Original Research Article
Correlation between Pulp Weight and Physio-Biochemical Traits of Mango (*Mangifera indica* L.) Germplasms

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ABSTRACT

Aim: The present study was conducted to evaluate the relationship between pulp weight and various physio-biochemical attributes among 30 diverse mango (*Mangifera indica* L.) germplasms under the *Tarai* region of Uttarakhand.

Place and Duration of Study: This investigation was carried out at Horticulture Research Centre, GB Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, during the years 2021 and 2022.

Methodology: The selected 30 germplasms included two commercially grown cultivars and 28 primary germplasms sourced from different eco-geographical locations of Uttar Pradesh and Uttarakhand states of India. Pulp weight, physical characteristics (fruit shape index, pulp/stone ratio) and biochemical parameters (Brix/Acid ratio and pH) were measured for each germplasm and statistically laid out in completely randomized design (CRD), and their relationships were analyzed using simple linear regression and Pearson's correlation coefficients.

Results: The maximum values recorded among the studied germplasms were 300.73 g for pulp weight (PMGC-19), 2.41 for fruit shape index (PMSS-31), 0.309 for pulp/stone ratio (PMGC-71), 140.87 for Brix/Acid ratio (PMGC-96) and 5.87 for pH (PMGC-96). Among the physical attributes, pulp weight exhibited a moderate positive correlation with fruit shape index (r = 0.419), indicating that fruits with a higher shape index tend to have increased pulp weight. Whereas, a moderate negative correlation was observed between pulp weight and pulp/stone ratio (r = -0.457), suggesting that as the pulp/stone ratio increases, pulp weight decreases. However, biochemical attributes such as Brix/Acid ratio and pH showed no significant correlation with pulp weight (r = 0.005 and r = 0.018, respectively), indicating an independent influence of these parameters on pulp characteristics.

Conclusion: These findings provide important insights into the complex relationships between pulp weight and other physio-biochemical traits in mango, some traits for breeding programs aimed to improving fruit quality and pulp content and identified superior and promising germplasms for cultivation as well as potential parental genotypes in mango improvement programs.

Keywords: Mangifera indica; regression; correlation; pulp weight; biochemical; germplasm

1. INTRODUCTION

Mango (*Mangifera indica* L.) is known as 'King of fruit' in India, where it is grown in an area of over 2.37 million ha, producing 20.95 million tonnes annually [1]. Over the decade, mango-producing countries including India witnessed a continuous increase in production and trade at the domestic and export market. Mango trade has now become a competitive affair among countries and fruit quality is an important aspect for trade at both domestic and export market [2, 3] . The fruit quality in domestic trade of India is maintained as per the specifications and guidelines laid down by certifying authorities such as 'The Agricultural and Processed Food Products Export Development Authority' and 'Bureau of Indian Standards', whereas at the international level, it is maintained as per the guidelines specified and followed by importing nation, for instance through guidelines of Eurep GAP, Global GAP, Codex Alimentarius, APEDA, etc. The improvement and maintenance of the external appearance of fruit along with fulfilling all other quality parameters have now become mandatory for successful trade [4, 5].

The identification and characterization of diversity is essential for crop improvement, as well as for the use and conservation of plant genetic resources [6]. A high degree of mango diversity is observed in India, which has led some authors to consider it the country of origin [7, 8]. Being the ancestral home of mango, India has over thousands of germplasms spread across various agro-climatic zones [9, 10]. In India current status of mango germplasms conserved in various gene banks are 2733 in field gene banks and 371 in pollen gene banks [11]. Mango has been reported to have extensive diversity due to alloploidy, outbreeding, repeated grafting and phenotypic differences arising from varied agroclimatic conditions in different mango growing regions [7, 12]. Unfortunately, several indigenous mangoes with a high potential for breeding have become extinct due to negligence and poor management practices. Consequently, it has become imperative to conserve existing germplasm. Inventorying mango genetic resources requires clear identification of varieties along with accurate evaluation of their quality, unique traits, and potential, combined with an assessment of genetic diversity. This kind of inventory would be useful for providing information not only on elite mango varieties which are worth conservation and mass propagation, but also help to select varieties/germplasms to be chosen as parent for breeding aimed at improving fruit yield and quality [13]. Physio-biochemical attributes such as pulp weight, fruit shape index, pulp/stone ratio, Brix/acid ratio, and pH are significant parameters influencing the quality, flavor and nutritional properties of mango fruits [14]. Understanding these characteristics in different germplasm under specific agro-climatic conditions helps in identifying promising genotypes for breeding and commercial purposes. Despite extensive research on mango germplasm, limited studies have focused on evaluating these attributes in the context of the Tarai region of Uttarakhand, making it essential to document the variability and relationships among these traits for better utilization and conservation strategies.

