Indian Journal of Agricultural Sciences **95** (10): 1156–1162, October 2025/Article
https://doi.org/10.56093/ijas.v95i10.168776

Evaluation of segregating guava (*Psidium guajava*) progenies for their pomological and biochemical parameters

M R CHANDANA[1], A K GOSWAMI[1]*, S K SINGH[1,2], CHAVLESH KUMAR[1], V S RANA[1], SHALINI GAUR RUDRA[1], SUNEHA GOSWAMI[1], R M SHARMA[1] and RAJEEV RANJAN KUMAR[3]

ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India

Received: 08 July 2025; Accepted: 26 September 2025

ABSTRACT

The perennial guava (*Psidium guajava* L.) tree, characterized by a heterozygous genetic constitution, has been exploited for commercial cultivation of novel recombinants (through vegetative multiplication) obtained via traditional breeding. The current study was carried out during 2021–2022 at ICAR-Indian Agricultural Research Institute, New Delhi to evaluate19 guava genotypes, including parental lines and hybrids, for various physical and biochemical parameters in order to explore the potential of hybridization. The fruit morphological parameters, such as fruit weight, pulp weight, seed hardness, seed weight/fruit, and pulp-to-seed weight ratio, as well as biochemical parameters like titratable acidity, total phenolics, total flavonoids, total antioxidant capacity, and total carotenoids, exhibited coefficient variations greater than 20% in selected guava genotypes. The hybrid GH-2017-8B (W) had a maximum fruit diameter (6.88 cm), fruit weight (175.67 g) and pulp weight (172.08 g), while hybrid GH-2017-4F had significantly higher titratable acidity (0.62%) and ascorbic acid content (285.03 mg/100 g pulp). The hybrid GH-2017-2C had a minimum number of seeds/fruit (222.33), seed weight/fruit (2.41 g) and maximum pulp: seed weight ratio (64.66) and higher total phenolic content (194.97 mg/100 g Gallic Acid Equivalent Fresh weight). The hybrid GH-2017-6C was found superior for total flavonoids (92.53 mg/100 g FW). In contrast, hybrid GH-2017-1F had higher total soluble solids (12.54ºBrix), total carotenoids (0.54 mg/100 g FW) and total sugars (9.09%) content. The fruit shape varied from roundish to ovate, the pulp colour from red to yellow and yellow-white, while the peel colour varied from yellow-green to pink. Hence, the hybrids GH-2017-4F, GH-2017-2C, GH-2017-6C, and GH-2017-1F were found to be superior to the selected guava genotypes.

Keywords: Antioxidants, Cluster plot, Full-sib progenies, Pulp-to-seed weight, Pearson's correlation, Seediness

Guava is botanically known as *Psidium guajava* L. and belongs to the subfamily Myrtoideae and family Myrtaceae. Guava is native to tropical America and it was introduced in India during the late 17th century and naturalized under the subtropical and tropical conditions of South Asia. Guava fruit is regarded as one of the richest sources of flavonols, anthocyanins and phenols, which function as powerful antioxidants and have various pharmacological effects (Menaka *et al.* 2024). Guava is popularly known as the "poor man's apple" and the "apple of the tropics" due to its high nutraceutical value and affordability (Shiva *et al.* 2017). Additionally, it yields optimum profit with good yield even when grown on marginal soils and under harsh climatic conditions (Pommer and Murakami 2009). Therefore, it could be the most suitable crop for ensuring nutritional security for the country under a changing climate scenario (Kumar *et al.* 2020). Guava has contributed to the economies of many countries in Latin America (Brazil, Mexico, and Colombia), Africa (Egypt) and Asia (India, Pakistan, Malaysia and Thailand). India has emerged as the largest guava producer in the world (Mitra *et al.* 2012, Padilla-Ramirez 2012), with an area of 0.30 million hectares of land and an annual production of 4.51 million tonnes (NHB 2022).

The galloping health-conscious population always demands guava fruits with the highest eating quality and enriched nutraceutical values. Therefore, guava breeders have established an ideotype to develop superior genotypes, which have thick pulp, soft and low seeds, prolonged shelf life, enhanced nutraceutical value, resistant/tolerant to biotic and abiotic stresses, among other traits (Kumar *et al.* 2020). The development of superior guava genotypes depends mainly on the traditional or classical breeding approach while selecting desirable guava parents from existing variability. Guava breeding is tedious due to its heterozygous genetic constitution and prolonged ontological

[1]ICAR-Indian Agricultural Research Institute, New Delhi; [2]Krishi Anusandhan Bhawan-II, New Delhi; [3]ICAR-Indian Agricultural Statistics Research Institute, New Delhi. *Corresponding author email: amit.tkg@gmail.com

phases (Usman *et al.* 2013). However, the existence of heterozygosity of guava provides potentialities for developing novel recombinants and subsequent utilization for their commercial cultivation through vegetative multiplication. Thus, in the current study, the recombinants developed as full-sib progenies were evaluated, along with their parental genotypes, for their physical pomological and biochemical parameters.

