Research Review Article

Current Horticulture **13**(2): 28–36, April–June 2025

DOI: 10.5958/2455-7560.2025.00019.7

Received: 13 December 2023 ; Accepted: 05 January 2025

Analysis of half-sib progenies of sapota (*Manilkara zapota*) for dwarf stature and fruit quality

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Abstract

The evaluation of 116 half-sib progenies of sapota (*Manilkara zapota* Royen) var. Cricket Ball was carried out for 6 years (2017-2022), at ICAR-IIHR,Bengaluru to develop a promising variety characterized by dwarf growth habit, high productivity, and quality fruits. All the progenies were evaluated for growth, yield, fruit, and biochemical parameters. Correlation among different yield-contributing traits in half-sib progenies revealed that yield was strongly correlated with the number of fruits (r=0.945) while the tree height showed a positive and significant correlation with tree volume (r=0.904) and tree spread (r=0.854). Regression analysis indicated a strong positive relationship between yield and both fruit weight and the number of fruits/tree. Half-sib progenies were grouped into seven clusters based on Euclidean distance, with the S-63 forming a separate single cluster with all desirable traits. Among half-sibs, one half-sib line, S-63, with desirable traits has been identified, multiplied and further evaluated in a row trial with Cricket Ball as the control for three years (2020-2022). In row trial, the progeny S-63 recorded a low tree height (1.95 m) and a high yield (90.21 fruits/tree), compared to Cricket Ball which recorded a tree height of 2.15 m and a yield of 10 fruits per tree at the sixth year. The average yield of S-63 was higher at 48.37 fruits per tree (5.9 kg) compared to Cricket Ball (13.67 fruits/tree; 1.4 kg). Fruit weight of S-63 (128.57 g) was higher compared to Cricket Ball (114 g). The TSS (20.33°Brix), and acidity (0.29%) were higher compared to Cricket Ball (19.66°Brix; 0.2%). Thus, S-63 was found to be the best performing line for yield, dwarf stature fruit and quality fruits

Key words: Half-sibs, Evaluation, Dwarf, Yield, Biochemical parameters

Sapota (*Manilkhara zapota* Royen) is a popular fruit belonging to family Sapotaceae. It is believed to have originated in tropical America, Mexico in particular, and spread to other countries due its sweet, tasty fruits. In India, is mainly grown in Andhra Pradesh, Gujarat, Maharashtra, Karnataka Tamil Nadu and to some extant in West Bengal and Orissa. Sapota is a diploid with basic chromosome number 2n=2x=26.A suitable dwarf tree will help in boosting the productivity. Improvement programs on sapota are being carried out at various research centers including Coimbatore, Periyakulam and Dharwad. The varieties CO-1, CO-2, CO-3, PKM-1, PKM-2, PKM-3, PKM-4, PKM-5, DHS-1 and DHS-2 are hybrids and/or clonal selections that bear better quality fruits with good yield potential and other desirable traits.

The Cricket Ball variety of sapota is usually grown in Tamil Nadu, Karnataka, Maharashtra, West Bengal and Andhra Pradesh. Its fruits are large in size, round and sweet with granular pulp. Several attempts were made to select superior types from existing clones. There is no variety with dwarf stature and single fruit instead of clusters. Fruits in clusters have other disadvantages like uneven size and higher infestation of pests. With the objective of developing dwarf type varieties, a breeding program using Cricket Ball, PKM-1 and Kalipatti as parents and their half-sibs were raised and evaluated for yield, fruit quality, and dwarf stature.

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MATERIALS AND METHODS

The experiment was conducted at ICAR-IIHR, Bengaluru (13° 7'N latitude and 77° 84 29'E longitude, 890 m above MSL). The Climate of the area is semi-arid climate with mean temperature range between 18^{0}C and 35^{0}C. The annual rainfall is 850 mm (bimodal with June-July and September). The soils of area are classified as red sandy loams. The soils contain about 0.52 % organic carbon, 163, 84, 164 kg/ha available N and P_2O_5 and exchangeable K_2O, respectively, 6.65 pH, Ec of 0.23 dS/m The half- sib population were derived from open pollinated seedlings of the sapota variety Cricket Ball. Initially 1000 open pollinated seeds of Cricket Ball were sown in polybags containing sand:soil:FYM (1:1:1ratio).

After sowing the polybags were drenched with 0.2%copper fungicide to control fungal infection. One year old half-sibs were planted in pits measuring 40 cm × 40 cm × 40 cm during February 2006 in a square system method at a spacing of 5 m × 5 m. These seedlings were managed according to standard practices, and watered as needed using a drip irrigation system. Fertilization was managed based on recommended nutrient doses. These doses were divided into two halves and applied in June and October. Pest populations were kept under control by recommended pest management measures.

Initially growth and yield parameters of 116 half-sib progenies of Cricket Ball planted were recorded during 2012-2017. The growth and yield parameters were recorded for all progenies. Tree height (m) was measured from the base to the tip and expressed in m. The canopy size was determined by measurements taken in four cardinal directions both north-south and east-west and expressed in m. Tree height and canopy spread were converted into tree spread and tree volume.

Tree spread (m^2) = plant spread (N-S) × plant spread (E-W/2)

The tree volume (m^3) = (tree spread × plant height) ×0.85).

The scion trunk circumference was measured at 10 cm above the bud union and converted into trunk cross-sectional area (TCSA, cm^2). The trunk cross-sectional area was calculated by using formula (TCSA= $Girth^2/4$) given by Kumar *et al*. (2008). All fruit samples of half-sibs were assessed for 6 years (2012–17) using standard procedures. In the month of October-March, which is commercial harvesting season of sapota in Bangalore, 10 matured fruits/tree were randomly sampled for recording data on physical parameters. The average fruit weight (g) was measured using an electronic weighing balance. The fruit length, width and thickness (in cm) were measured on these sampled fruits using a digital vernier calipers. Fruit shape was recorded based on visual observation. The pulp recovery (%) was calculated by subtracting fruit weight and pulp weight. Yield (kg/tree) were recorded annually during 6 years of production. Tree yield by canopy volume (kg/m^3) and trunk cross-sectional area (kg/cm^2) were also estimated.

