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Morphological characterization of mango (*Mangifera indica* L.) germplasm under Tarai region of Uttarakhand

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Abstract
A study was conducted to determine the nature and magnitude of variation among 30 mango germplasms for different tree growth, flowering and fruiting attributes. The data related to tree type, crown shape, tree growth habit and foliage density are showed variation among all mango germplasm. The germplasm PMSS-9 exhibited longest flowering duration. The secondary/ off-season flowering was absent and terminal position & semi erect inflorescence axis growth habit were observed in all the mango germplasm. The variation was noted with respect to shape of inflorescence and density of flowers in inflorescence. However, the variation was observed among all mongo germplasm with respect to bearing intensity, fruit shape, attractiveness, surface texture of fruit skin and density of lenticles on fruit skin. A considerable variation in fruit skin thickness and pulp content were observed in the different germplasm of mango. A better understanding of the relationship between the genotypic and phenotypic traits needs to be developed by further examination of the genetic parameters and divergence in the germplasm.

Keywords: *Mangifera indica* L., germplasm, characterization, growth, flowering, fruiting

1. Introduction
Mango (*Mangifera indica* L.) belongs to the Anacardiaceae family (order-Sapindales) and is an important fruit crop throughout the world. Southeast Asia is a natural distribution area for mangoes. In India, five species of *Mangifera* have been reported, including *M. indica, M. andamanica, M. khasiana, M. sylvatica* and *M. comptosperma* (Mukherjee, 1985) [10]. The high degree of mango diversity is observed in India and germplasms are conserved in various gene banks are 2733 in field gene banks and 371 in pollen gene banks (Agrawal *et al*., 2021) [1], which has led some authors to consider it the country of origin (Ravishankar *et al*., 2000) [14]. A wide range of germplasm exists in mangoes throughout the country. In spite of being the ancestral home of mango germplasm, India has over thousands of germplasms spread across various agro-climatic zones (Yadav and Rajan, 1993) [19]. There are only a dozen mango varieties grown commercially in India despite its rich mango diversity. India is renowned around the world for its diverse collection of mango types, each with its own distinct flavour, texture and attractiveness. As compared to other fruits in India, mango is one of the most popular and is also called the national fruit and king of fruits because no other fruit can rival it in terms of nutritional qualities, area and production. As part of the total horticultural area of 28.10 million hectares and production of 342.30 million tonnes, area under mango is over 2,370.80 thousand hectares and total production is 20,946.40 thousand MT in India (Anon., 2022) [3]. Several states in India produce mangoes, including Uttar Pradesh, Bihar, West Bengal, Maharashtra, Andhra Pradesh, Karnataka, Kerala, Gujarat, Delhi, Punjab and Jammu & Kashmir. Uttarakhand's mangoes are confined to subtropical regions encompassing 36914.46 hectares and yielding 156792.50 tons of fruits per year (Anon., 2020) [4].

The genetic diversity of any crop's germplasm is a prerequisite for a successful crop improvement program. There has been a challenge in improving mangoes for many years. In mango growing regions with varied agro-climatic conditions, there is extensive diversity caused by alloploidy, outbreeding and phenotypic differences (Ravishankar *et al*., 2000) [14]. Traditionally, characterization of collected germplasm primarily based on the morphological descriptors and it is easiest and less complex method (Korir *et al*., 2012) [8], which includes phenotypic characteristics like tree growth habit, floral characters and fruiting attributes etc. Keeping in view the importance of morphological variability of germplasm and the availability of a wide range of mango germplasm in Uttarakhand State, the present study was planned with the objective of morphological characterization.

2. Materials and Method

2.1 Experimental site and materials: The study was conducted on thirty mango germplasms (28 primary germplasms and 2 used as check variety i.e. Dashehari and Langra) maintained at HRC, Patharchatta, of G. B. Pant University of Agriculture and Technology, Pantnagar, which is located at 29.5° North latitude and 79.3° East longitude at an altitude of 243.94 metres above mean sea level. The experimental site has a humid subtropical climate with dry and hot summers.

