant genotypic variations were observed with respect to the observed fruit physical and biochemical quality traits. Cultivar Kesar exhibited the highest fruit weight (288.3 g), fruit size, and pulp percentage (71.7%) while Nashik-1 exhibited lowest fruit weight and, dimensions and pulp percentage. Musti-5 had the highest pulp percentage (78.7%) and the lowest peel thickness (1.04 mm). Khireswar-1 and Nashik-1 had significantly higher stone percentages (>44.00%). Musti-7 had the lowest peel percentage, making these germplasms ideal for fresh consumption. Darshnal-1 plants had the lowest stone-to-fruit weight ratio. Among pulp biochemical parameters, Papri-1 exhibited the highest TSS levels (23.7°B), but Kesar had highest total sugars (14.81%) and lowest acidity (0.14%), indicating potential for processing and fresh market suitability. The fruit pulp of the local mango germplasm is highly acidic and fibrous, indicating its suitability for pickling. These findings underscore the influence of genetic factors on fruit morphology and quality, identifying specific germplasms as valuable genetic resources for breeding high-quality market-oriented mango cultivars.

Keywords: Mango germplasm, *Mangifera indica*, fruit physical traits, fruit biochemical traits

1. Introduction

Mango (*Mangifera indica* L.), often called the "King of Fruits," is not only an important fruit crop in India but also a significant component of global horticulture. It is widely cherished for its flavour, texture, and nutritional richness, including high levels of vitamins A, C, and E; essential minerals such as copper and potassium; and bioactive phytochemicals, which contribute to antioxidant, anti-inflammatory, and anticancer properties (Goncalves *et al.*, 2017; Gunathilake *et al.*, 2018) [6, 7]. India is the world's largest producer of mangoes, with annual production exceeding 23 million metric tons (FAOSTAT, 2021) [2]. Despite this prominence, India's average mango productivity lags behind global standards due to several constraints, including the impacts of abiotic stresses, such as drought and salinity, worsened by climate change (Ravindran *et al.*, 2007) [15]. To address these challenges, it is essential to enhance mango quality and stress resilience through breeding programs. The quality of mango fruit is determined by traits, such as size, weight, pulp yield, and biochemical properties, which strongly influence its market appeal and usability. However, these traits vary significantly among mango germplasms, offering the potential for selecting and breeding varieties with optimal characteristics (Singh *et al.*, 2010; Kumar *et al.*, 2012) [18, 10]. Investigating local mango germplasm in specific regions, such as Maharashtra, which is known for its diverse mango varieties, can provide insights into quality traits and stress resilience. This research evaluates ten unique mango germplasms from Maharashtra to determine fruit quality parameters, contributing data that could guide breeding programs aimed at producing superior, adaptable mango varieties that meet consumer preferences and commercial demands.

2. Materials and Methods

To evaluate fruit quality parameters, naturally grown or cultivated mango seedling trees aged > 30 years were selected. During the peak fruiting season (June-July 2023), ten mango germplasms were surveyed, and fruits were collected from the Pune, Nashik, and Solapur districts of Maharashtra after a tree survey. The names of the local mango seedling germplasm, address, and geo-coordinates, which were the subjects of the investigation, are presented in Table 1. The germplasms Madh-1 and Khireshwar-1 were

collected from the Pune district's Junnar Taluka, and Loni Kalbhor-1 was collected from Haveli Taluka. Papri-1 came from Mohol Taluka, Musti-5, Musti-7, and Musti-9 came from South Solapur Taluka, and Darshnal-1 came from Akkalkot Taluka in the Solapur district. Germplasm Nashik-1 was collected from Trimbak Taluka in the Nashik district. Fruits of the cultivar Kesar cultivated at ICAR-NIASM, Baramati, were also included to compare fruit quality. They were then labelled, packed in gunny bags, and transported to the laboratory for further analysis.

