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Morphological and biochemical characterization of mango (*Mangifera indica* L.) genotypes under high density planting system

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Abstract

Experiment on evaluation of mango genotypes under high density planting system was conducted in six mango varieties of the same age group (5 years). The observation on tree characters indicated that the trunk circumference ranged from 20.51 cm (Prior) to 31.29 cm (Chandrakaran) and crown diameter ranged from 2.39 m (Ratna) to 3.09 m (Vellaikolumban). The qualitative data on morphological characters viz., tree, leaf, inflorescence, fruit, stone and seed characters were grouped into clusters based on the IPGRI descriptor. The observation on leaf characters revealed that the leaf blade length varied from 19.17 cm (Muvandan) to 25.40 cm (Ratna), leaf blade width ranged from 4.84 cm (Muvandan) to 7.68 cm (Vellaikolumban) and leaf petiole length varied from 2.29 cm (Chandrakaran) to 4.18 cm (Vellaikolumban). Based on the inflorescence characters studied, it was found that inflorescence length varied from 22.14 cm (Prior) to 36.47 cm (Vellaikolumban), hermaphrodite flowers ranged from 33.40% (Muvandan) to 85.80% (Chandrakaran) and number of stamens varied from 3 to 4. The observation on fruit characters revealed that the fruit length varied from 7.49 cm (Chandrakaran) to 18.71 cm (Mallika), fruit diameter ranged from 13.18 cm (Chandrakaran) to 25.25 cm (Mallika), fruit weight ranged from 8.93 g (Muvandan) to 24.69 g (Mallika), yield per tree ranged from 8.93 kg/tree (Muvandan) to 24.69 kg/tree (Mallika), and shelf life of fruits varied from 4 to 6 days. The observations on stone and seed characters revealed that Chandrakaran recorded the lowest stone length (5.58 cm), stone width (3.36 cm), stone thickness (1.23 cm), stone weight (17.79 g) and seed length (4.05 cm). The lowest seed width and seed weight was recorded by Prior (3.07cm) and Vellaikolumban (9.44 cm). The highest stone length was recorded by Mallika (11.67 cm), stone width by Ratna (8.67 cm), stone thickness by Vellaikolumban (2.19 cm), stone weight by Mallika (44.33 g), seed weight by Prior (22.22 g) and seed length and width by Ratna (7.91 cm and 8.47 cm respectively). From the fruit analysis conducted for assessing the quality attributes of different mango genotypes grown under high density planting system TSS ranged from 14.78 °Brix (Muvandan), acidity varied from 0.02% (Mallika) to 0.07% (Muvandan), ascorbic acid varied from 28.26 mg 100g⁻¹(Vellaikolumban) to 79.68 mg 100g⁻¹ (Chandrakaran), carotenoids ranged from 1.40 mg 100g⁻¹ (Vellaikolumban) to 4.80 mg 100 g⁻¹ (Ratna), and β carotene ranged from 13.54 mg 100g⁻¹ (Vellaikolumban) to 39.93 mg 100g⁻¹(Ratna). The results on sensory indicated that Ratna variety of mango as the best one as it recorded the highest rank for colour, flavour, sweetness, texture and taste, as Mallika recorded the highest rank only for appearance. Wide variability was observed for the vegetative, floral, fruit and biochemical characters among the mango genotypes.

Keywords: *Mangifera indica*, vegetative characters, high density planting

Introduction

Mango (*Mangifera indica* L.), the most important fruit crop as well as the national fruit of India has been under cultivation in India for over 4000 years. There are at least 1000 named cultivars in India. Besides delicious taste, excellent flavour and attractive fragrance, it is rich in vitamin A and C. Mango germplasm exhibits specific ecogeographical requirement for adequate vegetative growth, flowering and production of proper quality fruits. Commercial varieties of a region behave differentially when grown in other agroclimatic zones of the country. It is also observed that the growth pattern in mango germplasm is genetically controlled, but has influenced by environmental condition. Hence, the present investigation was taken up for recording basic information on the flushing, flowering and fruit development of selected genotypes of mango under high density planting system.

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Materials and Methods

The study was conducted utilizing 6 diverse mango genotypes planted under high system at a spacing of 3x3 m in mango orchard of College of Agriculture, Vellanikkara, Thrissur, Kerala. All the genotypes were of 5 years age and in the bearing stage. Five healthy and uniform trees of each genotype were utilized for the study.

Details of experiments

Design of experiment – CRD

Number of treatments – 6

Number of replications – 5

Total number of trees - 6 x 5 = 30

Years of observation - 2016, 2017, 2018

List of mango genotypes selected for the study

Sl. No.	Genotype
1	Prior
2	Mallika
3	Vellaikolamban
4	Ratna
5	Chandrakaran
6	Muvandan

Tree characters, inflorescence characters and fruit characters were recorded. Age of the tree was noted from the basic records maintained in the college. Height of the tree was recorded from the ground level to the top of the tree with hypsometer and expressed in meter (m). Tree characters, inflorescence characters and fruit characters were recorded. Mature fruits were collected. Standard descriptors prescribed by biodiversity international (2006) were used as the guideline to describe the vegetative, inflorescence, fruit and stone characters.

Quality attributes of fruits were also recorded. TSS of mango pulp was recorded with the help of digital refractometer and expressed as °Brix. Acidity, total carotenoids, total sugars, reducing sugars were determined by the method of Ranganna (1997) [12]. Ascorbic acid and crude fibres were determined by the method of Sadasivam and Manickam (1996) [14]. Content of β carotene was estimated by AOAC (1975) [3] method. Sensory evaluation were carried out using nine point hedonic scale at laboratory level. A panel of ten judges between the age group of 18-40 years did the sensory evaluation as suggested by Jellinek (1985) [7].

Results and Discussion

Morphological characters

Various observations on morphological characters *viz.*, tree characters, leaf characters, inflorescence characters, fruit characters and seed characters were recorded, analysed and the results are presented in Tables 1 to table 24. The trees of same age group (5 years) were selected for the study (Table 1). The data presented in Table 2 indicated the variation in plant height of different genotypes. All the trees were pruned and maintained at a height of 3 meter. The observation on trunk circumference of mango trees during three seasons were presented in Table 3. Chandrakaran (31.29 cm) recorded the highest circumference which were significantly different from the rest of the varieties / local types and Prior (20.51 cm) recorded the lowest trunk circumference. The crown diameter (North –South) of mango was measured and presented in table 4a. Vellaikolumban (3.09 m) recorded the highest crown diameter (North -South) and Ratna (2.39 m) recorded the

lowest crown diameter (North -South). The crown diameter (East-West) of mango was measured and presented in Table 4 b which was not found to significantly differ among the genotypes and season. Different crown shapes like oblong, semi-circular, and spherical were noticed among the hybrids/local types (Table 5a). Trees exhibited different growth habits like erect and spreading were noticed among the hybrids/local types (Table 5b). Dense and intermediate foliage density were noticed among the hybrid/local types (Table 5c) (Fig.1).