2.2 Measurements and observations: Thirty mango germplasm were morphologically characterized over two consecutive years, 2021 and 2022. The PPV&FRA test guidelines were followed to evaluate the mango germplasm for different morphological characters related to tree growth parameters *i.e*. tree type, crown shape, growth habit and foliage density, floral parameters *i.e*. flowering duration, secondary/off season flowering, inflorescence position, inflorescence axis growth habit, shape and density of inflorescence and fruit attributes *i.e*. fruit bearing intensity, shape, attractiveness and surface texture of fruit skin (IPGRI, 2006) [7]. Fruit skin thickness of mature ripe fruits was measured with the help of digital Vernier Caliper, Mitutoyo Inc., Japan and expressed in millimetre. Pulp weight was measured by subtracting skin weight and stone weight from fruit weight.

2.3 Statistical analysis: The experiment was conducted using a randomized block design (Panse and Sukhatme, 1978) [12]. The data were analyzed using Analyses of Variance (ANOVA). Duncan's multiple range tests were used to determine significant differences among groups at $p<0.05$. IBM SPSS Statistics 19 (IBM, NY, USA) for all computations and statistical analyses.

3. Results and Discussion

3.1 Tree growth characteristics: The data pertaining to tree type, crown shape, tree growth habit and foliage density are presented in Table 1. Out of 30 mango germplasm studied Dashehari and Langra were found to grafted and rest of germplasm seedling type. It was observed that the crown shape varied from semi-circular in Dashehari, Langra, PMGC-39, PMGC-48, PMCG-50, PMGC-97 & PMCG-163, oblong in PMGC-5, PMGC-19, PMGC-20, PMGC-21, PMGC-36, PMGC-51, PMGC-72, PMGC-96, PMGC-98, PMGC-164, PMSS-1, PMSS-7, PMSS-8, PMSS-9, PMSS-10, PMSS-14, PMSS-17, PMSS-18, PMSS-19, PMSS-30 & PMSS-31, spherical in PMSS-11 to broadly pyramidal in PMSS-15.

The spreading growth habit was observed in different mango germplasm like Dashehari, Langra, PMGC-50, PMGC-97, PMGC-163, PMSS-7, PMSS-8, PMSS-9, PMSS-11, PMSS-14, PMSS-15, PMSS-17, PMSS-19, PMSS-30 & PMSS-31, erect growth habit in PMGC-5, PMGC-19, PMGC-20, PMGC-21, PMGC-36, PMGC-51, PMGC-72, PMGC-96, PMGC-98, PMGC-164, PMSS-1, PMSS-10 & PMSS-18 and drooping growth habit in PMGC-39 & PMGC-48. Variation in foliage density was found to be dense in Dashehari, Langra, PMGC-39, PMGC-48, PMGC-50, PMGC-96, PMGC-97, PMGC-163, PMGC-164, PMSS-10, PMSS-11, PMSS-15 & PMSS-31, sparse in PMGC-20 & PMGC-36 and intermediate in PMGC-5, PMGC-19, PMGC-21, PMGC-51, PMGC-72, PMGC-98, PMSS-1, PMSS-7, PMSS-8, PMSS-9, PMSS-14, PMSS-17, PMSS-18, PMSS-19 and PMSS-30.