Promising haf-sib line, S-63 was identified based on desired traits and multiplied by grafting using 16-months-old khirni (*Manilkhara hexandra*) seedling stock. Approach grafting was done by taking 6 month old scion from new flush and grafting was carried out in February and kept in shade net (50%) near the mother plant till successful graft union and graft establishment. Twenty grafts of selected progeny, S-63, were evaluated in replicated trials along with the parent variety, Cricket Ball during 2020 to 2022. Data were recorded on tree height (m), tree girth, canopy spread N/S (m), canopy spread E/W(m), number of fruits/plant, yield/tree, fruit weight, fruit length, fruit width, TSS (°Brix), acidity, reducing sugars, non-reducing sugars and total sugars.

The soluble solid content TSS was determined in ripe fruits using a hand refractometer and expressed in Brix. Acidity (%) and vitamin C (mg/100g pulp) were estimated as per Ranganna (1986). The method developed by Lane and Eynon (1923) was used to determine sugar concentration.

$$\text{Total sugars (\%)} = \frac{\text{Factor} \times \text{volume made up (ml)} \times \text{volume taken (ml)}}{\text{Titre value} \times \text{weight of sample (g)}}$$

Reducing sugars (%) was calculated using the formula (Ranganna, 2001)

$$\text{Reducing sugars (\%)} = \frac{\text{Glucose factor x volume made up (ml)}}{\text{Titre value} \times \text{weight of sample (g)}}$$

The quantity of non-reducing sugars was calculated by deducting the value reducing sugars from total sugars. The distribution of half sib progenies of under each category was shown by totaling the number of individuals which belonged to each scale. Range, mean, and standard deviation of half-sibs were calculated by descriptive statistics using Excel. Pearson correlation coefficient among growth and yield characters, and regression analysis for yield and its contributing characters was done using PAST software (Hammer *et al*., 2001). The Euclidean distance matrix and Ward technique were used in a cluster analysis to achieve the grouping progenies according to their similarities, including quantitative and qualitative traits using PAST software. Dendrogram was developed using tree height, yield and fruit quality.

RESULTS AND DISCUSSION

Growth parameters of half-sibs

One hundred and sixteen half-sibs of Cricket Ball along with parent Cricket Ball as check variety were evaluated for growth and yield parameters during 2012-2017. Pooled analysis data over 6 years indicated that variability was observed for plant height, canopy spread, plant girth, tree volume, and Trunk Cross-Sectional Area (TCSA), as shown by a high coefficient of variation (CV). Tree height varied from 100.5 cm to 750 cm, with a mean of 276.21 cm (Table 1). Based on height, progenies were categorized as dwarf (100-350 cm), semi-tall (350-500 cm), and tall (>500 cm). The majority of progenies (93) were in the range of 100-350 cm that falling under dwarf category (Fig.1). Seventeen progenies were in the range of 350 cm to 500 cm and were considered as semi-tall. Only six progenies had plant height more than 500 cm and were treated as tall. Padi *et al.* (2012) found that the rate of increase in tree trunk cross-sectional area (TCSA) prior to bearing was an effective parameter in identifying families with large cumulative yields over the first five or six production years.

Mean stem girth was 27.81cm with highest recorded as 60.14 cm and a minimum of 8.38 cm. Thirty-four progenies had <20 cm girth; Fifty-nine progenies had 20-40 cm whereas twenty-three had >40 cm plant girth (Fig.1). The distribution pattern of growth parameters such as plant height, girth, canopy spread, and tree volume in half sib progenies showed that all these characters are segregating upon open-pollination.

Table 1. Descriptive statistics for growth parameters among half-sib progenies (N=116)

	Tree height (cm)	Tree girth (cm)	Canopy spread (cm) N-S	Canopy spread (cm) E-W	Tree spread (m^2)	Tree volume (m^3)	TCSA (cm^2)
Mean	276.21	27.81	219.67	228.04	3.22	10.66	73.48
Min	100.50	8.38	55.83	54.17	0.15	0.16	5.59
Max	750.00	60.14	546.67	654.00	17.88	97.5	287.96
SD	119.28	12.27	118.28	127.47	3.53	16.55	63.02
CV (%)	43.18	44.12	53.84	55.90	109.63	155.25	85.76

Mean canopy spread both NS and EW directions were 3.22 m^2 (Fig.1). The minimum canopy spread was 0.15 m^2 and maximum was 17.88 m^2. Mean tree volume was 10.66 m^3 and minimum was 0.16 m^3 and maximum recorded was 97.5 m^3. Low TCSA observed was 5.59 cm^2 and high being 287.96 cm^2 with a mean of 73.48 cm^2. The coefficient of variation was very high (>100%), indicating that values are exceeding the mean value (Table 1). The CV was >50 % for TCSA (85.76%) and canopy spread (55%). The CV for plant height and plant girth was 43 and 44 % respectively indicating magnitude of variability in these characters. The summary statistics which showed that half-sib progenies are highly heterogeneous for all the parameters as coefficient of variation was very high (Table 1). Numerous breeding programmes throughout the world have made different tree designs and genetic control of tree size as the main objective. The three basic genetic characteristics for regulating tree size are compact, semi-dwarf, and dwarf. Trunk cross-sectional area, indicative

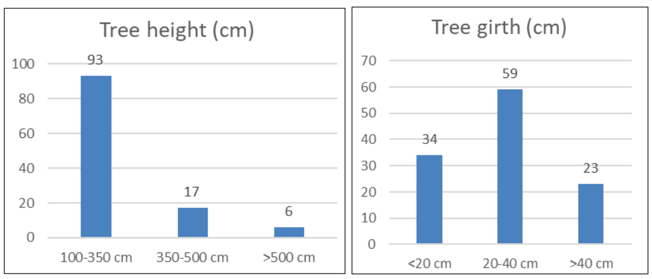


Fig.1. Variability in tree height and girth in half-sibs (N=116) of Cricket Ball

of vegetative growth intensity is the regular trait used to estimate cumulative growth in perennial tree species.