Table 1: Location, geo-coordinates and number of fruits collected of local mango germplasm

Germplasm	Locations	Latitude	Longitude	Number of fruits collected
Khireshwar-1	Khireshwar, Tq.: Junnar, Dist.: Pune	19.379695°N	73.805493°E	51
Madh-1	Madh, Tq.: Junnar, Dist.: Pune	19.303938°N	73.834618°E	26
Kesar	Malegaon, Tq.: Baramati, Dist.: Pune	18.1592°N	74.5007°E	52
Musti-9	Musti, Tq.: South Solapur, Dist.: Solapur	17.42°21'N	76.06°31'E	31
Loni Kalbhor-1	Loni Kalbhor, Tq.: Haveli, Dist.: Pune	18.4879°N	74.0234°E	31
Musti-5	Musti, Tq.: South Solapur, Dist.: Solapur	17.42°31'N	76.06°42'E	32
Darshnal-1	Darshnal, Tq.: Akkalkot, Dist.: Solapur	17.41°52'N	76.07°47'E	62
Musti-7	Musti, Tq.: South Solapur, Dist.: Solapur	17.42°23'N	76.06°27'E	31
Papri-1	Papri, Tq.: Mohol, Dist.: Solapur	17.826° N	75.474°E	32
Nashik-1	Trimbakeshwar, Dist.: Nashik	20.0012° N	73.8075°E	48

Four fruits of uniform size, ripeness, and freedom from pests and diseases were selected to determine their physical and biochemical traits. The weight of four uniform fruits of each germplasm was measured using a digital balance, and the average of four fruits per germplasm was calculated. Fruit length and width were measured with a Vernier caliper at the longest and widest points, respectively, and the results were expressed in centimeters (cm). The fruit pulp was separated and weighed after the entire fruit had been weighed. The pulp percentage was calculated using the following formula:

$$\text{Pulp percentage (\%)} = \frac{\text{Weight of pulp (g)}}{\text{Fruit weight (g)}} \times 100$$

The peel was removed, weighed, and calculated as a percentage of the total weight of the fruit using the following formula:

$$\text{Peel percentage (\%)} = \frac{\text{Weight of peel (g)}}{\text{Fruit weight (g)}} \times 100$$

Stones were separated, and their length, width, and thickness were measured using a Vernier calliper and recorded in centimeters (cm) for further analysis of size and shape variations. The stone percentage on a weight basis is calculated as

$$\text{Stone percentage (\%)} = \frac{\text{Weight of stone (g)}}{\text{Fruit weight (g)}} \times 100$$

The pulp of uniformly ripened fruits was separated and used to analyze the TSS, titratable acidity, and sugar content. TSS content of the mango pulp was measured using a hand refractometer. After calibration with distilled water, a drop of pulp juice was placed on the prism of the refractometer, and the Brix value was recorded to one decimal place (Rathore *et al.*, 2007) ^[14]. The prism was cleaned with distilled water and dried between readings to maintain accuracy. Titratable acidity was determined according to AOAC guidelines (Md. Khairul *et al.*, 2013) ^[12]. Ten grams of mango pulp were diluted with distilled water in a 100 mL

beaker, filtered, and transferred to a volumetric flask. Ten milliliters of the filtrate were titrated against 0.1 N NaOH using phenolphthalein as an indicator until a permanent pink color appeared. The titratable acidity percentage was calculated based on the volume of NaOH used. Total sugar content was measured using the phenol-sulfuric acid method (AOAC Official Method 988.12). A four grams of mango pulp was homogenized in distilled water, filtered, and adjusted to 100 mL volume in a volumetric flask. The filtrate (1 mL) was combined with 1 mL of 5% phenol and 5 mL of sulfuric acid, mixed, and allowed to react for 10 min at RT.. The absorbance of the yellow-orange solution was measured at 490 nm against a distilled water blank. The total sugar content was calculated using a standard curve and expressed as a percentage of the fresh weight of the sample.

The data was analyzed using R statistical software (version 4.1.1, R Core Team, 2021), Analysis of variance (ANOVA) was then performed using the 'Doebioresearch' package, enabling the identification of statistically significant differences across observed parameters.

3. Results and Discussion

Analysis of ten mango germplasms collected from different regions showed significant variations in physical and biochemical parameters, indicative of high genetic diversity among the sampled mango germplasms. This diversity highlights the potential of selecting specific traits for breeding programs to enhance quality and resilience.