The data presented in Table 6 indicated the variation in leaf lade length among different genotypes during three seasons. Ratna (25.40 cm) recorded the highest leaf blade length which was significantly different from the rest of the hybrid/local types and Muvandan (19.17 cm) recorded the lowest leaf blade length. The variation in leaf blade width among different genotypes during the three seasons under study are given as Table 7. Vellaikolumban (7.68 cm) recorded the highest leaf blade width which was significantly different form the rest of the hybrid/local types and Muvandan (4.84 cm) recorded the lowest leaf blade width.

The data presented in Table 8 indicated the variation in petiole length among different genotypes during three seasons. Ratna (4.18 cm) recorded the highest petiole length whereas Chandrakaran (2.29 cm) recorded the lowest petiole length. Elliptic, obovate, lanceolate and oblong leaf blade shape were noticed among the hybrids/local types (Table 9a). Obtuse, acuminate and acute leaf apex shape were noticed among the hybrids/local types (Table 9b). Round, acute and obtuse leaf base shape were noticed among the hybrids/local types (Table 9c) (Fig.2).

Different flowering durations like January – February and December – January were noticed among the hybrids/local types (Table 10a). Secondary/off season flowering were absent among all the hybrids/local types (Table 10a). All the hybrids/local types had trees with terminal inflorescence position (Table 10a). Pyramidal and conical inflorescence shape were noticed among the hybrids/local types (Table 10a). Sparse, medium and dense flowers were observed among the inflorescence of different hybrids/local types (Table 10a). Yellowish green, green with red patches, light green and light greenish with red patches were the inflorescence colour observed among the different hybrids/local types (Table 10b). Shorter and equal length of stamen in relation to pistil were found among the hybrids/local types (Table 10c) (Fig.3).

The data presented in Table 11 shows the variation in inflorescence length of different genotypes during the two seasons. Vellaikolumban (36.47 cm) recorded the highest inflorescence length and Prior (22.14 cm) recorded the lowest inflorescence length. The data presented in Table 12 shows the variation in inflorescence width of different genotypes during the two seasons. Vellaikolumban (23.54 cm) recorded the highest inflorescence width which was significantly different from the rest of the hybrid/local types and Chandrakaran (12.53 cm) recorded the lowest inflorescence width. The data presented in Table 12 shows the variation in inflorescence width of different genotypes during the two seasons. Chandrakaran (85.80 cm) recorded the highest hermaphrodite flowers in the inflorescence and Muvandan (36.40 cm) recorded the lowest hermaphrodite flowers in the inflorescence (Table 13). The data presented in Table 14 shows the variation in number of stamens per flower of different genotypes during the two seasons. All the local types

and the variety Mallika had 5 number of stamens per flower whereas Ratna had 5 number of stamens per flower. There was no seasonal effect on the number of stamens per flower.

A great diversity was found in morphological characters of mango varieties/types under the study and the variation in the vegetative characters might be due to the variation in the genetic make-up and interaction of various genotypes with agroclimatic conditions. Morphological characters can be used as an efficient tool for proper identification of different mango cultivars well before the commencement of that cultivar to bearing stage. Phenotypic characters are mainly influenced by environments and plant developmental stages. In addition, species with similar morphological characters cannot be easily distinguished. High variability in terms of morphological characters have also been reported by Singh *et al.*, (2017) [15], Ribeiro *et al.* (2013) [13], Rajwana (2011) [10] and (Joshi, 2013) [8].

Fruit characters

All the hybrids/local types were in fruiting during April-May (Table 15a). The data pertaining to the fruit characters are given in table 15a, 15b and 15c. (Fig.4)

The data presented in Table 16 indicated the variation in fruit length and fruit diameter of different genotypes during the two seasons. Mallika (18.71 cm) recorded the highest fruit length and Chandrakaran (7.49 cm) recorded the lowest fruit length. The data presented in Table 17 indicated the variation in fruit weight, fruit yield and shelf life of different genotypes during the two seasons.

Variability in mango varieties showed that fruit shape was the most important and stable character for discriminating varieties from each other. Other fruit characters also have a degree of varying importance for the purpose of identification. Presence of beak, fruit size, sinus, cavity of stalk insertion is important for studying variability in mango germplasm (Ram and Rajan, 2003) [11].

Stone characters

The data presented in Table 18 indicated the variation in stone length, stone width and stone thickness of different genotypes during the two seasons. The data presented in Table 19 showed the variation in stone weight, seed length and seed width of different genotypes during the two seasons.

Low, intermediate and high quantity of fibre on stone were observed among the different hybrids/local types (Table 20). Weak, intermediate and strong adherence of fibre to stone were observed among the different hybrids/local types (Table 20a). Coarse and soft texture of stone fibre were observed among the different hybrids/local types (Table 20b). Ellipsoid and reniform seed shapes were observed among the different hybrids/local types (Table 20c) (Fig.5).

Quality attributes

Different quality attributes like TSS ($^{\circ}$ Brix), acidity (%), ascorbic acid ($\text{mg } 100\text{g}^{-1}$), total carotenoids ($\text{mg } 100\text{g}^{-1}$), β carotene ($\text{mg } 100\text{g}^{-1}$), total sugar (%), reducing sugar (%) and crude fibre (%) were recorded and presented from table 21 to table 22. Wide variation was found in quality attributes of mango varieties/types under the study and the variation in these characters might be due to the variation in the genetic make-up. Physio-chemical characteristics are the important qualitative indexes of any fruit for fresh consumption. Total soluble solids determine the quality of juice and other canned products. High variability in terms of quality attributes have

also been reported by Pradeepkumar *et al.* (2006) [9], Anila and Radha (2003) [1], (Bhuyan and Kobra 2007) [4] and Abdullah *et al.* (2013) [2].

Sensory evaluation

Among the hybrids/local types, the highest rank for appearance was given for Mallika followed by Ratna and Muvandan (Table 23). For colour highest rank was given for Ratna followed by Chandrakaran and Prior. Ratna got the highest rank for flavour followed by Chandrakaran and Mallika. Ratna recorded highest rank for sweetness followed by Mallika and Chandrakaran. Ratna also recorded highest rank for taste followed by Mallika and Chandrakaran. Ratna was given highest rank for texture followed by Mallika and Prior.