This study aims to assess the physio-biochemical attributes of various mango germplasm under the Tarai region of Uttarakhand, to analyze the interrelationships between these attributes, and to identify potential germplasm with desirable traits for future breeding programs.

2. EXPERIMENTAL DETAILS

2.1 Description of the experiment

This research work conducted to evaluate relationship between pulp weight and physio-biochemical attributes in mango (*Mangifera indica* L.) was carried out at the Horticulture

Research Centre, GB Pant University of Agriculture and Technology, Pantnagar, Uttarakhand during the two consecutive years 2021 and 2022. Experimental site located at 29.5° North latitude and 79.3° East longitude with an altitude of 243.84 meters above mean sea level in the foothills of the Shivalik range of the Himalayas. The germplasms procured from different eco-geographical locations of India are maintained at HRC, Pantnagar (Table 1). In the study selected the 30 diverse mango germplasms included (i) 2 selections (commercially grown mango cultivars), (ii) 28 primary germplasms.

Table: 1: List of primary germplasm and commercial varieties (as check) undertaken for characterization in mango.

Sr. No.	Accession No.	Method of Crop Improvement	Source	Latitude	Longitude
1.	Dashehari	Seedling Selection	Dashehari (Lucknow), Pantnagar, U.K.	29.0222° N	79.4908° E
2.	Langra	Seedling Selection	Langra (Varanasi), Pantnagar, U.K.	29.0222° N	79.4908° E
3.	PMGC-5	Seedling Selection	Safeda Sharbati, Amroha, U.P.	28.9052° N	78.4673° E
4.	PMGC-19	Seedling Selection	Kaloo, Amroha, U.P.	28.9052° N	78.4673° E
5.	PMGC-20	Seedling Selection	Suhag, Amroha, U.P.	28.9052° N	78.4673° E
6.	PMGC-21	Seedling Selection	Beera, Amroha, U.P.	28.9052° N	78.4673° E
7.	PMGC-36	Seedling Selection	Chikna Mulgoa, Amroha, U.P.	28.9052° N	78.4673° E
8.	PMGC-39	Seedling Selection	Gulab Kevera, Amroha, U.P.	28.9052° N	78.4673° E
9.	PMGC-48	Seedling Selection	Surkhuru No. 2, Amroha, U.P.	28.9052° N	78.4673° E
10.	PMGC-50	Seedling Selection	Rahmat Bidiwala, Amroha, U.P.	28.9052° N	78.4673° E
11.	PMGC-51	Seedling Selection	Sharbati, Amroha, U.P.	28.9052° N	78.4673° E
12.	PMGC-72	Seedling Selection	Bhoordas, Amroha, U.P.	28.9052° N	78.4673° E
13.	PMGC-96	Seedling Selection	Surkhuru No. 1, Amroha, U.P.	28.9052° N	78.4673° E
14.	PMGC-97	Seedling Selection	Dadamiyo, Amroha, U.P.	28.9052° N	78.4673° E
15.	PMGC-98	Seedling Selection	Amin Khurd, Amroha, U.P.	28.9052° N	78.4673° E
16.	PMGC-163	Seedling Selection	Pant Sinduri, Pantnagar, U.K.	29.0222° N	79.4908° E
17.	PMGC-164	Seedling Selection	Pant Chandra, Rudrapur, U.K.	28.9875° N	79.4141° E
18.	PMSS-1	Seedling Selection	Nagala, Pantnagar, U.K.	29.0222° N	79.4908° E
19.	PMSS-7	Seedling Selection	1/19, Phoolbag, Pantnagar, U.K.	29.0222° N	79.4908° E
20.	PMSS-8	Seedling Selection	1/104, Phoolbag, Pantnagar, U.K.	29.0222° N	79.4908° E
21.	PMSS-9	Seedling Selection	Lambert Square, Pantnagar, U.K.	29.0222° N	79.4908° E
22.	PMSS-10	Seedling Selection	Sahashpur, Vikasnagar, Dehradun, U.K.	30.4750° N	77.7652° E
23.	PMSS-11	Seedling Selection	Jashowala, Vikasnagar, Dehradun, U.K.	30.4750° N	77.7652° E
24.	PMSS-14	Seedling Selection	1/3, Phoolbag, Pantnagar, U.K.	29.0222° N	79.4908° E
25.	PMSS-15	Seedling Selection	P-23, Patharachatta, U.K.	29.0280° N	79.4131° E
26.	PMSS-17	Seedling Selection	CB-II, Pantnagar, U.K.	29.0222° N	79.4908° E
27.	PMSS-18	Seedling Selection	1/3/5, Phoolbag, Pantnagar, U.K.	29.0222° N	79.4908° E
28.	PMSS-19	Seedling Selection	Shivpuri, Haldwani, Nainital, U.K.	29.2183° N	79.5130° E
29.	PMSS-30	Seedling Selection	HRC, Patharachatta, U.K.	29.0280° N	79.4131° E
30.	PMSS-31	Seedling Selection	Sainik Farm, Patharachatta, U.K.	29.0280° N	79.4131° E