Fruit characters

The fruit evaluation was carried out in 59 half-sib progenies that came to fruiting. Fruiting started during sixth year after planting. Similarly in Punjab condition, Cricket Ball came to fruiting at 6 yrs after planting (Rattanpal *et al.* 2013). Fruit weight ranged from 40 g to 190g with a mean of 81.5 g (Table 2). We categorized fruit weight into three categories, viz., < 80g, 80-120g, 120-160g and >160g (Fig.2). The 33 progenies had fruit weight with <80g; 19 progenies had fruit weight between 80-120g and five progenies had 120-160g (S-7, S-16, S-23, S-26 and S-63) and only 2 progenies (S- 6 and S-18) had fruit weight with > 160g. The fruit length was 5.93 cm with minimum of 4.6 cm and maximum of 9.33 cm. Majority of progenies (52) had fruit length between 5-7 cm. Only three progenies had < 5 cm, and three had 7-9 cm and only one had >9 cm. Mean Fruit diameter was 5.64 cm with minimum being 4.08 and maximum 7.90 cm. Eleven progenies exhibited fruit width < 5cm; 4 progenies had 5-7cm and only 5 progenies had > 7cm fruit width. Similarly longest fruit length (5.51±0.33), highest fresh weight (75.22±2.24), highest total soluble solids (26.79±0.95) and highest fruit yield (8.64±1.34) were found in BAU Sapota 3 (Rafiul Islam *et al.* 2016).

Fruit size index ratio denotes the shape of fruit. Twenty-one progenies had <1, while 38 progenies had ratio of >1. Fruit index ratio was positively corroborated with visual recording of fruit shape. Fruit index ratio of 1 and <1 was recorded as round and oval if the ratio is more than 1. In watermelon, Takayuki Tanaka *et al.* (1995) found that spherical and oval were controlled by a single allele with incomplete dominance.

Fruit yield in terms of number of fruits/pl was classified into 5 categories. Maximum progenies recorded <30 fruits/plant. Five progenies produced 30-60 fruits and six progenies had 60-90 fruits. Only 2 progenies produced 90-120 (S-13, S-63) fruits and only one progeny (S-12) recorded highest number of fruits/ plant (>120 fruits). Number of fruits recorded maximum variability with CV >100%. Maximum number of fruits/plants recorded was 122.50 with yield of 14.75 kgs. Fruit weight and number of seeds/fruits also exhibited variability with CV >30%. Similar studies on evaluation of 17 years old 22 sapota cultivars under Arabhavi in North Karnataka revealed that Cricket Ball showed superior results with respect to growth and yield parameters like canopy volume (154.90 m^3), fruit weight (102.83 g), fruit yield (111.67 kg/tree), fruit volume and shelf-life (6.50 days). In Mango the fruit yields per unit