Performance analysis of genotypes under both normal and high-density planting system

In Prior the yield under HDP (20055.56 kg/ha) was significantly higher than those planted under normal planting density (5365.16 kg/ha). In Mallika the yield under HDP (22807.41 kg/ha) was significantly higher than those planted under normal planting density (3799.73 kg/ha). In Vellaikolumban the yield under HDP (13437.04 kg/ha) was significantly higher than those planted under normal planting density (4213.99 kg/ha). In Ratna the yield under HDP (19955.56 kg/ha) was significantly higher than those planted under normal planting density (3419.75 kg/ha). In Chandrakaran the yield under HDP (20318.52 kg/ha) was significantly higher than those planted under normal planting density (1491.08 kg/ha). In Muvandan the yield under HDP (7762.96 kg/ha) was significantly higher than those planted under normal planting density (5600.82 kg/ha) (Table 24).

In all the genotypes *viz.*, Prior, Mallika, Vellaikolumban, Ratna, Chandrakaran and Muvandan under HDP had significantly higher yield compared to normal planting density. Mallika (22807.41 kg/ha) recorded the highest yield under HDP followed by Chandrakaran (22807.41 kg/ha) (Table 24). These observations were in accordance with the results obtained by Gunjate *et al.*, (2009) [6].

Table 1: Age (years) of different mango genotypes under HDP system

Sl. No.	Genotypes	Year		
		2015-16	2016-17	2017-18
1	Prior	5	6	7
2	Mallika	5	6	7
3	Vellaikolumban	5	6	7
4	Ratna	5	6	7
5	Chandrakaran	5	6	7
6	Moovandan	5	6	7

Table 2: Plant height (m) of different mango genotypes under HDP system

Sl. No.	Genotypes	Year		
		2015-16	2016-17	2017-18
1	Prior	3	3	3
2	Mallika	3	3	3
3	Vellaikolumban	3	3	3
4	Ratna	3	3	3
5	Chandrakaran	3	3	3
6	Moovandan	3	3	3

Table 3: Trunk circumference (cm) of different mango genotypes under HDP system

Sl. No.	Genotypes	Year			Mean
		2015-16	2016-17	2017-18	
1	Prior	22.12	19.54	19.88	20.51
2	Mallika	26.54	26.74	25.02	26.10
3	Vellaikolumban	23.50	23.34	23.54	23.46
4	Ratna	25.56	24.88	25.66	25.37
5	Chandrakaran	29.64	31.26	32.96	31.29
6	Moovandan	23.40	23.52	25.74	24.22
		25.13	24.88	25.47	
	Factors	CD	SE(d)	SE(m)	
	Genotype	2.19	1.10	0.78	
	Year x Genotype	NS	1.90	1.35	

Table 4a: Crown diameter North – South (m) of different mango genotypes under HDP system

Sl. No.	Genotypes	Year			Mean
		2015-16	2016-17	2017-18	
1	Prior	2.44	2.60	2.76	2.60
2	Mallika	2.88	2.66	2.62	2.72
3	Vellaikolumban	3.02	3.22	3.04	3.09
4	Ratna	2.71	2.56	1.90	2.39
5	Chandrakaran	3.07	2.90	3.04	3.00
6	Moovandan	2.71	2.94	2.68	2.78
		2.81	2.81	2.67	
	Factors	CD	SE(d)	SE(m)	
	Genotype	0.31	0.16	0.11	
	Year x Genotype	NS	0.27	0.19	

Table 4b: Crown diameter East - West (m) of different mango genotypes under HDP system

Sl. No.	Genotypes	Year			Mean
		2015-16	2016-17	2017-18	
1	Prior	2.71	3.00	2.86	2.86
2	Mallika	3.05	2.93	2.66	2.88
3	Vellaikolumban	2.84	2.66	2.80	2.77
4	Ratna	2.80	3.40	3.30	3.17
5	Chandrakaran	3.00	3.24	2.84	3.03
6	Moovandan	2.74	3.04	2.86	2.88
		2.86	3.05	2.89	
	Factors	CD	SE(d)	SE(m)	
	Genotype	NS	0.15	0.11	
	Year x Genotype	NS	0.27	0.19	

Table 5: Crown shape, tree growth habit and foliage density of different mango genotypes under HDP system

Sl. No.	Genotypes	Crown shape	Tree growth habit	Foliage density
1	Prior	Oblong	Erect	Dense
2	Mallika	Oblong	Spreading	Intermediate
3	Vellaikolumban	Semi circular	Spreading	Dense
4	Ratna	Spherical	Erect	Intermediate
5	Chandrakaran	Spherical	Spreading	Dense
6	Moovandan	Oblong	Erect	Dense

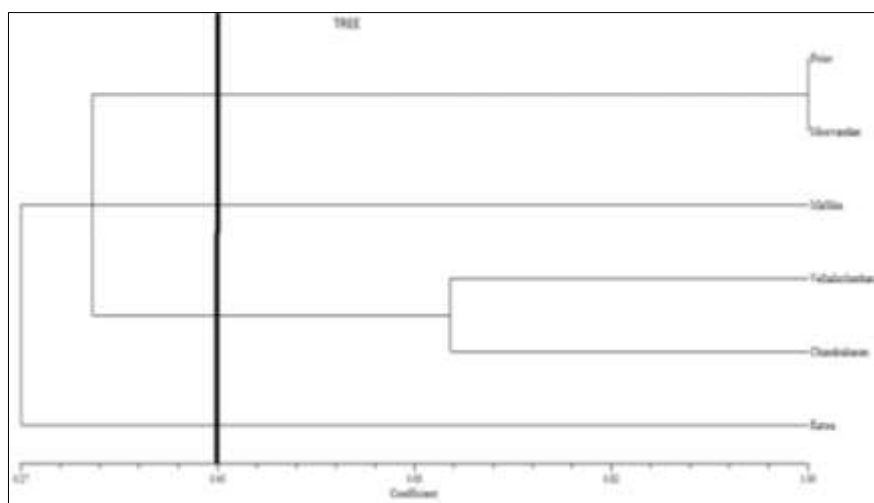


Fig 1: Dendrogram of tree characters under HDP

Table 5b: Cluster wise listing of hybrids/local types according to tree characters under HDP system

Clusters			
I	II	III	IV
Prior	Mallika	Vellaikolumban	Ratna
Moovandan		Chandrakaran	

Table 5c: Cluster wise summary statistics of hybrids/local types according to tree characters under HDP system

Characters	Clusters			
	I	II	III	IV
Crown shape	Oblong	Oblong	Semicircular, Spherical	Spherical
Tree growth habit	Erect	Spreading	Spreading	Erect
Foliage density	Dense	Intermediate	Dense	Intermediate

Table 6: Leaf blade length (cm) of different mango genotypes under HDP system

Sl. No.	Genotypes	Year			Mean
		2015-16	2016-17	2017-18	
1	Prior	20.22	18.98	20.66	19.95
2	Mallika	21.24	21.12	24.88	22.41
3	Vellaikolumban	27.42	19.62	20.90	22.65
4	Ratna	24.80	27.74	23.64	25.40
5	Chandrakaran	20.58	19.36	20.72	20.22
6	Moovandan	19.44	19.72	18.34	19.17
	Mean	22.28	21.09	21.52	
	Factors	CD	SE(d)	SE(m)	
	Genotype	1.90	0.95	0.67	
	Year x Genotype	3.28	1.64	1.16	