3.1 Fruit weight and dimension

The Kesar genotype had the highest fruit weight (288.35 g, followed by the Musti-5 genotype (247.83 g). The other genotypes had intermediate fruit weights, whereas Loni Kalbhor-1 and Darshnal-1 had moderately lower values. Nashik-1 and Khireshwar-1 had the lowest fruit weights, both at par with each other. The variation in fruit weight among the genotypes was largely due to genetic factors (Table 2). Patil *et al.* (2017) ^[13] highlighted the genotype-dependent nature of fruit weight. Verma *et al.* (2018) ^[19]

discussed the influence of genotype on fruit weight and genotype consistently outperformed others in terms of fruit size. Jadhav *et al.* (2019) ^[9] observed significant genotype-related differences in mango fruit weight.

The analysis of fruit dimensions, including fruit length and width, across the various mango genotypes is presented in Table 2. The Kesar genotype stands out with the largest dimensions (10.35 cm length and 7.26 cm width) and a balanced shape index of 1.42, indicating a desirable elongated fruit shape. Similarly, Musti-5 and Musti-7 exhibited large sizes and moderately elongated shapes, respectively. In contrast, Musti-9 and Loni Kalbhor-1 show intermediate sizes and shapes, while Khireshwar-1, despite being the smallest (6.18 cm length and 3.88 cm width), has the highest shape index (1.60), suggesting a more elongated shape. Nashik-1, the smallest fruit (4.79 cm in length and 4.53 cm in width), had the lowest shape index (1.05), indicating a rounded shape, which may be less preferred in commercial markets. Patil *et al.* (2017) ^[13] discussed the influence of genotype on mango fruit dimensions, noting that certain genotype consistently produced larger and more elongated fruits. Verma *et al.* (2018) ^[19] suggested the genetic basis of fruit shape and size in mango, with significant variations in fruit dimensions across different genotype. Jadhav *et al.* (2019) ^[9] claimed that mango fruit length, width, and shape index are genotype-specific traits, with considerable diversity observed among cultivars.

3.2 Fruit pulp parameters

The Kesar genotype exhibited the highest pulp weight (207.90 g, significantly surpassing all the other genotypes (Table 2). It was followed by Musti-9 with a pulp weight of 101.10 g and Musti-5 at 78.75 g, both of which also demonstrated relatively high pulp weights. Intermediate pulp weights were observed in Madh-1 (72.05 g), Musti-7 (73.92 g), and Darshnal-1 (64.40 g). Loni Kalbhor-1 (59.80 g) and Papri-1 (46.37 g) exhibited lower pulp weights. The genotypes Khireshwar-1 (20.65 g) and Nashik-1 (16.92 g) had the lowest pulp weights among those tested. These results indicate that the genetic makeup of each genotype contributes to the observed variability in pulp weight. Sharma *et al.* (2015) ^[17] observed that different mango genotype exhibits considerable differences in pulp weight, supporting the influence of genetic factors. Patil *et al.* (2017) ^[13] highlighted the genetic basis of pulp weight variation in mango, noting that certain genotype consistently yields higher pulp weights. Verma *et al.* (2018) ^[19] discussed the variability in pulp weight among mango genotype, attributing these differences to genetic diversity.

The highest pulp percentage (71.78%) was observed in Kesar, which significantly surpassed all other genotypes (Table 2). Following Kesar, Madh-1 and Musti-9 had relatively high pulp percentages of 56.00% and 54.85%, respectively. Intermediate pulp percentages were observed in genotypes Loni Kalbhor-1 (40.79%), Khireshwar-1 (41.01%), and Papri-1 (43.22%). In contrast, Musti-5 (31.83%), Musti-7 (35.42%), and Nashik-1 (31.57%) recorded the lowest pulp percentages among the tested

genotypes, with Musti-5 and Nashik-1 having the least pulp content. Kumar *et al.* (2012) ^[10] found similar results where the significant variations in pulp percentage among mango genotype was a result of genetic factors. Similar findings were reported by previous research like, Chaudhary *et al.* (2014) ^[3], Sharma *et al.* (2015) ^[17], Patil *et al.* (2017) ^[13], Verma *et al.* (2018) ^[19], and Jadhav *et al.* (2019) ^[9] observed differences in the pulp percentage across various mango cultivars, attributing these variations to genetic diversity.