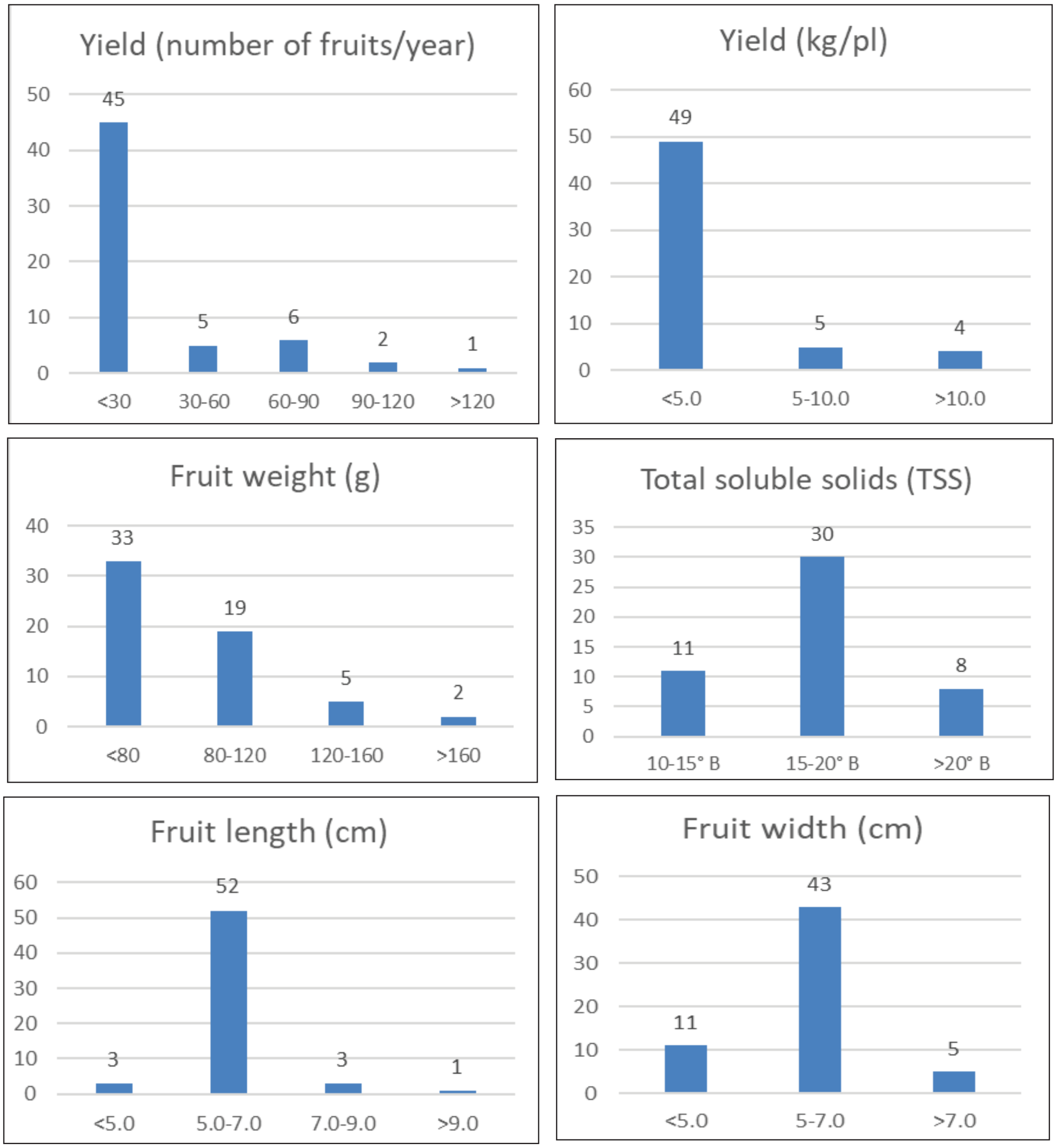


Fig.2. Distribution of progenies for different fruit parameters (N=59)

canopy volume and per unit land area were higher with the dwarfing 'Vellaikulamban' rootstock.

Number of seeds/fruits was as low as 1.8 and as high as 8.40. Number of seeds/fruits was 2-4 in majority of the progenies (42). Low seed number is a desirable trait and only one progeny (S-63) had <2 seeds/fruit. Fourteen progenies had 4-6 seeds, 22 had 6-8 seeds/fruit, while one progeny had >8 seeds/fruit (S- 40).

Pooled fruit yield was 2.41 kg/ tree with lowest of <1 kg (121) and highest of 14.75 kg (S-63). Fruit yield in terms of was classified into 5 categories. Forty-nine progenies were poor yielding (<5 kgs/pl), 5 moderately yielding (5-10 kg/plant), 4 progenies (S-6, S-7, S-12, S-13, S-63) high yielding (10-15 kg/plant) and progeny, S- 63 exhibited highest yield of 14.75 kg/plant.

The TSS ranged from 10.9 to 23° Brix with a mean of 17.46. The 11 progenies had 10-15 ° Brix; 30 contained 15-20 ° Brix and 8 half sibs had > 20 ° Brix (S-12, S-54, S-63, S-94, S -122, S-108, S-116 and S-120). The progenies, S-13, S-6 and S-7 had other desirable traits such as fruit weight

Table 2. Fruit and yield parameters among seed progenies (N= 59)

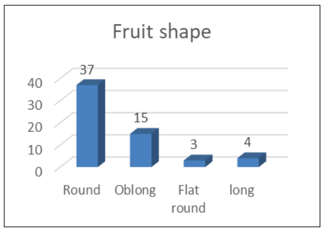
Seedling No.	Fruit weight (g)	Fruit length (cm)	Fruit width (cm)	Fruit length: width ratio	TSS (°B)	Number of seeds/ fruit	Number of fruits/plant	Yield/ tree (kg)	Yield (kg/ m^3 tree vol.)	Yield (kg/ m^2TCSA)
Mean	81.52	5.93	5.64	1.06	17.46	3.56	24.56	2.41	0.23	224.69
Min	40.08	4.60	4.08	0.78	10.90	1.80	2.00	0.11	0.01	19.54
Max	189.50	9.33	7.90	1.50	23.00	8.40	122.50	14.75	3.31	1381.16
SD	29.57	0.87	0.84	0.15	2.46	1.16	29.44	3.49	0.45	246.64
CV (%)	36.27	14.67	14.89	14.15	14.09	32.58	119.87	144.81	195.65	109.77

and fruit size with desirable traits like big size fruits with fruit weight, higher TSS, with low yield and exhibited tall growth habit.

Variability in open-pollinated seedlings was quite large with desirable characters like fruit yield and quality. Similar results were reported on 20 sapota accessions collected from different parts of India. Similarly in Punjab condition, Cricket Ball produced round-shaped large fruits (147.0g), gritty granular pulp, TSS (22.8 °Brix), acidity (0.21%) 4.3 seeds/fruit and average yield of 85.0 kg fruits/tree (Rattanpal *et al.* 2013).

In mango, dwarfness induced EMS concentration included reduced plant height along with other morphological changes such as thicker stem, more branching, shorter internodal length in dwarf mutant populations (Jome Rime *et al.*, 2019). Thus, it is clear that substantial differences exist among progenies for growth and yield characters. The open-pollinated half-sibs generated by seed propagation became the basis of variability. Most of cultivars and varieties are originated by selection. Presence of high degree of variation (due to high degree of heterozygosity) is an opportunity for improvement in sapota cultivars by selection. Our results indicate that selection of sapota seedlings for yield and dwarf is possible, based on vegetative characteristics assessed very early in their development. Out of 116 open-pollinated seedling progenies of Cricket Ball, S-63 seedlings was selected based on desirable traits such as high yield, big size fruits, fruit quality (high TSS) and dwarf stature.

Correlation was worked out for different growth and yield parameters (Table 3). The existence of correlations between the growth traits and time to first flowering, yield and dwarfness was investigated.



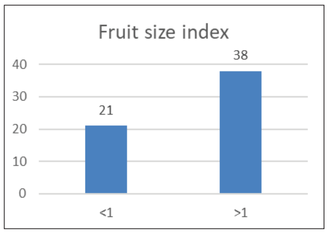


Fig. 3. Variability in fruit shape and fruit size index among half-sib progenies (N=59)

Table 3. Correlation among growth and yield in sapota.