2.2 Physio-biochemical attributes

Pulp content was measured as a ratio of pulp to skin plus stone. Pulp weight (g) was measured by subtracting skin weight and stone weight from fruit weight. Fruit shape index value was calculated as ratio of fruit length to width. The Pulp/ stone ratio was calculated by dividing pulp weight with the stone weight of fruit. Total soluble solids were determined using a digital refractometer (RX 5000, ATAGO, Japan) following standard method [15], with readings noted in degrees Brix (ºBrix) [16]. Titratable acidity, expressed in terms of percent malic acid was determined following Ranganna [17]. The Brix/ acid ratio was calculated by dividing TSS (°Brix) with the acidity (%). pH value determination was carried out by an Orion 868 pH meter (Thermo Orion, USA) with a combined pH electrode at 25 °C.

2.3 Analysis of the data

Each mango germplasm replicated thrice were analyzed for pulp weight and physio-biochemical attributes. The cumulative mean of both the years was used for statistical analysis of studied attributes. Similarly, the pulp weight was correlated with the studied attributes [18]. The experimental design was CRD. The obtained observations were analyzed by Duncan's multiple range test at $p < 0.05$ level, whereas correlation studies were done using R^2 values for establishing a relationship between pulp weight with physio-biochemical parameters using the Origin [19] software package and SPSS Package 28 [20].

Simple linear regression (SLR) is one of the statistical method which attempts to model the relationship between one interpretive variable (independent) and a response variable (dependent) by fitting a linear equation into the observed data [21, 22]. The model for SLR is:

$$Y = \beta_0 + \beta_1 X + \epsilon$$

Where, Y is the dependent variable; X is the independent variable; β0 is an intercept (the value of Y when X=0); β1 is the slope of the regression line (the change in Y for a one-unit change in X); ϵ is represents the error term. In the present study, SPSS Package 28 was used to calculate the correlation and simple linear regression.

3. RESULTS AND DISCUSSION

3.1 Pulp weight (g)

Our results revealed that significant variability existed among various germplasm of mango related to pulp weight (Table 2). The maximum pulp weight was found in 'PMGC-19' (300.73 g), followed by 'PMGC-97' (299.61 g) and 'PMSS-10' (292.20 g) while the minimum pulp weight was recorded in 'PMGC-51' (98.14 g) followed by 'PMGC-72' (99.88 g) and 'PMGC-21' (119.37 g). Similar results related to pulp weight were found by Bhoyar and Kumar [23] and Esan et al. [24] in mango.

3.2 Relationship between pulp weight and physical attributes

3.2.1 Pulp weight (PW) vs. fruit shape index (FSI)

These results revealed that significant differences occurred for the fruit shape index among the mango germplasm. The highest FSI (2.41) was exhibited by the fruit of germplasm 'PMSS-31' and it was followed by 'PMSS-17' (2.07) and 'PMGC-19' (1.81), while 'PMGC-51'

(1.02) exhibited the least FSI and it was followed by ‘PMGC-21’ (1.04) (Table 2). Further, the direct positive correlation ($r2 = 0.176$) was observed between PW and FSI (Table 3 and Fig. 1a).