3.3 Peel parameters

The peel weights of the different mango genotypes are presented in Table 2. The Musti-7 genotype recorded the highest peel weight at 45.05 g, followed by Kesar at 37.85 g and Loni Kalbhor-1 at 32.05 g, both of which also demonstrated relatively high peel weights. Intermediate peel weights were observed for Papri-1 (25.77 g) and Musti-9 (26.16 g). In contrast, Khireshwar-1 (13.47 g), Nashik-1 (13.60 g), and Darshnal-1 (18.72 g) exhibited the lowest peel weights among the tested genotypes. Similar findings were obtained by Patil *et al.* (2017) ^[13], who discussed the specific genetic determinants responsible for higher peel weight, and Verma *et al.* (2018) ^[19] emphasized the genetic role in determining both peel weight and pulp percentage.

The evaluation of peel thickness among various mango genotypes revealed significant differences (Table 2). The Musti-7 (2.03 mm), Papri-1 (1.93 mm), and Nashik-1 (1.84 mm) genotypes demonstrated notably thicker peels than the others, indicating a trend toward thicker peel development in these cultivars. In contrast, genotypes Khireshwar-1 (1.04 mm), Musti-5 (1.05 mm), and Madh-1 (1.36 mm) exhibited relatively thinner peels. Other genotypes, including Kesar (1.17 mm), Musti-9 (1.22 mm), Loni Kalbhor-1 (1.15 mm), and Darshnal-1 (1.15 mm) showed intermediate levels of peel thickness. These differences suggest that genetic makeup plays a key role in determining peel development across various cultivars, consistent with a previous study by Kumar *et al.* (2012) ^[10], who demonstrated that peel thickness in mangoes is significantly influenced by genetic factors, with considerable variability observed among different genotypes.

Analysis of peel percentage among different mango genotypes revealed that Khireshwar-1 had the highest peel percentage (26.57%), followed by Nashik-1 (25.17%), and Papri-1 (23.93%), (Table 2). These genotypes exhibited significantly higher peel percentages than other genotypes. Genotypes Loni Kalbhor-1 (21.96%) and Musti-7 (21.52%) also demonstrated relatively high peel percentages, while Madh-1 (17.89%) displayed intermediate values. In contrast, genotypes Kesar (13.15%), Musti-9 (14.44%), Darshnal-1 (11.85%), and Musti-5 (10.72%) had the lowest peel percentages. The differences suggest that genetic makeup plays a key role in determining peel development across various cultivars, consistent with previous study by Kumar *et al.* (2012) ^[10] that demonstrated peel thickness in mango is significantly influenced by genetic factors with considerable variability observed among different genotype.

Table 2: Fruit physical parameters of local mango germplasm

Genotype	Fruit Weight (g)	Fruit length (cm)	Fruit width (cm)	Pulp weight (g)	Pulp (%)	Peel weight (g)	Peel (%)	Peel thickness (mm)
Khireshwar-1	52.25	6.18	3.88	20.65	41.01	13.47	26.57	1.04
Madh-1	129.5	7.45	5.30	72.05	56.00	23.05	17.89	1.36
Kesar	288.3	10.35	7.26	207.90	71.78	37.85	13.15	1.17
Musti-9	187.0	8.96	6.13	101.10	54.85	26.16	14.44	1.22
Loni kalbhor-1	146.5	8.13	6.11	59.80	40.79	32.05	21.96	1.15
Musti-5	247.8	9.85	6.91	78.75	31.83	25.97	10.72	1.05
Darshnal-1	157.8	7.61	6.29	64.40	40.69	18.72	11.85	1.15
Musti-7	210.6	9.24	6.74	73.92	35.42	45.05	21.52	2.03
Papri-1	107.7	6.59	5.11	46.37	43.22	25.77	23.93	1.93
Nashik-1	55.77	4.79	4.53	16.92	31.57	13.60	25.17	1.84
SE.m $\pm$	8.29	0.24	0.11	6.72	4.24	2.19	2.12	0.16
CD at 5%	24.06	0.71	0.33	19.52	12.30	6.35	6.17	0.47

3.4 Stone physical parameters

The observations on stone weight indicated that the Musti-7 genotype recorded the highest stone weight of 58.63 g, as presented in Table 3. Kesar also displayed a relatively high stone weight of 46.55 g, followed by Madh-1 at 37.97 g and Loni Kalbhor-1 at 35.77 g. Genotypes Musti-5 (33.55 g), Papri-1 (33.82 g), and Musti-9 (32.12 g) showed intermediate stone weights. In contrast, Darshnal-1 (27.90 g), Nashik-1 (24.15 g), and Khireshwar-1 (22.62 g) had the lowest stone weights among the tested genotypes. These findings are consistent with previous research conducted by Chaudhary *et al.* (2014) [3], who observed that stone weight in mangoes is highly variable across different genotypes, indicating genetic influence.