Table 1: Tree growth characters of mango germplasm under *Tarai* condition (Recorded during the year 2021 & 2022)

S No.	Germplasms	Tree type	Crown shape	Tree growth habit	Foliage density
1.	Dashehari	Grafted	Semi circular	Spreading	Dense
2.	Langra	Grafted	Semi circular	Spreading	Dense
3.	PMGC-5	Seedling	Oblong	Erect	Intermediate
4.	PMGC-19	Seedling	Oblong	Erect	Intermediate
5.	PMGC-20	Seedling	Oblong	Erect	Sparse
6.	PMGC-21	Seedling	Oblong	Erect	Intermediate
7.	PMGC-36	Seedling	Oblong	Erect	Sparse
8.	PMGC-39	Seedling	Semi circular	Drooping	Dense
9.	PMGC-48	Seedling	Semi circular	Drooping	Dense
10.	PMGC-50	Seedling	Semi circular	Spreading	Dense
11.	PMGC-51	Seedling	Oblong	Erect	Intermediate
12.	PMGC-72	Seedling	Oblong	Erect	Intermediate
13.	PMGC-96	Seedling	Oblong	Erect	Dense
14.	PMGC-97	Seedling	Semi circular	Spreading	Dense
15.	PMGC-98	Seedling	Oblong	Erect	Intermediate
16.	PMGC-163	Seedling	Semi circular	Spreading	Dense
17.	PMGC-164	Seedling	Oblong	Erect	Dense
18.	PMSS-1	Seedling	Oblong	Erect	Intermediate
19.	PMSS-7	Seedling	Oblong	Spreading	Intermediate
20.	PMSS-8	Seedling	Oblong	Spreading	Intermediate
21.	PMSS-9	Seedling	Oblong	Spreading	Intermediate
22.	PMSS-10	Seedling	Oblong	Erect	Dense
23.	PMSS-11	Seedling	Spherical	Spreading	Dense
24.	PMSS-14	Seedling	Oblong	Spreading	Intermediate
25.	PMSS-15	Seedling	Broadly pyramidal	Spreading	Dense
26.	PMSS-17	Seedling	Oblong	Spreading	Intermediate
27.	PMSS-18	Seedling	Oblong	Erect	Intermediate
28.	PMSS-19	Seedling	Oblong	Spreading	Intermediate
29.	PMSS-30	Seedling	Oblong	Spreading	Intermediate
30.	PMSS-31	Seedling	Oblong	Spreading	Dense

The 30 mango germplasms studied showed considerable variation in tree growth characteristics. Different germplasm exhibits different behaviours in tree growth characteristics, confirming their genetic variability.

3.2 Flowering characters: The data pertaining to flowering duration, secondary/off season flowering, inflorescence position, inflorescence axis growth habit, shape and density of inflorescence are presented in Table 2. The estimate of flowering duration clearly indicates that the germplasm differs significantly for the duration of flowering during both the years. The pooled data indicates the germplasm PMSS-9 exhibited longest flowering duration (24.91 days) which was statistically *at par* with PMSS-1 (24.75 days), PMGC-163 (24.50 days), PMSS-15 (23.90 days) and PMSS-7 (23.0 days), while, PMGC-48 showed the shortest (16.50 days) duration of flowering. The observation recorded for secondary/off-season flowering during the year 2021 and 2022 as revealed that it was absent in all the mango germplasm. Inflorescence position was observed to be terminal in all germplasm. Growth habit of the inflorescence axis in mango germplasm showed no variations and it was observed as semi-erect type.

Table 2: Flowering characters of mango germplasms under *Tarai* condition (Recorded during the year 2021 & 2022)