Table 7: Leaf blade width (cm) of different mango genotypes under HDP system

Sl. No.	Genotypes	Year			Mean
		2015-16	2016-17	2017-18	
1	Prior	4.22	5.56	5.10	4.96
2	Mallika	4.39	5.16	5.58	5.05
3	Vellaikolumban	8.66	6.72	7.66	7.68
4	Ratna	5.53	6.68	6.54	6.25
5	Chandrakaran	5.23	5.12	5.66	5.34
6	Moovandan	4.40	5.14	4.98	4.84
	Mean	5.40	5.73	5.92	
	Factors	CD	SE(d)	SE(m)	
	Genotype	0.57	0.29	0.20	
	Year x Genotype	1.00	0.50	0.35	

Table 8: Leaf petiole length (cm) of different mango genotypes under HDP system

Sl. No.	Genotypes	Year			Mean
		2015-16	2016-17	2017-18	
1	Prior	2.96	2.88	2.50	2.78
2	Mallika	4.00	4.22	3.60	3.94
3	Vellaikolumban	4.28	3.98	2.52	3.59
4	Ratna	4.73	4.18	3.62	4.18
5	Chandrakaran	2.56	2.22	2.08	2.29
6	Moovandan	3.38	3.30	2.12	2.93
	Mean	3.65	3.46	2.74	
	Factors	CD	SE(d)	SE(m)	
	Genotype	0.38	0.19	0.14	
	Year x Genotype	NS	0.33	0.23	

Table 9a: Leaf blade shape, leaf apex shape, leaf base shape, leaf margin, leaf pubescence, colour of young leaf, colour of fully developed leaf and leaf fragrance of different mango genotypes under HDP system

Sl. No.	Genotypes	Leaf blade shape	Leaf apex shape	Leaf base shape	Leaf margin	Leaf pubescence	Colour of young leaf	Colour of fully developed leaf	Leaf fragrance
1	Prior	Oblong	Obtuse	Acute	Wavy	Absent	Light green	Dark green	Mild
2	Mallika	Lanceolate	Acuminate	Acute	Wavy	Absent	Light green	Green	Strong
3	Vellaikolumban	Elliptic	Acuminate	Round	Entire	Absent	Light green	Green	Mild
4	Ratna	Oblong	Acuminate	Obtuse	Entire	Absent	Reddish brown	Green	Mild
5	Chandrakaran	Obovate	Acuminate	Acute	Entire	Absent	Light green	Dark green	Mild
6	Moovandan	Lanceolate	Acute	Round	Entire	Absent	Light green	Green	Mild

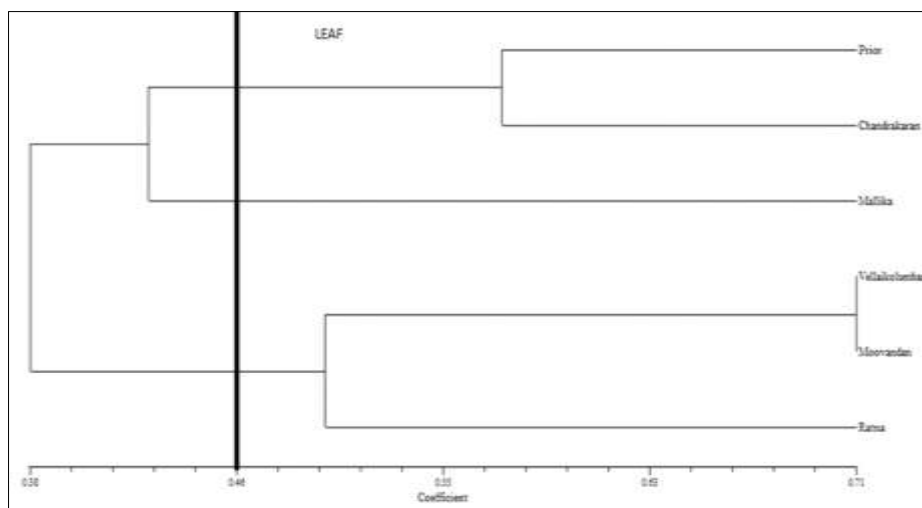


Fig 2: Dendrogram of leaf characters under HDP

Table 9b: Cluster wise listing of hybrids according to leaf characters under HDP system

Cluster			
I	II	III	IV
Prior	Mallika	Vellaikolumban	Ratna
Chandrakaran		Moovandan	

Table 9c: Cluster wise summary statistics of hybrids according to leaf characters under HDP system

Characters	Clusters			
	I	II	III	IV
Leaf blade shape	Oblong, Obovate	Lanceolate	Elliptic, Lanceolate	Oblong
Leaf apex shape	Obtuse, Acuminate	Acuminate	Acuminate, Acute	Acuminate
Leaf base shape	Acute	Acute	Round	Obtuse
Leaf margin	Wavy, Entire	Wavy	Entire	Entire
Leaf pubescence	Absent	Absent	Absent	Absent
Colour of young leaf	Light green	Light green	Light green	Reddish brown
Colour of fully developed leaf	Dark green	Green	Green	Green
Leaf fragrance	Mild	Strong	Mild	Mild

Table 10a: Flowering duration, secondary/off season flowering, inflorescence position, inflorescence shape, density of flowers in the inflorescence, inflorescence colour, length of stamen in relation to pistil and nature of disc of different mango genotypes under HDP system

Sl. No	Genotypes	Flowering duration	Secondary/off season flowering	Inflorescence position	Inflorescence shape	Density of flowers in the inflorescence	Inflorescence colour	Length of stamen in relation to pistil	Nature of disc
1	Prior	Dec - Jan	Absent	Terminal	Conical	Sparse	Light green	Shorter	Narrow, reduced or absent
2	Mallika	Dec - Jan	Absent	Terminal	Pyramidal	Medium	Yellowish green	Equal	Swollen, broader than ovary
3	Vellaikolumban	Jan - Feb	Absent	Terminal	Conical	Sparse	Light greenish with red patches	Shorter	Narrow, reduced or absent
4	Ratna	Jan - Feb	Absent	Terminal	Conical	Dense	Green with red patches	Equal	Swollen, broader than ovary
5	Chandrakaran	Dec - Jan	Absent	Terminal	Conical	Dense	Light greenish with red patches	Shorter	Narrow, reduced or absent
6	Moovandan	Jan - Feb	Absent	Terminal	Conical	Dense	Light greenish with red patches	Shorter	Narrow, reduced or absent