	TH	SG	TS	TV	FW	FL	FD	FL/FD	TSS	NS	NF	Y
TH	1											
SG	0.784**	1.000										
TS	0.854**	0.786**	1.000									
TV	0.904**	0.739**	0.963**	1.000								
FW	0.509**	0.533**	0.589**	0.561**	1.000							
FL	0.176 NS	0.275 NS	0.244 NS	0.233 NS	0.616**	1.000						
FD	0.414**	0.440**	0.494**	0.479**	0.818**	0.552**	1.000					
FL/FD	-0.276NS	-0.187 NS	-0.267 NS	-0.268	-0.212 NS	0.450**	-0.478**	1.000				
TSS	0.061 NS	0.173 NS	0.078 NS	0.067 NS	0.145 NS	0.041 NS	0.226 NS	-0.202 NS	1.000			
NS	0.163 NS	0.256 NS	0.188 NS	0.145 NS	0.053 NS	-0.065 NS	0.049 NS	-0.129 NS	-0.218 NS	1.000		
NF	0.538**	0.603**	0.664**	0.650**	0.472**	0.299 NS	0.453**	-0.178 NS	0.233 NS	0.075 NS	1.000	
Y	0.567**	0.644**	0.693**	0.674**	0.678**	0.464**	0.586**	-0.150 NS	0.208 NS	0.071	0.94**5	1.000

Tree height was positively and highly significantly correlated with tree volume (0.904), tree spread (0.854), and girth (0.784). It is moderately correlated with fruit weight (0.509), number of fruits/tree (0.538) and yield (0.567). Low/no correlation was observed for TSS and number of seeds/fruit. Similar results were reported by Rekha et al. (2011). Number of seeds/fruit had significant negative correlation with fruit length, indicating that it can influence fruit shape. Yield was highly correlated with number of fruits (0.945). It was moderately correlated with tree spread (0.693), fruit weight (0.678), tree volume (0.674), girth (0.644) and tree height (0.567). It was negatively correlated with fruit length/fruit width ratio.

There was a positive correlation between tree height and canopy spread. The number of fruits/ tree and canopy spread had positive correlation with fruit yield/tree. The biochemical traits such total sugars and ascorbic acid content had negative correlation with fruit yield, indicating that simultaneous improvement of yield and quality were not possible.

A positive Pearson correlation between total yield number of fruits/plants, and flower length was strongly correlated with fruit size in *Annona squamosa* (Nogueira *et al.,* 2022). The fruit weight, fruit length, fruit width, pulp weight and seed weight showed highly significant positive correlations with fruit yield, while peel per cent showed negative correlation with fruit yield in avocado (Muralidhara *et al.*, 2024).

From the correlations it may not be possible to simultaneously select for dwarfness and high yield. Among half-sibs. S-63 recorded most of the desirable traits.

Regression analysis

The Multiple Linear Regression (MLR) analysis was carried out by considering all the independent variables that contribute to dwarfness, yield and fruit quality (Table 4) such as plant height, girth, tree spread, tree volume, fruit weight, fruit length, fruit width, number of fruits/tree and yield. It was found that coefficient of determination (R^2) of MLR model was very high (Table 4). Although the R^2 value of MLR model was very high, most of the variables in model were non -significant.

Table 4: Multiple linear regression model

Source of variation	DF	Sum of squares	Mean squares	F-calculated	Significance
Regression	9	708.474	78.719	166.591	0
Error	49	23.154	0.473		
Total	58	731.628			

R-square value : 0.9684
Multiple R-value : 0.9840

Only fruit weight and number of fruits were highly significant which infer that as fruit weight and number of fruits increases, the yield also increases (Table 5). Thus, it can concluded that selection should be based on fruit weight and number of fruits/tree. Similar result was obtained in guava (Padilla-Ramírez *et al.,* 2007)

Table 5: Regression analysis of sapota yield- contributing characters.

Variable	Coefficients	Standard error	t-value	Significance	
Tree height (cm)	-0.002	0.002	-0.816	0.418	NS
Stem girth (cm)	0.016	0.015	1.053	0.297	NS
Tree spread (m^2)	-0.1	0.099	-1.01	0.317	NS
Tree volume(m^3)	0.019	0.023	0.818	0.416	NS
Fruit wt	0.039	0.006	6.298	0	HS
Fruit length	0.235	0.138	1.703	0.094	NS
Fruit width	-0.315	0.195	-1.621	0.111	NS
TSS	-0.028	0.04	-0.699	0.487	NS
No of fruits/ tree	0.097	0.004	22.037	0	HS
Yield	-2.039				

The stability analysis based on regression coefficient (b_i) of nine sapota varieties including cricket ball revealed that all the sapota varieties exhibited a regression coefficient close to one and had a stable yield (Dhakar *et al.,* 2023).

Genetic relationships between half-sibs

A Dendrogram was developed based on tree height, canopy spread, stem girth, fruit weight, fruit size (length and width), number of fruits/tree and total yield per plant. Based on similarity coefficient, progenies were grouped into 7 clusters (Fig.4). First cluster consists of 8 progenies (S-18, S-4, S-20, S-1, S-5, S-10, S-11, S-28). The progenies in this group were semi tall, moderate to thick girth, medium fruit weight, medium fruit length and width, medium TSS**,** and very low yield. Second cluster comprised 7 progenies (S- 6, S-7, S-8, S-17, S-12, S-16 and S-19). These progenies were tall to semi-tall, thick girth, medium to big fruits, medium to large fruit size, moderate TSS and moderate yielders. Third cluster consist of 17 progenies (S- 9, S-29, S-46, S-2, S-24, S-34, S-55, S-31, S-32, S-50, S-47, S-42, S-37, S-57, S-39, S-45 and S-40).