S No.	Germplasms	Flowering duration (days)	Secondary/off-season flowering	Inflorescence position	Inflorescence axis growth habit	Inflorescence shape	Density of flowers in inflorescence
1.	Dashehari	18.34ghij*	Absent	Terminal	Semi erect	Pyramidal	Dense
2.	Langra	17.75hij	Absent	Terminal	Semi erect	Pyramidal	Medium
3.	PMGC-5	18.58ghi	Absent	Terminal	Semi erect	Pyramidal	Medium
4.	PMGC-19	18.00hij	Absent	Terminal	Semi erect	Broadly pyramidal	Medium
5.	PMGC-20	18.34ghij	Absent	Terminal	Semi erect	Pyramidal	Medium
6.	PMGC-21	19.49fgh	Absent	Terminal	Semi erect	Broadly pyramidal	Dense
7.	PMGC-36	18.84ghi	Absent	Terminal	Semi erect	Pyramidal	Medium
8.	PMGC-39	19.50fgh	Absent	Terminal	Semi erect	Pyramidal	Denes
9.	PMGC-48	16.50j	Absent	Terminal	Semi erect	Pyramidal	Medium
10.	PMGC-50	17.75hij	Absent	Terminal	Semi erect	Conical	Sparse
11.	PMGC-51	17.17ij	Absent	Terminal	Semi erect	Pyramidal	Medium
12.	PMGC-72	18.00hij	Absent	Terminal	Semi erect	Broadly pyramidal	Dense
13.	PMGC-96	19.67fgh	Absent	Terminal	Semi erect	Pyramidal	Sparse
14.	PMGC-97	21.08def	Absent	Terminal	Semi erect	Pyramidal	Medium
15.	PMGC-98	19.17gh	Absent	Terminal	Semi erect	Conical	Medium
16.	PMGC-163	24.50ab	Absent	Terminal	Semi erect	Pyramidal	Medium
17.	PMGC-164	19.08ghi	Absent	Terminal	Semi erect	Pyramidal	Medium
18.	PMSS-1	24.75a	Absent	Terminal	Semi erect	Conical	Medium
19.	PMSS-7	23.00bc	Absent	Terminal	Semi erect	Pyramidal	Medium
20.	PMSS-8	21.75cde	Absent	Terminal	Semi erect	Pyramidal	Medium
21.	PMSS-9	24.91a	Absent	Terminal	Semi erect	Pyramidal	Dense
22.	PMSS-10	19.25fgh	Absent	Terminal	Semi erect	Conical	Sparse
23.	PMSS-11	17.92hij	Absent	Terminal	Semi erect	Conical	Medium
24.	PMSS-14	21.58cde	Absent	Terminal	Semi erect	Conical	Sparse
25.	PMSS-15	23.25abc	Absent	Terminal	Semi erect	Conical	Sparse
26.	PMSS-17	19.25fgh	Absent	Terminal	Semi erect	Pyramidal	Medium
27.	PMSS-18	18.08ghij	Absent	Terminal	Semi erect	Conical	Sparse
28.	PMSS-19	19.09ghi	Absent	Terminal	Semi erect	Pyramidal	Sparse
29.	PMSS-30	20.00efg	Absent	Terminal	Semi erect	Pyramidal	Medium
30.	PMSS-31	21.91def	Absent	Terminal	Semi erect	Pyramidal	Sparse
	SEm±	0.57					
	CD at 5%	1.62					

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

The shape of inflorescence varied in different mango germplasm as indicated in Table 4.3. The Pyramidal shape was recorded in Dashehari, Langra, PMGC-5, PMGC-20, PMGC -36, PMGC-39, PMGC-48, PMGC-51, PMGC-96, PMGC-97, PMGC-163, PMGC-164, PMSS-7, PMSS-8, PMSS-9, PMSS-17, PMSS-19, PMSS-30 and PMSS-31; broadly pyramidal shape in PMGC-19, PMGC-21, PMGC-72, while, conical shape was found in PMGC-50, PMGC-98, PMSS-1, PMSS-10, PMSS-11, PMSS-14, PMSS-15 and PMSS-18. The density of flowers in inflorescence in different mango germplasm recorded to be dense in germplasm such as Dashehari, PMGC- 21, PMGC-39, PMGC-72, PMSS-9; medium in Langra, PMGC-5, PMGC-19, PMGC-20, PMGC-36, PMGC-48, PMGC-51, PMGC-97, PMGC-98, PMGC-163, PMGC-164 PMSS-1, PMSS-7, PMSS-8, PMSS-11, PMSS-17 and PMSS-30 and sparse in PMGC-50, PMGC-96, PMSS-10, PMSS-14, PMSS-15, PMSS-18, PMSS-19 and PMSS-31. Similar results were found by Singh *et al*. (2010) [18] when studying flowering duration in mango varieties. It has been observed that mango flowering duration varies with maturity of the shoot and prevailing weather conditions. Warm temperatures shorten the flowering period compared to moderate temperatures. Conversely, cool temperatures prolong flowering duration. These results are in conformity with results of Ribeiro *et al*. (2013) [16] who found that in 72% of the mango accessions, the predominant inflorescence shape was pyramidal whereas, Campbell and Malo (1974) [6], found the inflorescence of the mango has a pyramidal shape, while, Mukherjee (1985) [10] mentioned a conical and pyramidal shape among different accessions. Raza *et al*. (2017) [15] and Rahman *et al*. (2022) [13] found similar results regarding inflorescence position and density of flowers.