The analysis of stone percentage among various mango genotypes revealed significant differences (Table 3). Genotypes Nashik-1 (44.45%) and Khireshwar-1 (43.77%) exhibited the highest stone percentages, indicating that a larger portion of the fruit weight was attributed to the stone in these cultivars. In contrast, genotypes Kesar (16.15%), Musti-5 (13.61%), Musti-9 (17.61%), and Darshnal-1 (17.67%) displayed considerably lower stone percentages. Other genotypes, including Madh-1 (29.47%), Loni Kalbhor-1 (24.41%), and Papri-1 (31.51%), fell within the intermediate range. Overall, the analysis highlighted notable genetic variability in stone percentage among the mango genotypes, with Nashik-1 and Khireshwar-1 showing higher proportions of stone weight compared to the significantly lower percentages observed in genotypes like Kesar and Musti-5. These differences suggest the influence of genetic factors on stone percentage, as supported by previous

research done by Patil *et al.* (2017) [13], who discussed the significant influence of genotype on stone percentage in *Mangifera indica*, noting that some genotypes have a higher proportion of stones relative to fruit weight. Jadhav *et al.* (2019) [9] concluded, stone percentage varies considerably among mango genotype, emphasizing the role of genetic factors.

The evaluation of stone dimensions (Table 3) revealed significant variability among different mango genotypes. Musti-5 (8.23 cm), Loni Kalbhor-1 (8.03 cm), and Musti-9 (7.99 cm) exhibited the longest stone lengths, while Nashik-1 (4.40 cm) and Khireshwar-1 (5.37 cm) had the shortest stone lengths.

Musti-5 (4.16 cm) and Musti-7 (4.09 cm) displayed the greatest stone widths, whereas Khireshwar-1 (2.90 cm) and Musti-9 (2.98 cm) recorded the narrowest widths. Musti-5 (3.01 cm) and Musti-7 (2.93 cm) had the thickest stones, while Kesar (1.71 cm) and Loni Kalbhor-1 (1.77 cm) presented the thinnest stones. This analysis underscores the genetic variability in the stone dimensions among the evaluated mango genotypes. These findings align with those of previous research conducted by Kumar *et al.* (2012) [10], which highlighted the significant genotype-related differences in stone dimensions, including length, width, and thickness, across various mango cultivars, underscoring the role of genetic factors. Similarly, Sharma *et al.* (2015) [17] and Gupta *et al.* (2020) [8] reported substantial variability in stone dimensions among mango genotypes, with specific cultivars exhibiting distinctive stone lengths, widths, and thicknesses.

Table 3: Variations in fruit stone physical parameters

Genotype	Stone weight(g)	Stone (%)	Stone length (cm)	Stone width (cm)	Stone thickness (cm)
Khireshwar-1	22.62	43.77	5.37	2.90	2.22
Madh-1	37.97	29.47	6.33	3.27	2.09
Kesar	46.55	16.15	7.95	3.33	1.71
Musti-9	32.12	17.61	7.99	2.98	1.88
Loni kalbhor-1	35.77	24.41	8.03	3.27	1.77
Musti-5	33.55	13.61	8.23	4.16	3.01
Darshnal-1	27.9	17.67	7.18	3.35	1.98
Musti-7	58.63	28.26	7.48	4.09	2.93
Papri-1	33.82	31.51	5.55	3.28	2.32
Nashik-1	24.15	44.45	4.40	3.20	2.34
SE.m $\pm$	1.62	2.49	0.27	0.09	0.15
CD at 5%	4.72	7.24	0.79	0.27	0.45

3.5 Fruit pulp biochemical parameters

The analysis of total soluble solids (TSS) across various mango genotypes, as presented in Table 4, showed that