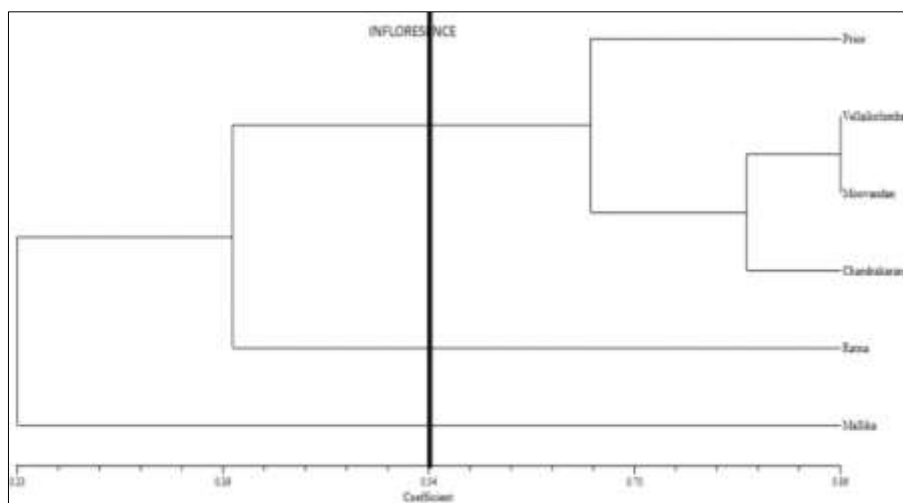


Fig 3: Dendrogram of inflorescence characters under HDP

Table 10c: Cluster wise summary statistics of hybrids according to inflorescence characters under HDP system

Characters	Clusters		
	I	II	III
Flowering duration	Dec – Jan, Jan - Feb	Jan - Feb	Dec - Jan
Secondary/off season flowering	Absent	Absent	Absent
Inflorescence position	Terminal	Terminal	Terminal
Inflorescence shape	Conical	Conical	Pyramidal
Density of flowers in the inflorescence	Sparse, Dense	Dense	Medium
Inflorescence colour	Light greenish with red patches, Light green	Green with red patches	Yellowish green
Length of stamen in relation to pistil	Shorter	Equal	Equal
Nature of disc	Narrow, reduced or absent	Swollen, broader than ovary	Swollen, broader than ovary

Table 11: Inflorescence length (cm) of different mango genotypes under HDP system

Sl. No.	Genotypes	Year		
		2015-16	2016-17	Mean
1	Prior	23.40	20.88	22.14
2	Mallika	27.34	29.84	28.59
3	Vellaikolumban	33.34	39.60	36.47
4	Ratna	26.10	24.74	25.42
5	Chandrakaran	24.56	24.42	24.49
6	Moovandan	24.90	25.64	25.27
	Mean	26.61	27.52	
	Factors	CD	SE (d)	SE (m)
	Genotype	2.42	1.20	0.85
	Year x Genotype	3.42	1.70	1.20

Table 12: Inflorescence width (cm) of different mango genotypes under HDP system

Sl. No.	Genotypes	Year		
		2015-16	2016-17	Mean
1	Prior	20.04	16.96	18.50
2	Mallika	15.26	18.38	16.82
3	Vellaikolumban	27.38	19.70	23.54
4	Ratna	17.58	17.50	17.54
5	Chandrakaran	11.88	13.18	12.53
6	Moovandan	14.36	14.78	14.57
	Mean	17.75	16.75	
	Factors	C.D.	SE (d)	SE (m)
	Genotype	1.47	0.73	0.52
	Year x Genotype	2.08	1.03	0.73

Table 13: Evaluation of mango genotypes for hermaphrodite flowers in the inflorescence (%) under HDP system

Sl. No.	Genotypes	Year		
		2015-16	2016-17	Mean
1	Prior	50.00	59.40	54.70
2	Mallika	85.20	74.20	79.70
3	Vellaikolumban	73.20	79.20	76.20
4	Ratna	56.80	71.40	64.10
5	Chandrakaran	88.40	83.20	85.80
6	Moovandan	29.60	37.20	33.40
	Mean	63.87	67.43	
	Factors	CD	SE(d)	SE(m)
	Genotype	13.71	6.80	4.81
	Year x Genotype	NS	9.61	6.80

Table 14: Evaluation of mango genotypes for number of stamens under HDP system

Sl. No.	Genotypes	Year		
		2015-16	2016-17	Mean
1	Prior	1	1	1
2	Mallika	3	3	3
3	Vellaikolumban	2	2	2
4	Ratna	3	3	3
5	Chandrakaran	3	3	3
6	Moovandan	2	2	2

Table 15a: Fruiting duration, fruit bearing intensity, fruit shape, shape of fruit apex, fruit attractiveness, skin colour of unripe fruit, skin colour of ripe fruit, depth of fruit stalk cavity, fruit neck prominence, fruit beak type, pulp colour of ripe fruit and aroma of ripe fruit of different mango genotypes under HDP system

Sl. No.	Genotypes	Fruiting duration	Fruit bearing intensity	Fruit shape	Shape of fruit apex	Fruit attractiveness	Skin colour of unripe fruit	Skin colour of ripe fruit	Depth of fruit stalk cavity	Fruit neck prominence	Fruit beak type	Pulp colour of ripe fruit	Aroma of ripe fruit
1	Prior	April - May	Medium	Roundish	Acute	Excellent	Green	Yellow	Absent	Absent	Perceptible	Light yellow	Mild
2	Mallika	April - May	Medium	Obovoid	Obtuse	Good	Green	Greenish yellow	Absent	Slightly prominent	Prominent	Light yellow	Intermediate
3	Vellaikolumban	April - May	Medium	Obovoid	Acute	Average	Green	Greenish yellow	Absent	Present	Pointed	Light yellow	Intermediate
4	Ratna	April - May	Medium	Obovoid	Round	Average	Green	Yellow	Absent	Absent	Pointed	Light yellow	Intermediate
5	Chandrakaran	April - May	High	Roundish	Acute	Average	Green	Greenish yellow	Shallow	Absent	Pointed	Light yellow	Strong
6	Moovandan	April - May	Medium	Obovoid	Acute	Average	Green	Greenish yellow	Absent	Slightly prominent	Perceptible	Light yellow	Strong