3.3 Fruiting characters: The data regarding fruit bearing intensity, fruit shape, attractiveness, surface texture of fruit skin, density of lenticles and thickness of fruit skin presented in Table 3.

Table 3: Fruiting characters of mango germplasms under *Tarai* condition (Recorded during the year 2021 & 2022)

S No.	Germplasms	Fruit bearing intensity	Fruit shape	Fruit attractiveness	Fruit skin surface texture	Density of lenticels on fruit skin	Fruit skin thickness (mm)
1.	Dashehari	High	Elliptic	Excellent	Smooth	Dense	0.63^{j}
2.	Langra	High	Roundish	Good	Smooth	Medium	0.85^{f}
3.	PMGC-5	Medium	Roundish	Good	Smooth	Sparse	0.42^{p}
4.	PMGC-19	Medium	Elliptic	Average	Smooth	Sparse	0.58^{kl}
5.	PMGC-20	Medium	Elliptic	Excellent	Smooth	Medium	0.68^{h}
6.	PMGC-21	High	Roundish	Average	Rough	Dense	1.05^{ab}
7.	PMGC-36	High	Roundish	Average	Smooth	Dense	0.75^{g}
8.	PMGC-39	High	Oblong	Average	Smooth	Medium	0.66^{hi}
9.	PMGC-48	Medium	Oblong	Good	Smooth	Dense	0.54^{mn}
10.	PMGC-50	Medium	Oblong	Good	Smooth	Dense	0.86^{ef}
11.	PMGC-51	High	Roundish	Good	Smooth	Medium	1.03^{ab}
12.	PMGC-72	Medium	Oblong	Good	Smooth	Dense	1.00^{c}
13.	PMGC-96	High	Oblong	Average	Smooth	Dense	0.92^{d}
14.	PMGC-97	High	Oblong	Average	Smooth	Dense	1.05^{ab}
15.	PMGC-98	Medium	Elliptic	Excellent	Smooth	Sparse	0.46^{o}
16.	PMGC-163	High	Oblong	Good	Smooth	Medium	0.57^{lm}
17.	PMGC-164	High	Oblong	Good	Smooth	Medium	0.67^{h}
18.	PMSS-1	Medium	Oblong	Excellent	Smooth	Medium	0.33^{q}
19.	PMSS-7	Medium	Elliptic	Good	Smooth	Dense	0.35^{q}
20.	PMSS-8	Low	Elliptic	Good	Smooth	Dense	0.63^{ij}
21.	PMSS-9	Medium	Oblong	Average	Smooth	Dense	0.67^{h}
22.	PMSS-10	Medium	Oblong	Good	Smooth	Medium	0.60^{jk}
23.	PMSS-11	Medium	Roundish	Good	Smooth	Medium	1.06^{a}
24.	PMSS-14	Medium	Oblong	Excellent	Smooth	Medium	1.05^{ab}
25.	PMSS-15	High	Elliptic	Excellent	Smooth	Sparse	0.44^{op}
26.	PMSS-17	Medium	Elliptic	Good	Smooth	Sparse	0.43^{p}
27.	PMSS-18	Medium	Elliptic	Excellent	Smooth	Dense	0.59^{kl}
28.	PMSS-19	Medium	Oblong	Excellent	Smooth	Sparse	0.88^{e}
29.	PMSS-30	High	Oblong	Good	Smooth	Medium	0.53^{n}
30.	PMSS-31	High	Oblong	Average	Rough	Medium	1.02^{bc}
	SEm±						0.01
	CD at 5%						0.03