Here most of them were dwarf, moderate girth, small to medium fruit weight, medium fruit size, low to medium TSS and very low yielders. Fourth cluster consists of 7 progenies (S-14, S-52, S-15, S-41, S-21, S-36, S-22). They were semi-tall, moderate to thick girth, low to medium fruit weight (except S-22), medium fruit size, moderate TSS, very low yielding except S-36 and S-52. Fifth cluster comprised 17 progenies (S-3, S-56, S-58, S-26, S-48, S-51, S-54, S-25, S-49, S-43, S-44, S-27, S-33, S-38, S-59, S-53,and S-30). They were dwarf, medium thick girth, small to medium fruit weight, medium fruit size, moderate to high TSS, very low yielding except S-48, S-53, S-25, S-26.

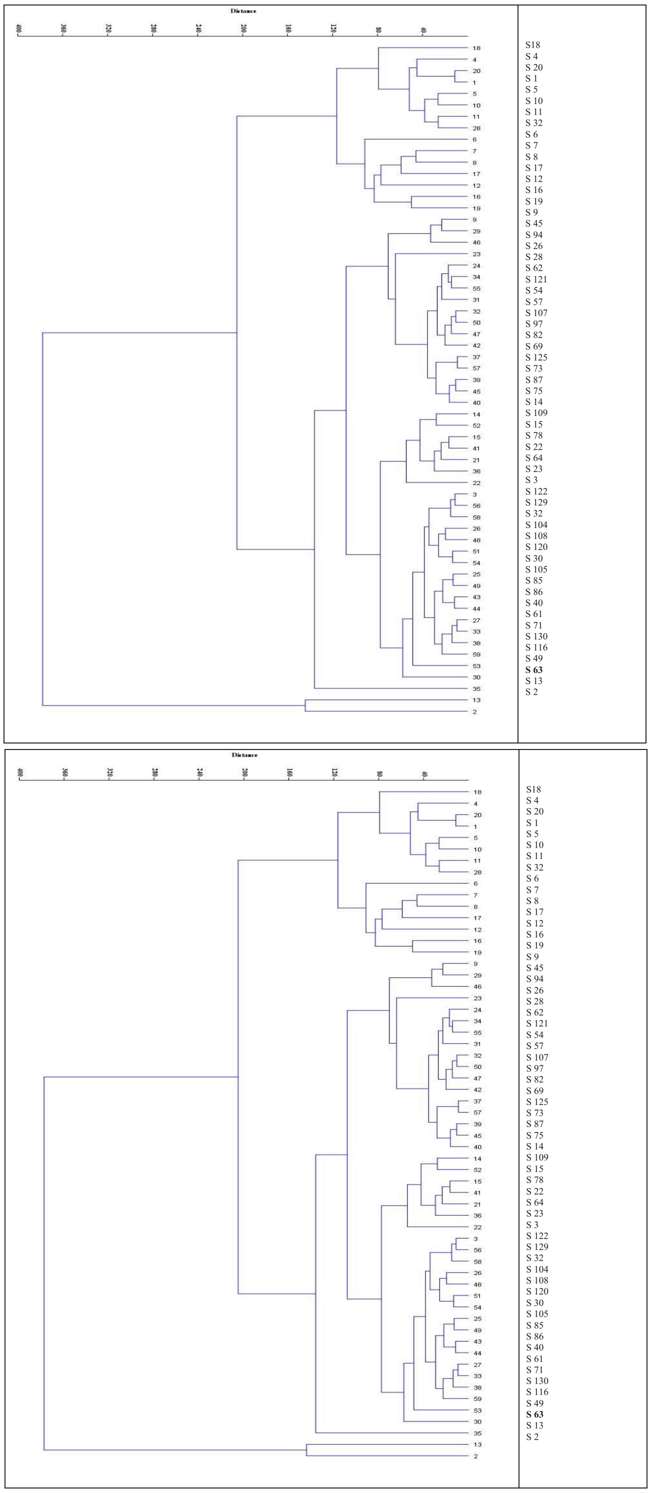


Fig.4. Dendrogram showing genetic relationships based on morphological traits among half-sibs of Cricket Ball

Sixth cluster consists of only one genotype (S-63) that was dwarf, thick girth, big fruits of medium size, high TSS and high yielder. Seventh cluster consists of 2 progenies (S-13 and S-2) which were tall, thick girth, medium fruit weight with medium fruit size, medium TSS and low yielding.

To ascertain the superiority of S-63, a row trial was taken up and 25 grafts of S-63 were planted along with Cricket Ball for further evaluation. The tree height of 4-year old plants was 1.95 m in S-63 as compared to 2.15 m in Cricket Ball. Pooled data on tree height, girth, canopy spread, yield, fruit weight, fruit size, TSS, acidity is presented in Table 6.

Table 6. Comparative evaluation of IIHR S 63 with Cricket Ball for growth, yield and fruit quality parameters (pooled data from 2020-2022)

	IIHR S 63	Cricket ball	SD	T test
Tree height (m)	2.26	2.52	0.3	13.019**
Stem girth(cm)	13.33	13.67	1.528	15.119 **
Canopy spread N/S (m)	2.41	2.80	0.611	6.825 **
Canopy spread E/W(m)	2.34	2.86	0.512	7.914**
Av. no. fruits/Plant	48.37	13.67	12.973	6.457**
Yield/Tree Kg	5.91	1.40	0.881	11.62**
Fruit Weight(g)	128.57	114.00	16.92	13.161**
Fruit length (cm)	6.34	5.27	0.58	18.919
Fruit Diameter (cm)	6.34	5.62	0.265	41.505**
TSS (^{O}Brix)	20.33	19.66	0.289	122**
Acidity (%)	0.29	0.20	0.044	11.52**
Reducing sugars (%)	8.60	10.43	0.501	29.753**
Non reducing sugars (%)	11.28	7.49	0.462	42.303**
Total sugar (%)	19.55	17.93	0.784	43.171

Total sugars, non-reducing sugars and reducing sugars analysed by t test for 3 years (2020-2022) showed significant difference between the selected progeny (S-63) and the check (cricket ball) for all the parameters (Table 6).