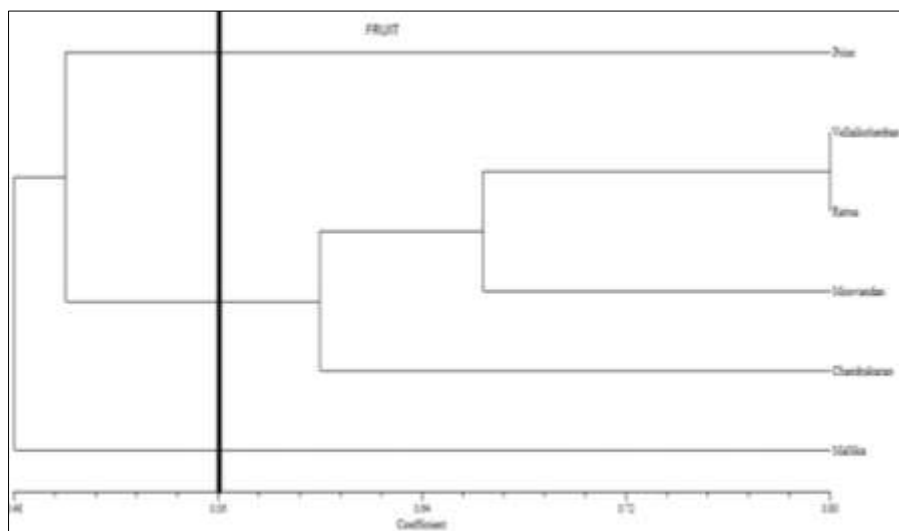


Fig 4: Dendrogram of fruit characters under HDP

Table 15b: Cluster wise listing of hybrids according to fruit characters under HDP system

Clusters		
I	II	III
Prior	Vellaikolamban	Mallika
	Ratna	
	Muvandan	
	Chandrakaran	

Table 15c: Cluster wise summary statistics of hybrids according to fruit characters under HDP system

Characters	Clusters		
	I	II	III
Fruiting duration	April - May	April - May	April - May
Fruit bearing intensity	Medium	Medium, High	Medium
Fruit shape	Roundish	Obovoid, Roundish	Obovoid
Shape of fruit apex	Acute	Acute, Round	Obtuse
Fruit attractiveness	Excellent	Average	Good
Skin colour of unripe fruit	Green	Green	Green
Skin colour of ripe fruit	Yellow	Greenish yellow, Yellow	Greenish yellow
Depth of fruit stalk cavity	Absent	Absent, Shallow	Absent
Fruit neck prominence	Absent	Present, Absent, Slightly prominent	Slightly prominent
Fruit beak type	Perceptible	Pointed	Prominent
Pulp colour of ripe fruit	Light yellow	Light yellow	Light yellow
Aroma of ripe fruit	Mild	Intermediate, Strong	Intermediate

Table 16: Fruit length (cm) and fruit diameter (cm) of different mango genotypes under HDP system

Sl. No.	Genotypes	Fruit length (cm)			Fruit diameter		
		Year		Mean	Year		Mean
		2015-16	2016-17		2015-16	2016-17	
1	Prior	13.38	12.90	13.14	24.26	23.13	23.69
2	Mallika	18.21	19.20	18.71	24.43	26.06	25.25
3	Vellaikolumban	12.35	13.18	12.76	19.99	24.56	22.28
4	Ratna	13.86	12.62	13.24	25.15	25.34	25.24
5	Chandrakaran	7.52	7.46	7.49	13.34	13.02	13.18
6	Moovandan	12.02	12.12	12.07	21.04	20.94	20.99
	Mean	12.89	12.91		21.37	22.17	
	Factors	CD	SE(d)	SE(m)	CD	SE(d)	SE(m)
	Genotype	0.75	0.37	0.26	1.33	0.66	0.47
	Year x Genotype	1.06	0.53	0.37	1.89	0.94	0.66

Table 17: Fruit weight (g), yield per tree (kg year⁻¹) and shelf life (days) of different mango genotypes under HDP system

Sl. No.	Genotypes	Fruit weight (g)			Yield per tree (kg year ⁻¹)			Shelf life (days)		
		Year		Mean	Year		Mean	Year		Mean
		2015-16	2016-17		2015-16	2016-17		2015-16	2016-17	
1	Prior	296.10	274.64	285.37	13.10	23.00	18.05	6.0	6.0	6.0
2	Mallika	511.14	454.28	482.71	18.90	30.48	24.69	6.0	6.0	6.0
3	Vellaikolumban	241.45	334.34	287.89	13.10	17.88	15.49	4.0	4.0	4.0
4	Ratna	415.61	340.28	377.95	15.40	25.52	20.46	6.0	6.0	6.0
5	Chandrakaran	52.46	63.72	58.09	12.18	31.64	21.91	4.0	4.0	4.0
6	Moovandan	249.54	248.08	248.81	6.36	11.50	8.93	4.0	4.0	4.0
	Mean	294.38	285.89		13.17	23.34		5.0	5.0	
	Factors	CD	SE(d)	SE(m)	CD	SE(d)	SE(m)	CD	SE(d)	SE(m)
	Genotype	40.28	19.92	14.08	2.21	1.10	0.78	0.26	0.13	0.09
	Year x Genotype	56.96	28.17	19.92	3.13	1.55	1.10	NS	0.18	0.13

Table 18: Stone length (cm), stone width (cm) and stone thickness (cm) of different mango genotypes under HDP system

Sl. No.	Genotypes	Stone length (cm)			Stone width (cm)			Stone thickness (cm)		
		Year			Year			Year		
		2015-16	2016-17	Mean	2015-16	2016-17	Mean	2015-16	2016-17	Mean
1	Prior	10.30	11.68	10.99	4.58	5.78	5.18	2.06	2.30	2.18
2	Mallika	11.86	11.48	11.67	4.50	4.88	4.69	1.34	1.46	1.40
3	Vellaikolumban	7.22	7.78	7.50	3.58	4.40	3.99	2.20	2.18	2.19
4	Ratna	10.48	11.22	10.85	8.42	8.92	8.67	1.48	1.52	1.50
5	Chandrakaran	5.44	5.72	5.58	3.46	3.26	3.36	1.26	1.20	1.23
6	Moovandan	5.96	5.86	5.91	4.80	4.92	4.86	1.24	1.40	1.32

	Mean	8.54	8.96		4.89	5.36		1.60	1.68	
	Factors	CD	SE (d)	SE (m)	CD	SE (d)	SE(m)	CD	SE (d)	SE (m)
	Genotype	0.58	0.29	0.20	0.39	0.19	0.14	0.17	0.08	0.06
	Year x Genotype	NS	0.41	0.29	0.55	0.27	0.19	NS	0.12	0.08

Table 19: Stone weight (g), seed length (cm), seed width (cm) and Seed weight (g) of different mango genotypes under HDP system