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

Results indicated that high fruit bearing intensity observed in mango germplasm such as Dashehari, Langra, PMGC-21, PMGC-36, PMGC-39, PMGC-51, PMGC-96, PMGC-97, PMGC-163, PMGC-164, PMSS-15, PMSS-30 and PMSS-31; medium intensity in PMGC-5, PMGC-19, PMGC-20, PMGC-48, PMGC-50, PMGC-72, PMGC-98, PMSS-1, PMSS-7, PMSS-9, PMSS-10, PMSS-11, PMSS-14, PMSS-17, PMSS-18 and PMSS-19 and low intensity in PMSS-8. The shape of mature fruits was found elliptic in Dashehari, PMGC-19, PMGC-20, PMGC-98, PMSS-7, PMSS-8, PMSS-15, PMSS-17 and PMSS-18; roundish in Langra, PMGC-5, PMGC-21, PMGC-36, PMGC-51 and PMSS-11 and oblong in PMGC-39, PMGC-48, PMGC-50, PMGC-163, PMGC-164, PMSS-1, PMSS-9, PMSS-10, PMSS-14, PMSS-19, PMSS-30 and PMSS-31. The fruit attractiveness was found to be excellent for the germplasm such as Dashehari, PMGC-20, PMGC-98, PMSS-1, PMSS-14, PMSS-15, PMSS-18 and PMSS-19; good for Langra, PMGC-5, PMGC-48, PMGC-50, PMGC-51, PMGC-72, PMGC-163, PMGC-164, PMSS-7, PMSS-8, PMSS-10, PMSS-11, PMSS-17 and PMSS-30 and average for PMGC-19, PMGC-21, PMGC-36, PMGC-39, PMGC-96, PMGC-97, PMSS-9 and PMSS-31. Based on the fruit skin surface texture, mango germplasm were found to be smooth and rough textured. The rough textured skin surface was noted in PMGC-21 and PMSS-31, while, rest of the germplasm were observed as smooth textured during the experimentation. The density of lenticels on fruit skin were found to be dense in mango germplasm such as Dashehari, PMGC-21, PMGC-36, PMGC-48, PMGC-50, PMGC-72, PMGC-96, PMGC-97, PMSS-7, PMSS-8, PMSS-9 and PMSS-18; medium in Langra, PMGC-20, PMGC-39, PMGC-51, PMGC-163, PMGC-164, PMSS-1, PMSS-10, PMSS-11, PMSS-14, PMSS-30 and PMSS-31 and sparse in PMGC-5, PMGC-19, PMGC-98, PMSS-15, PMSS-17 and PMSS-19. Data on the thickness of fruit skin is showed significantly difference among all these mango germplasms and maximum value was noted in PMSS-11 (1.06 mm) and minimum in PMSS-1 (0.33 mm). A considerable variation in pulp content was observed in the different germplasm of mango studied (Fig. 1). Pooled analysis of data further revealed that PMGC-19 had maximum pulp content (300.73 g) followed by PMGC-97 (299.61 g) and PMGC-51 had the lowest pulp content (98.14 g).