Table 2: Physio-biochemical attributes of mango germplasm under *Tarai* region of Uttarakhand

Germplasm	Pulp weight (g)	Fruit shape index	Pulp/Stone ratio	Brix/Acid ratio	pH
Dashehari	146.74^{m}	1.54^{gh}	0.228^{gh}	97.63^{d}	5.59^{b-d}
Langra	163.48^{i-l}	1.42^{ij}	0.266^{c}	111.11^{c}	5.49^{c-f}
PMGC-5	255.16^{bc}	1.17^{n}	0.136^{o}	92.40^{e}	5.45^{c-g}
PMGC-19	300.73^{a}	1.81^{c}	0.211^{i}	78.18^{f}	5.34^{e-i}
PMGC-20	233.74^{de}	1.39^{j}	0.209^{i}	98.38^{d}	5.38^{c-i}
PMGC-21	119.37^{n}	1.04^{o}	0.247^{e}	46.13^{p}	4.69^{m-o}
PMGC-36	185.42^{gh}	1.32^{k}	0.235^{f-h}	58.46^{kl}	5.21^{h-k}
PMGC-39	223.07^{e}	1.31^{k}	0.190^{k}	70.22^{i}	5.27^{f-j}
PMGC-48	177.10^{g-j}	1.64^{f}	0.152^{mn}	132.06^{b}	5.76^{ab}
PMGC-50	227.50^{de}	1.67^{ef}	0.232^{f-h}	65.42^{j}	5.25^{g-j}
PMGC-51	98.14^{o}	1.02^{o}	0.293^{b}	59.62^{k}	5.10^{jk}
PMGC-72	99.88^{o}	1.24^{lm}	0.309^{a}	40.23^{q}	4.23^{r}
PMGC-96	169.46^{h-k}	1.72^{e}	0.256^{d}	140.87^{a}	5.87^{a}
PMGC-97	299.61^{a}	1.57^{g}	0.148^{n}	57.10^{k-m}	4.71^{m-o}
PMGC-98	184.13^{gh}	1.49^{hi}	0.167^{l}	52.46^{o}	4.58^{o-q}
PMGC-163	243.17^{cd}	1.65^{f}	0.227^{h}	69.42^{i}	5.15^{i-k}
PMGC-164	189.85^{fg}	1.28^{kl}	0.214^{i}	93.21^{e}	5.61^{bc}
PMSS-1	232.06^{de}	1.26^{k-m}	0.165^{l}	73.70^{gh}	5.32^{e-j}
PMSS-7	258.27^{b}	1.70^{ef}	0.291^{b}	55.34^{m-o}	4.87^{lm}
PMSS-8	173.42^{h-k}	1.84^{c}	0.160^{lm}	71.61^{hi}	5.30^{f-j}
PMSS-9	153.14^{lm}	1.48^{i}	0.237^{fg}	68.83^{i}	5.36^{d-i}
PMSS-10	292.20^{a}	1.42^{ij}	0.104^{p}	49.08^{p}	4.45^{pq}
PMSS-11	131.05^{n}	1.21^{mn}	0.129^{o}	39.78^{q}	4.37^{qr}
PMSS-14	183.55^{ghi}	1.79^{d}	0.199^{j}	79.18^{f}	5.43^{c-h}
PMSS-15	159.12^{k-m}	1.55^{g}	0.235^{f-h}	56.30^{l-n}	5.01^{kl}
PMSS-17	228.72^{de}	2.07^{b}	0.151^{n}	78.85^{f}	5.54^{c-e}
PMSS-18	200.99^{f}	1.67^{ef}	0.240^{ef}	76.23^{fg}	5.41^{c-h}
PMSS-19	182.09^{g-i}	1.45^{ij}	0.235^{f-h}	53.73^{no}	4.81^{l-n}
PMSS-30	167.68^{i-l}	1.74^{de}	0.207^{ij}	77.27^{f}	5.45^{c-g}
PMSS-31	262.28^{b}	2.41^{a}	0.206^{ij}	48.27^{o}	4.63^{n-p}
SEm±	5.08	0.02	0.003	1.01	0.07
CD @ 5%	14.37	0.06	0.008	2.85	0.20

*Means with same letter within a column shows non-significant differences (at $p \leq 0.05$) as per Duncan’s multiple-range test

3.2.2 Pulp weight (PW) vs. Pulp/Stone ratio (PSR)

The PSR of fruits varied significantly among the selected mango germplasm (Table 2). The fruit of ‘PMGC-71’ exhibited the maximum PSR (0.309), followed by the fruit of germplasm such as ‘PMGC-51’ (0.293), ‘PMSS-7’ (0.291) and ‘Langra’ (0.266). Similarly, the minimum PSR were recorded in germplasm such as ‘PMSS-10’ (0.104), ‘PMSS-11’ (0.129) and ‘PMGC-5’ (0.136). The direct positive correlation was observed between PSR and PW ($r2 = 208$) (Table 3 and Fig. 1b) in mango germplasm. Similar results related to variability in fruit shape index and pulp/stone ratio were reported by Tandel et al. [25] and Esan et al. [24] in mango.