Sl. No.	Genotypes	Stone weight (g)			Seed length (cm)			Seed width (cm)			Seed weight (g)		
		Year			Year			Year			Year		
		2015-16	2016-17	Mean	2015-16	2016-17	Mean	2015-16	2016-17	Mean	2015-16	2016-17	Mean
1	Prior	30.50	29.50	30.00	5.34	6.16	5.75	2.70	3.44	3.07	22.52	21.92	22.22
2	Mallika	42.00	46.66	44.33	7.50	7.04	7.27	4.16	4.00	4.08	22.54	21.18	21.86
3	Vellaikolumban	17.44	18.30	17.87	5.02	4.84	4.93	3.32	3.38	3.35	8.72	10.16	9.44
4	Ratna	24.60	23.88	24.24	8.22	7.60	7.91	8.34	8.60	8.47	19.54	18.38	18.96
5	Chandrakaran	17.72	17.86	17.79	3.94	4.16	4.05	3.36	3.36	3.36	16.32	16.70	16.51
6	Moovandan	23.38	21.76	22.57	4.62	4.66	4.64	3.38	2.96	3.17	16.08	17.74	16.91
	Mean	25.94	26.33		5.77	5.74		4.21	4.29		17.62	17.68	
	Factors	CD	SE(d)	SE(m)	CD	SE(d)	SE(m)	CD	SE(d)	SE(m)	CD	SE(d)	SE(m)
	Genotype	2.71	1.35	0.95	2.71	1.35	0.95	0.39	0.19	0.14	1.51	0.75	0.53
	Year x Genotype	NS	1.90	1.35	NS	1.90	1.35	NS	0.27	0.19	NS	1.06	0.75

Table 20a: Quantity of fibre on stone, adherence of fibre to stone, texture of stone fibre and seed shape of different mango genotypes under HDP system

Sl. No.	Genotypes	Quantity of fibre on stone	Adherence of fibre to stone	Texture of stone fibre	Seed shape
1	Prior	Low	Strong	Coarse	Reniform
2	Mallika	Low	Intermediate	Coarse	Reniform
3	Vellaikolumban	Intermediate	Intermediate	Coarse	Ellipsoid
4	Ratna	Intermediate	Intermediate	Soft	Reniform
5	Chandrakaran	High	Weak	Coarse	Reniform
6	Moovandan	High	Weak	Coarse	Reniform

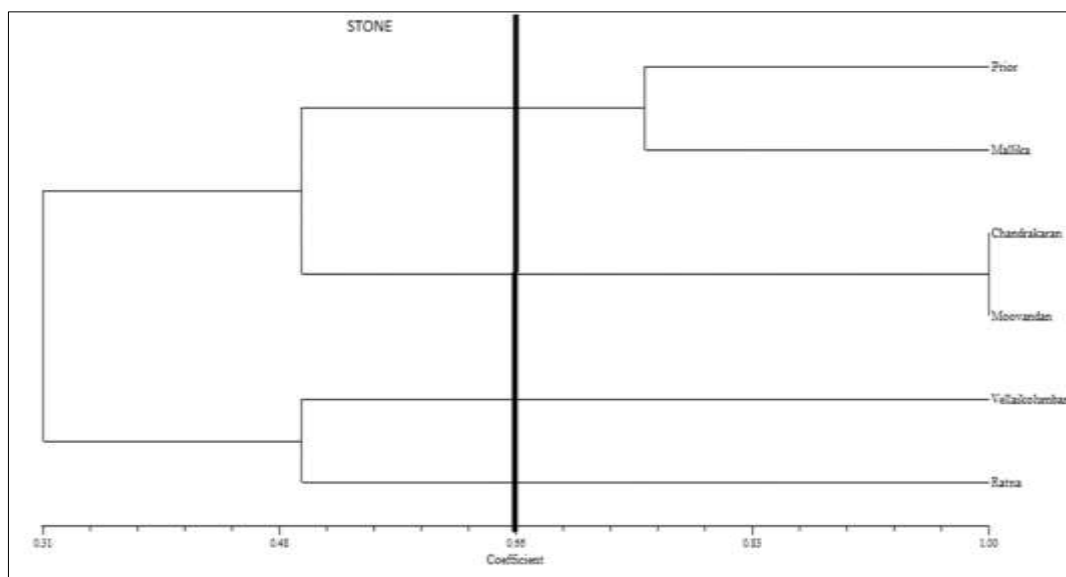


Fig 5: Dendrogram of stone characters under HDP

Table 20b: Cluster wise listing of hybrids/local types according to stone characters under HDP system

Clusters		
I	II	III
Prior	Vellaikolumaban	Ratna
Mallika		
Chandrakaran		
Muvandan		

Table 20c: Cluster wise summary statistics of hybrids/local types according to stone characters under HDP system

Characters	Clusters		
	I	II	III
Quantity of fiber on stone	Low, High	Intermediate	Intermediate
Adherence of fiber to stone	Strong, Intermediate, Weak	Intermediate	Intermediate
Texture of stone fiber	Coarse	Coarse	Soft
Seed shape	Reniform	Ellipsoid	Reniform

Table 21: TSS content ($^{\circ}$ Brix), acidity content (%), ascorbic acid content (mg 100g⁻¹) and total carotenoids content (mg 100g⁻¹) of different mango genotypes under HDP system

Sl. No.	Genotypes	TSS content ($^{\circ}$ Brix)			Acidity content (%)			Ascorbic acid content (mg 100 g ⁻¹)			Total carotenoids content (mg 100g ⁻¹)		
		Year			Year			Year			Year		
		2015-16	2016-17	Mean	2015-16	2016-17	Mean	2015-16	2016-17	Mean	2015-16	2016-17	Mean
1	Prior	19.18	19.34	19.26	0.03	0.03	0.03	31.75	33.02	32.38	2.11	2.49	2.30
2	Mallika	23.42	24.14	23.78	0.02	0.02	0.02	30.48	36.83	33.65	2.94	3.44	3.19
3	Vellaikolumban	15.74	15.16	15.45	0.02	0.03	0.03	29.21	27.30	28.26	1.34	1.46	1.40
4	Ratna	26.10	27.44	26.77	0.03	0.02	0.03	40.64	45.72	43.18	4.62	4.98	4.80
5	Chandrakaran	24.74	25.64	25.19	0.06	0.06	0.06	63.49	95.87	79.68	3.05	3.55	3.30
6	Moovandan	14.58	14.98	14.78	0.07	0.07	0.07	36.83	40.00	38.41	4.39	5.21	4.80
	Mean	20.63	21.12		0.04	0.04		38.73	46.46		3.08	3.52	
	Factors	CD	SE(d)	SE(m)	CD	SE(d)	SE(m)	CD	SE(d)	SE(m)	CD	SE(d)	SE(m)
	Genotype	1.82	0.90	0.64	0.01	0.01	0.01	8.54	4.23	2.99	0.44	0.22	0.15
	Year x Genotype	NS	1.27	0.90	NS	0.01	0.01	12.07	5.99	4.23	NS	0.31	0.22

Table 22: β carotene content (mg 100g⁻¹), total sugar content (%), reducing sugar (%) and crude fiber content (%) of different mango genotypes under HDP system