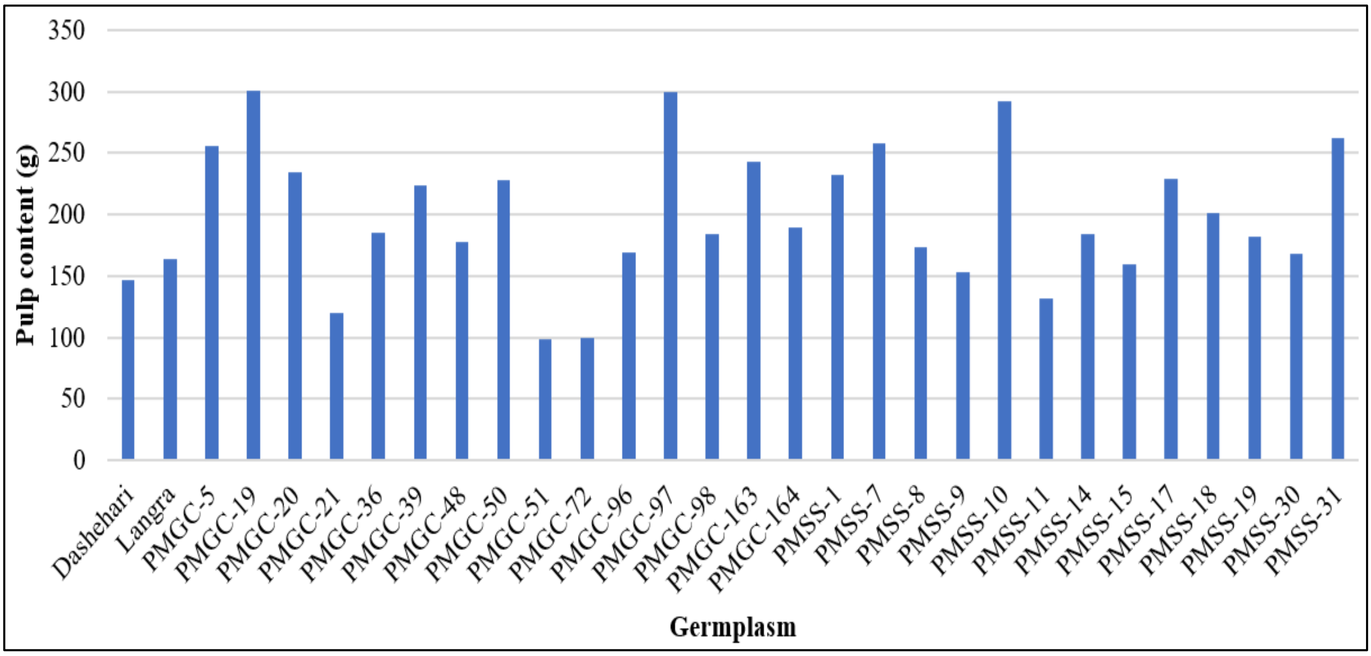

Fig 1: Pulp content of mango germplasms under *Tarai* condition

Sennhenn *et al*. (2014) [17] and Alcasid *et al*. (2015) [2] observed similar results in terms of fruit attractiveness, skin thickness and fruit skin texture. Bora *et al*. (2017) [5], Narvariya *et al*. (2017) [11] and Kumar *et al*. (2022) [9] reported that mango cultivars had a wide range of variation in fruit characters.

4. Conclusion
To exploit useful traits in fruit breeding, it is necessary to identify and describe the genetic variability available in germplasms. The germplasm having variation in flowering duration, floral characters, related to fruit skin attractiveness, texture, thickness of skin and pulp content can be useful for initiating any hybridization programme. In crop improvement, fruit size and attractiveness are a key objective. As a result, the present study suggests that the germplasm, PMGC-20, PMGC-98, PMSS-1, PMSS-14, PMSS-15, PMSS-18 and PMSS-19, that show superiority in these attributes would make suitable parents for breeding mango germplasm.

5. Future Scope
To understand the relationship between genotypes and phenotypes, genetic variability in germplasms has to be further examined for its genetic parameters and divergence. The mango germplasm has also not been characterized on a molecular basis for future breeding programs. Developing a new cultivar with desirable traits such as late maturity, more shelf life, colour, and pickling type requires an understanding of how these traits are inherited as well as possible parent combinations.

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7. Conflict of Interest: None.

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