3.3 Relationship between pulp weight and biochemical attributes

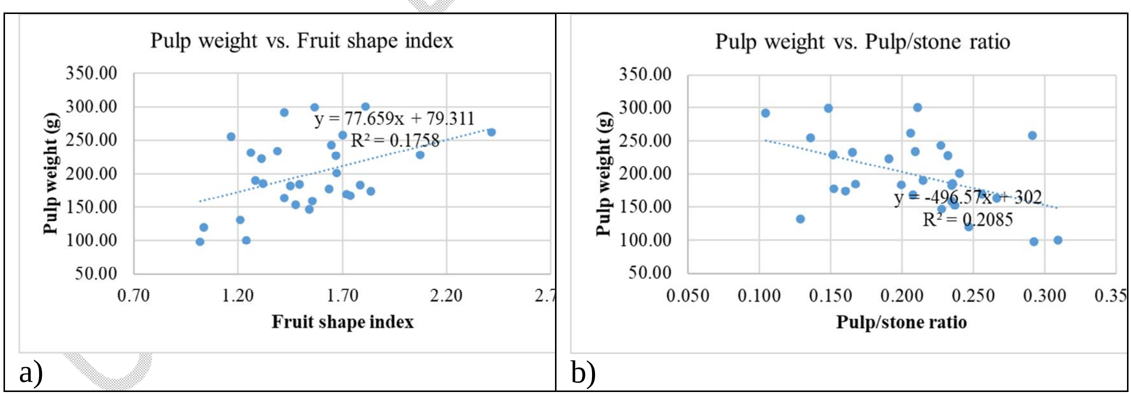
3.3.1 Pulp weight (PW) vs. Brix/Acid ratio (BAR)

The significant differences observed among the germplasm and found highest BAR was exhibited in germplasm ‘PMGC-96’ (140.87), followed by ‘PMGC-48’ (132.06) and ‘Langra’ (111.11) while minimum was recorded with the germplasm ‘PMSS-11’ (39.78), whereas, this variation might be due to the genetic characteristic of the variety [2] (Table 2). The BAR is an important biochemical attribute which affects the taste of mango fruit [17, 20]. The correlation between BAR and PW was found to be non-related (r2 = 0.00002) (Table 3 and Fig. 1c).

Table 3. Pearson correlation coefficient (r), coefficient of determination (r2), linear regression equation (y) and significance of the relationship (p) between dependent and independent variables

Variables	*r* =	r^2 =	*y* =	*p* =
PW vs FSI	-0.419	0.176	77.659x + 79.311	.01
PW vs PSR	0.457	0.208	-496.57x + 302	.01
PW vs BAR	0.005	0.00002	0.0103x + 197.29	.01
PW vs pH	0.018	0.00033	2.3772x + 185.78	.01

Note: Depended variable is pulp weight (PW) and independent are fruit shape index (FSI), pulp/stone ratio (PSR), brix/acid ratio (BAR) and pH for various germplasm of mango.



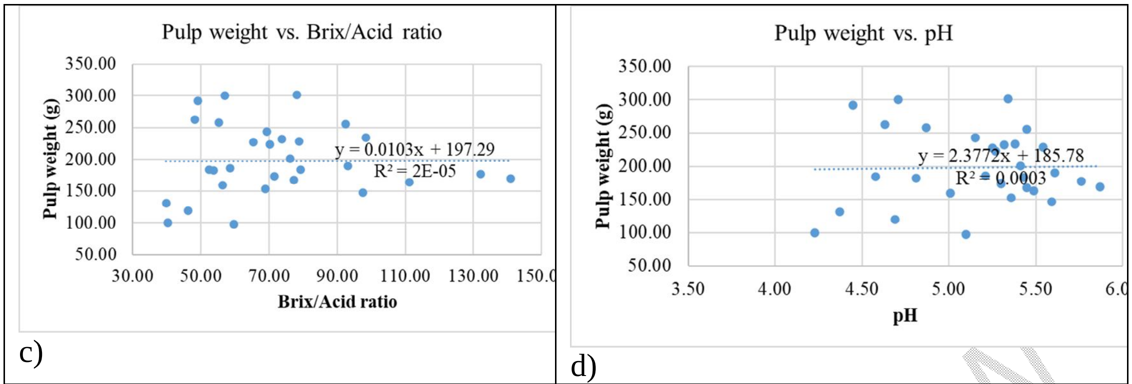


Fig. 1a-d. Scatter plots and linear egression lines showing the relationship between subjective pulp weight and fruit shape index (a), Pulp/stone ratio (b), Brix/acid ratio (c) and pH (d) for mango germplasm.