The S-63 exhibited comparatively lower tree height (2.26 m) compared to Cricket Ball (2.52 m) (Fig.5).It was found that the S-63 has dwarf plant type with single fruit bearing habit. Yield in terms of number of fruits/tree and total weight of fruits/tree were high in S-63 (48.37 fruits; 5.91 kgs) compared to cricket ball (13.67; 1.40 kg). The fruit yield, size, colour and quality were found equivalent to cv. Cricket Ball. Based on similar studies in arecanut, Ananda *et al.* (2017) stated that dwarf varieties (VTLAH-1 and VTLAH- 2) were bred with high yield potential from open pollinated progenies and the selected progeny is likely to benefit the growers by enhanced returns and reduced cost (40%) of various cultural operations. VTLAH–2 yielded

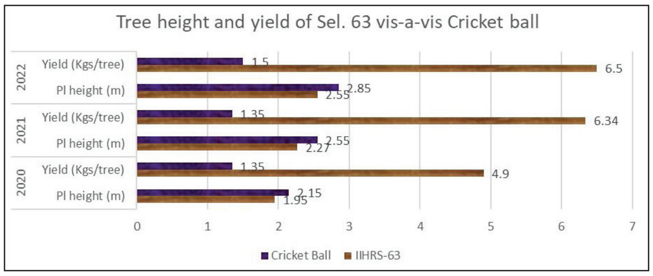


Fig. 5. Comparative evaluation on tree height and yield of IIHR S-63 and Cricket Ball

2.64 kg and grew up to 4 m in height and plant density can be increased to 800 from 600/acre.

The stem girth was almost same with 13.33 cm and 13.67 cm in S-63 and Cricket Ball respectively (Fig.6). Canopy spread was comparatively less in S- 63 (2.41*2.34 m) compared to the cricket ball (2.80*2.86 m).

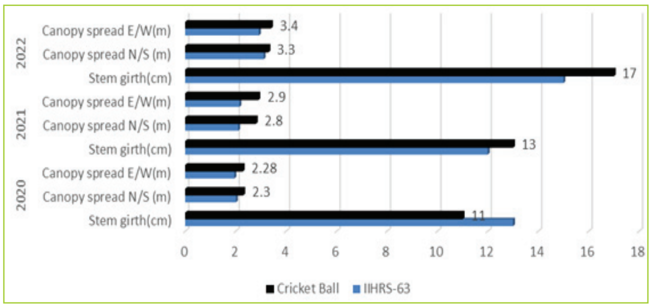


Fig.7. Comparative evaluation on canopy spread and girth of IIHR S-63 and Cricket Ball

Canopy spread (in both directions) was more in cricket ball through the study period compared to S-63. Stem girth higher in S-63 during the third year and fourth and fifth year the increase was less compared to cricket ball. Fruit quality parameters were evaluated to ascertain the superiority of the desirable parameters in the selected progeny (Table 6). Fruit weight was more in S-63 (128.57 g) compared to cricket ball (114 g). Fruit size was also more in the S-63 (6.34*6.34 cm) compared to the Cricket Ball (5.27 * 5.62 cm).

Biochemical parameters: Total sugars, non-reducing sugars and reducing sugars analysed by t test for 3 years (2020-2022) showed significant difference between the selected progeny (S-63) and the check (Cricket Ball) for all the parameters (Table 7). Sweetness measured as TSS was comparatively high in S-63 (20.33 B) compared to check (19.66) (Table 7). Fruit acidity expressed as citric acid was slightly more in S-63 (0.29 %) compared to cricket ball (0.20%). Fruit taste and flavour is determined by TSS/acidity ratio. Total sugars expressed in % was also high S-63 (19.55%) compared to cricket ball (17.93 %). In the selected progeny, S-63, reduced sugars accounted to 8.6% and non-reducing sugars accounted for 11.28%. Cricket ball variety recorded higher value for reducing (10.43%) and lower value for non-reducing sugars (7.49%) compared to S-63. The sugar/acid blend contributes to the taste and flavor of the fruits compared to the individual levels of sugars and acidity. Tripathi *et al.*, (2024) reported a carbohydrate content of 30.12 g/100g in the ripe fruits of avocado.

High morphological variability and genetic diversity were obtained by open-pollination in sapota. The S-63 is a high-yielding, with big fruits round fruits having sweet, soft pleasant flavoured, orange brown pulp and less number of seeds. Its tree is dwarf, compact and suitable for high-density planting. The half sibs generated would be used as parents in breeding program of sapota, to obtain more genotypes that are productive and with good fruit quality. The S-63 has also been planted at different centers across India for evaluation under various agro climatic regions to study its performance and stability for dwarf stature, yield and fruit quality.

ACKNOWLEDGMENTS

We would like to thank the Director ICAR-IIHR for their support and encouragement extended through the project period.

CRediT AUTHOR STATEMENT

Rekha: Conceptualization, Methodology, Data recording P C Tripathi: Data curation, Writing- Original draft preparation. Anuradha Sane: Data analysis, Writing-Reviewing and Editing. M R Dinesh: Methodology, Validation.

Table 7. Biochemical parameters of IIHRS-63 *vis- a- vis* Cricket Ball

	TSS (^{O}Brix)	Acidity (%)	Reducing sugars (%)	Non reducing sugars (%)	Total sugar (%)
IIHRS-63	20.33	0.29	8.60	11.28	19.55
Cricket Ball	19.66	0.20	10.43	7.49	17.81
Mean	20.00	0.25	9.52	9.39	18.74
SD	0.48	0.06	1.06	2.11	1.09
Min	19.38	0.20	8.12	7.10	17.25
Max	20.50	0.32	10.60	11.56	20.13
CV (%)	2.39	22.30	11.16	22.45	5.79

REFERENCES

Ananda, K S, Nagaraja, P Chowdappa. 2017. Arecanut varieties and hybrids released by ICAR-CPCRI. *Indian Journal of Arecanut, Spices, and Medicinal Plants* **18**(4):16-21

Dhakar M K, Bikash Das, Mathura Rai, Vishal Nath. 2023. Fruit Yield, Quality, and Stability in Sapota (*Manilkara achras* [Mill.] Fosb.) Varieties: Under Short-, Medium- and Long-Term. *Erwerbs-Obstbau* **65**:557–66

Hammer Ø, Harper D A T, and Ryan P D 2001. *PAST* Paleontological Statistics *software* Package for Education and Data Analysis. *Palaeontologia Electronica* **4**(1):1-9.