Sl. No.	Genotypes	β carotene content (mg 100g ⁻¹)			Total sugar content (%)			Reducing sugar (%)			Crude fiber content (%)		
		Year			Year			Year			Year		
		2015-16	2016-17	Mean	2015-16	2016-17	Mean	2015-16	2016-17	Mean	2015-16	2016-17	Mean
1	Prior	13.49	15.10	14.29	15.94	13.52	14.73	7.96	9.39	8.67	7.96	9.39	8.67
2	Mallika	19.00	18.70	18.85	14.77	13.79	14.28	8.56	9.12	8.84	8.56	9.12	8.84
3	Vellaikolumban	14.60	12.48	13.54	15.26	13.18	14.22	8.48	10.42	9.45	8.48	10.42	9.45
4	Ratna	40.42	39.43	39.93	16.50	14.94	15.72	7.68	8.52	8.10	7.68	8.52	8.10
5	Chandrakaran	15.57	18.04	16.81	17.08	15.95	16.51	8.00	8.70	8.35	8.00	8.70	8.35
6	Moovandan	12.70	14.63	13.66	17.38	15.27	16.32	7.24	8.19	7.72	7.24	8.19	7.72
	Mean	19.30	19.73		16.15	14.44		7.99	9.06		7.99	9.06	
	Factors	CD	SE(d)	SE(m)	CD	SE(d)	SE(m)	CD	SE(d)	SE(m)	CD	SE(d)	SE(m)
	Genotype	2.37	1.17	0.83	NS	1.43	1.01	NS	0.81	0.57	NS	0.81	0.57
	Year x Genotype	NS	1.66	1.17	NS	2.02	1.43	NS	1.14	0.81	NS	1.14	0.81

Table 23: Sensory evaluation of mango genotypes under HDP system by Kendall's coefficient of concordance

Appearance		Colour		Flavour		Sweetness		Taste		Texture	
	Mean rank		Mean rank		Mean rank		Mean rank		Mean rank		Mean rank
Mallika	5.75	Ratna	4.95	Ratna	4.65	Ratna	5.20	Ratna	4.85	Ratna	4.90
Ratna	4.10	Chandrakaran	4.10	Chandrakaran	3.85	Mallika	3.60	Mallika	4.20	Mallika	3.90
Muvandan	3.40	Prior	3.40	Mallika	3.50	Chandrakaran	3.55	Chandrakaran	3.40	Prior	3.20
Prior	2.75	Mallika	3.15	Vellaikolumban	3.30	Prior	3.00	Prior	3.35	Vellaikolumban	3.15
Vellaikolumban	2.70	Vellaikolumban	2.70	Prior	2.90	Muvandan	2.85	Vellaikolumban	2.80	Chandrakaran	3.05
Chandrakaran	2.30	Muvandan	2.70	Muvandan	2.80	Vellaikolumban	2.80	Muvandan	2.40	Muvandan	2.80
Kendall's Wa	0.52	Kendall's Wa	0.32	Kendall's Wa	0.16	Kendall's Wa	0.27	Kendall's Wa	0.26	Kendall's Wa	0.21

Table 24: Performance analysis of genotypes under normal and high-density planting system (Yield kg/ha)

Prior				
	Mean Yield (kg/ha)	SE(d)	SE(m)	t value
Normal planting	5365.16	1224.37	408.12	
High density planting	20055.56	6606.99	2089.31	6.55
Mallika				
Normal planting	3799.73	2884.79	961.60	
High density planting	22807.41	11075.54	2859.69	5.01
Vellaikolumban				
Normal planting	4213.99	1447.78	482.59	
High density planting	13437.04	7688.89	1985.26	3.53
Ratna				
Normal planting	3419.75	1007.40	335.80	
High density planting	19955.56	9886.37	2552.65	4.96
Chandrakaran				
Normal planting	1491.08	361.46	120.49	
High density planting	20318.52	14126.90	3647.55	3.96
Muvandan				
Normal planting	5600.82	1346.32	448.77	
High density planting	7762.96	5001.21	1291.31	1.260

Conclusion

The morphological characters of six mango varieties/types under study showed great diversity and the variation in the vegetative characters can be attributed to the variation in the genetic make-up and also due to the interaction of various genotypes with agroclimatic conditions. Morphological characters can be used as an efficient tool for identifying the different mango cultivars well before the commencement of that cultivar come to the bearing stage.

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References

- Anila R, Radha T. Physico-chemical analysis of mango varieties under Kerala conditions. *J trop. Agric.* 2003;41:20-22.
- Abdullah F, Mahdzir AA, Abdul Aziz AS, Malik TMT, Abdullah H, Latifah MN. Preliminary study on fruit variability of Chok Anan mango (*Mangifera indica* L.). *Acta Hort*; c2013. p. 281-285.
- AOAC. Official Methods of Analysis. 12th Edition, Association of Official Analytical Chemists, Washington DC; c1975.
- Bhuyan MAJ, Kobra K. Fruit characteristics of some uncommon mango varieties grown under joydepur condition. *Bangladesh J Agril Res.* 2007;32(3):493-500.
- Biodiversity international. Descriptors for Mango (*Mangifera indica*). International Plant Genetic Resources Institute, Rome, Italy; c2006. p. 57.
- Gunjate RT, Kumbhar AR, Thimaiah IM, Amin SM. Growth and fruiting of some mango cultivars under high density plantation in arid conditions of Gujarat (India). *Acta Hort.* 2009;820:463-468.
- Jellinek G. Sensory Evaluation of Food: Theory and Practice. Ellis Horwood, Chichester, 1985, 34.
- Joshi R, Kundu M, Singh CP. Morphological Characters: Efficient Tool for Identification on Different Mango Cultivars. *Environment & Ecology.* 2013;31(1A):-385-388.
- Pradeepkumar T, Philip J, Johnkutty I. Variability in physico-chemical characteristics of mango genotypes in northern Kerala. *J Trop. Agric.* 2006;44(1):57-60.
- Rajwana IA, Khan IA, Malik AU, Saleem BA, Khan AS, Ziaf K, *et al.* Morphological and biochemical markers for varietal characterization and quality assessment of potential indigenous mango (*Mangifera indica*) germplasm. *Internat. J Agric. Biology.* 2011;10:151-158.
- Ram S, Rajan S. Status Report on Genetic Resources of Mango in Asia- Pacific Region. IPGRI Office for South Asia, New Delhi, India; c2003. p. 64-68.
- Ranganna S. Manual of Analysis of Fruit and Vegetable products. Tata Mc. Graw Hill Pub. Co. Ltd., New Delhi; c1977. p. 634.
- Ribeiro S, Santos CAF, Neto FPL. Morphological characterization of mango (*Mangifera indica*) accessions based on Brazilian adapted descriptors. *J Agric Sci. Technol.* 2013;3:798-806.
- Sadasivam S, Manickam A. Biochemical Methods for Agricultural Sciences, New Age International (P) Ltd., New Delhi; c1996. p. 1-97
- Singh A, Tyagi M, Singh CP. Studies on morphology and physical attributes of mango varieties. *Int. J Curr. Microbiol. App. Sci.* 2017;6(10):2324-2330.