3.3.2 Pulp weight (PW) vs. pH

The maximum pH was recorded in germplasm 'PMGC-96' (5.87) and it was followed by 'PMGC-48' (5.76) and 'Dashehari' (5.59) (Table 2). While, the lowest pH was recorded in the germplasm 'PMGC-72' (4.23). The correlation between pH and PW was found to be non-related (r2 = 0.00033) (Table 3 and Fig. 1d). The pH is a component of the nutritional value of mango fruit [26, 27]. The significant differences among the germplasm concerning pH might be due to the genotypic feature [2]. The results related to variation in brix/acid ratio and pH were observed by Vu et al. [28] and Chahal et al. [29] in mango.

3.4 Pearson's correlation matrix for physio-biochemical attributes

The Pearson correlation matrix reveals the positive and negative relationships between various physio-biochemical attributes of the mango germplasm (Fig. 2). Fruit shape index shows moderate significant positive correlation with pulp weight (r = 0.419), indicating that as the fruit shape index increases, the pulp weight tends to increase. While, it has a negative correlation with Pulp/Stone ratio (r = -0.118), suggested that a higher fruit shape index corresponds to a lower pulp/stone ratio, although this relationship is relatively weak. Pulp/Stone ratio exhibited significant moderate negative correlation with pulp weight (r = -0.457), implying that a higher pulp/stone ratio is associated with a lower pulp weight.

Brix/Acid ratio is strong significant positively correlated with pH (r = 0.863), revealed that as the Brix/Acid ratio increases, the pH value also rises significantly. However, it exhibits a very weak positive correlation with pulp weight (r = 0.005), suggesting almost no association between these two attributes. pH shows a very weak positive correlation with pulp weight (r = 0.018), indicating that the pH has a negligible effect on pulp weight.

The Pearson's correlation matrix revealed significant relationships between various physio-biochemical attributes of mango germplasm. The moderate positive correlation between pulp weight and fruit shape index implies that as the fruits become more elongated, the pulp weight tends to increase. While, a moderate negative correlation was observed between pulp weight and pulp/stone ratio, suggesting that fruits with a higher PSR tend to have less pulp weight. This relationship could be attributed to the fact that, in some germplasm, a higher PSR indicates a higher stone content relative to pulp, thereby reducing the overall pulp yield. The strong positive correlation between Brix/acid ratio and pH (r = 0.863) indicated that germplasm with a higher Brix/acid ratio also exhibit higher pH values, reflecting a lower acidity level. This relationship is critical for determining the flavor profile of mangoes, as a higher BAR with a corresponding higher pH result in a sweeter and less acidic fruit. However, the weak positive correlations of BAR and pH with pulp weight suggest that biochemical traits like sweetness and acidity are important for flavor, they are not directly linked to pulp yield.

Fig 2. Pearson's correlation matrix for physio-biochemical attributes of mango germplasm under *Tarai* region of Uttarakhand.

4. CONCLUSION

The study successfully highlighted the significant variation in pulp weight among various mango germplasms and provided critical insights into the relationships between pulp weight and various physio-biochemical attributes. While pulp weight showed a moderate positive correlation with the fruit shape index, it exhibited a moderate negative correlation with the pulp/stone ratio, suggesting that certain physical traits could be predictive of pulp weight. However, biochemical parameters such as Brix/Acid ratio and pH showed less or negligible substantial association with pulp weight. The variability observed in the germplasm and the correlations established can be utilized in mango breeding programs to select for desirable fruit quality traits, particularly for enhancing pulp content. Based on the fruit quality parameters, seven genotypes (PMGC-163, PMSS-1, PMSS-17, PMSS-18, PMGC-48, PMGC-96, and PMSS-11) were found to be superior and promising for cultivation s well as potential parental genotypes in mango improvement programs. Overall, this research provides a foundational understanding of the complex interplay between pulp weight and physio-biochemical attributes in mango, thereby contributing to the development of improved cultivars for commercial cultivation.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text to image generators have been used during writing or editing of manuscripts.

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Review Form 3