Hearn C J. 986. Development of seedless grapefruit cultivars through bud wood irradiation. *Journal of American Society of Horticultural Science* **3**: 304–6.

Jome Rime, Dinesh M R, Sankaran M, Shivashankara K S, Rekha A, Ravishankar K V. 2019. Evaluation and characterization of EMS-derived mutant populations in mango. *Scientia Horticulturae* **254**: 55-60

Kotasias D, Vemmos S. 1998. Improvement of satsuma mandarin (Wase group) using the appearance of clones with desirable characteristics. *Fruit Varieties Journal* **52**(3): 144–9.

Kumar D, Pandey V, Anjaneyul K, Nath V. 2008. Relationship of trunk cross-sectional area with fruit yield, quality and leaf nutrients status in Allahabad Safeda guava (*Psidium guajava*). *Indian Journal of Agricultural Science* **78**:337–39.

Mendel K. 1981. Bud mutations in citrus and their potential commercial value. *Proceedings of International Society of Citriculture*: **86**–9.

Muralidhara B M, Venugopalan R, Sakthivel T, Karunakaran G, Honnabyraiah M K, Siddanna Savadi. 2024. Correlation studies in avocado (*Persea americana*) accessions for morphological and biochemical characters. *Current Horticulture* **12**(1): 46–49.

Nogueira, D´ebora Souza Mendes, Rosane Borges Mendes, Samy Pimenta, Marlon Cristian Toledo Pereira, Alcinei Místico Azevedo, Silvia Nietsche, 2022. Selection in half-sib progenies of Annona squamosa L.: An important step in the development of new cultivars. *Scientia Horticulturae* **302**: 111173

Padilla-Ramírez J S, E. González-Gaona M A, Perales de la Cruz F, Gutierrez-Acosta N and Mayek-Pérez. 2007. Fruit yield and quality of twelve outstanding selections of guava (*psidium guajava*) from the calvillo-cañones region, méxico. *Acta Horticulturae* **735** (https://doi.org/10.17660/ActaHortic.2007.735.1)

Padi F K, Domfeh O K, Arthur A, Ofori A. 2012. Potential of recurrent selection for developing improved cocoa varieties in Ghana. Cocoa Research Institute of Ghana.

Patil S N, Kulapati Hipparagi, Mallikarjun Awati, Kantharaju V. 2019. Evaluation of Different Cultivars of Sapota (*Manilkara achras* L.) under Northern Dry Zone of Karnataka, India Rashmi Ingalagavi, *Int.J.Curr.Microbiol. App.Sci* **8**(9): 1705-1710

Panse V G, Sukhatme V G. 1995. *Statistical Methods for Agricultural Workers*, 2nd edn. Indian council of Agricultural Research, New Delhi.

Rafiul Islam K M, Md. Rezwanul Habib, Md. Shajedur Hossain, Md. Habibur Rahman. 2016. Morphological characterization of Sapota (*Manilkara zapota*) germplasm. Asian Australas. *J. Biosci. Biotechnol.* **1** (1): 108-115

Ranganna S. 1986. Handbook of Analysis and Quality Control for Fruit and Vegetable Products. Tata Mc Grow Hill Publishing Company Ltd, New Delhi.

Rattanpal H S, Gurteg Singh, Sandeep Singh, Sarbjeet Kaur, Anita Arora. 2013. Evaluation of Sapota (*Manilkara archas* (Mill) Forb.) Genotypes for Yield and Quality Attributes under Ludhiana Conditions of Punjab, *Environment & Ecology* **31** (3): 1260—62

Rekha A, Dinesh M R, Venugopalan R, Murthy B N S. 2011. Genetic Correlation and Cluster Analysis in Sapota (*Manilkara zapota*). *Journal of Horticultural Sciences* **6**(2): 101–104.

Robles Gonzales M M, Medina Urrutia V M, Velazquez Monreal J J and Simpson J. 2008. Field performance and molecular profiles of Mexican lime selections. *Euphytica* **161**: 401–11

Saraswathy S, Parameswari, Parthiban S, Selvarajan M, Ponnuswami V. 2010. Evaluation of Sapota genotypes for growth, yield and quality attributes, *Electronic Journal of Plant Breeding* **1**(4): 441- 446

Singh Awtar. 2009. Variability in fruit physic-chemical characters of Nagpur mandarin (*Citrus reticulata* Blanco): A scope for selection of improved clones. International *Journal of Tropical Agriculture* **27**(1-2): 79–83.

Takayuki Tanaka, Satit Wimol and Takayuki Mizutani, 1995. Inheritance of Fruit Shape and Seed Size of Watermelon *J. Japan. Soc. Hort. Sci.* **64**(3): 543-548.

Tripathi, P C, Anuradha Sane, A Shamina, Sriram S and Nesara Begane, 2024. Morphological and biochemical changes in avocado (*Persea americana*) during ripening. *Current Horticulture* **12**(1): 43–45

Ulubelde M, Ozcan M O, Erkan S and Sarp H. 1986. Bud wood selection of Satsuma mandarin in Aegean region in Turkey. *Derim* **3**: 120–8.

Uzun T, Yesiloglu and Tuzcu O. 2004. Determination of the yield and fruit characters some Washington Navel orange (*Citrus sinensis* L. Osb.) types selected in Turkey. *Proceedings of International Society of Citriculture*: 347–9.