Papri-1 had the highest TSS at 23.8 °Brix, closely followed by Kesar at 22.67 °Brix. Genotypes Madh-1 (19.75 °Brix), Musti-9 (19.67 °Brix), and Musti-5 (19.3 °Brix) demonstrated moderately high TSS levels. In contrast, Nashik-1 (16.5 °Brix), Khireswar-1 (18.25 °Brix), Darshnal-1 (18.35 °Brix), and Musti-7 (18.58 °Brix) exhibited the lowest TSS values among the tested genotypes. Lal *et al.* (2017) ^[11] studied the variation in TSS among different mango genotype and found significant differences in sweetness levels due to genetic diversity. TSS is a critical quality attribute in mangoes and is largely influenced by genetic factors (Dinesh *et al.*, 2010) ^[4].

The acidity assessment among the various mango genotypes, as shown in Table 4, revealed that Nashik-1 had the highest acidity (0.52%), followed by Darshnal-1 (0.34%), Musti-7 (0.33%), and Musti-5 (0.30%), which also had relatively higher acidity levels. In contrast, Loni Kalbhori-1 (0.09%), Kesar (0.12%), and Madh-1 (0.18%) showed the lowest acidity levels. Genotypes Khireswar-1 (0.24%) and Papri-1 (0.14%) displayed intermediate acidity values. Similar results were reported by Kumar *et al.* (2012) ^[10], who investigated the genetic variability in mango acidity and differences among genotypes owing to the influence of genetic factors. Patil *et al.* (2019) ^[9] examined the acidity levels in various mango cultivars and found substantial genotype dependent variation. Singh *et al.* (2010) ^[18] also studied the role of genetic diversity in determining mango fruit acidity.

Analysis of total sugar content across mango genotypes indicated significant variation, as shown in Table 4. Genotypes Kesar (14.81%) and Musti-7 (13.83%) recorded the highest total sugar levels. Other genotypes, including Khireswar-1 (10.76%) and Papri-1 (14.64%), also displayed relatively high sugar contents. Conversely, Loni Kalbhori-1 (9.30%) and Musti-5 (10.36%) had the lowest total sugar contents. Intermediate levels were found for Madh-1 (12.53%) and Nashik-1 (11.41%). Ghosh and Kumar (2022) ^[10] had similar research findings regarding total soluble solids and sugar content in mangoes from different agro-climatic zones, and their findings concluded that locational impacts sugar levels in mango fruits. Reddy and Babu (2019) ^[16] investigated the effect of environmental conditions on the total sugar content of various mango varieties.

Table 4: Fruit pulp bio-chemical quality parameters

Genotype	TSS (°B)	Acidity (%)	Total sugars (%)
Khireswar-1	18.25	0.24	10.76
Madh-1	19.75	0.18	12.53
Kesar	22.67	0.12	14.81
Musti-9	19.67	0.17	11.44
Lonikalbhori-1	17.95	0.09	9.30
Musti-5	19.30	0.30	10.36
Darshnal-1	18.35	0.34	10.35
Musti-7	18.58	0.33	13.83
Papri-1	23.80	0.14	14.64
Nashik-1	16.50	0.52	11.41
SE.m (±)	0.71	0.04	0.59
CD at 5%	1.61	0.09	1.33

4. Conclusion

This study highlights the rich diversity of traits across different mango genotypes from semi-arid region, each offering various qualities and traits for breeding programs focusing on yield, quality, shelf-life enhancement, and

abiotic and biotic stress mitigation strategies. Genotypes such as Papri-1 and Kesar stand out for their high level of natural sweetness, that is, TSS value, which makes it a choice for fresh fruit and an option for mango processed products. Germplasms with high pulp percentages, such as Kesar and Madh-1, show promising performance in processing industries as they provide more edible content per fruit. This study also shows that Maharashtra's semi-arid conditions influence the phenotypic traits of these mango genotypes. Some genotypes exhibited higher acidity, fibrous pulp, and lower sugar content, indicating their suitability for pickling. These findings indicate the importance of genetic selection in mango breeding because specific traits such as pulp yield and TSS are strongly genotype-dependent. These germplasms could be further explored as parental lines in breeding programs to develop high-quality mango cultivars that align with the market demands for fresh and processed products. Overall, these findings suggest that germplasm exploration programs focused on exploring local and wild diversity could be used to harness potential varieties suited for processing, yield, and resilience to climatic stress.

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