MATERIALS AND METHODS

The current study was carried out during 2021–2022 at ICAR-Indian Agricultural Research Institute (28°75´N; 77°12´E; at an elevation of 228.6 m amsl), New Delhi. 19 guava genotypes, including hybrids and some of their parents were maintained in the guava experimental orchard with uniform horticultural practices (Table 1). The fruits were randomly selected for evaluation at the optimum maturity stage (turning stage from dark green to light green peel colour). The experiment was laid out in randomized block design (RBD) with three replications. Each replication consisted of three trees/progeny. Each progeny/tree was considered as a treatment. The average of recorded observations was used for analysis. Physical fruit parameters, i.e. weight, diameter and length, number of seeds, seed hardness, seed weight, pulp-seed ratio were evaluated following the 'Guava Descriptor' developed by ICAR-Central Institute for Subtropical Horticulture, Lucknow, Uttar Pardesh (Rajan *et al.* 2011). The peel colour and pulp colour of guava were observed using the Royal Horticultural Society Colour Chart.

The fruit biochemical parameters, viz. total soluble solids (TSS), total phenolic content (TPC), titratable acidity (TA), ascorbic acid content (AAC), antioxidant activity-[Cupric Reducing Antioxidant Capacity (CUPRAC)] (AA-CUPRAC), the total sugars (TS), total flavonoid content (TFC) and carotenoid content were analyzed in the collected fruit samples. The TSS of guava genotypes was determined using an MA871 Digital Brix refractometer. TA and AAC of guava fruit samples were determined by titration according to AOAC methods (AOAC 1970). The TPC was determined using the Folin-Ciocalteu Reagent (FCR) method (Singleton and Rossi 1965) and results were expressed in mg of gallic acid equivalent (GAE) per 100 g of pulp on a fresh weight (FW) basis. The AA-CUPRAC was determined using the CUPRAC method, as suggested by Apak *et al.* (2006). The results were expressed as Trolox equivalent antioxidant activity (TEAC) strength in µM Trolox equivalent per gram FW. The total sugars (TS) was determined following the methodology proposed by Thimmaiah (1999), with some modifications. TS was calculated using the graph and expressed as a percentage. The TFC of fruit extract was determined using Lombard *et al.* (2002) method, with minor modifications, and expressed as mg quercetin equivalent (QE)/100 g FW. The carotenoid content of guava fruit extract was measured using the methodology described by Thimmaiah (1999) with some minor modifications. Guava pulp (5 g) was extracted with acetone, partitioned into petroleum ether and the absorbance of the extract was measured at 450 nm using a UV–Vis spectrophotometer. The results of total carotenoid content were expressed in mg/100 g of FW.

Statistical analyses of datasets were performed using randomized block design (RBD). ANOVA analysis of fruit physical parameters and biochemical data, and the means separation by least significant difference (LSD) was calculated at 5% significance using the R studio ver. 2024.09.1. The datasets were also used for principal component analysis, Pearson's correlation coefficient, cluster analysis, and cluster plot analysis using the R studio ver. 2024.09.1.

RESULTS AND DISCUSSION

Physical parameters: The physical pomological traits of guava are important in attracting consumers and farmers. Results showed large variability in the physical pomological parameters, viz. fruit shape, fruit colour, peel colour, fruit weight, fruit diameter, fruit length, pulp weight, seed number/fruit, seed hardness, seed weight/fruit and pulp to seed weight ratio (Table 2). The quantitative fruit physical parameters like fruit weight, pulp weight, seed

Table 1 Details of guava genotypes used in the experiment

Sl. no.	Guava genotype	Description	S.no.	Guava genotype	Description
1	Allahabad Safeda	Open-pollinated seedling	11	GH-2017-6C	Shweta × Arka Kiran
2	Lalit	Half sib selection from Apple Colour	12	GH-2017-8C	Thai × Black Guava
3	Shweta	Half sib selection from Apple Colour	13	GH-2017-4F	Lucknow-49 × Arka Kiran
4	Hisar Surkha	Apple Colour × Banarasi Surkha	14	GH-2017-8B (W)	Thai × Hisar Surkha
5	GH-2017-8E(W)	Thai × Lalit	15	GH-2017-6D	Shweta × Punjab Pink
6	GH-2017-8E(R)	Thai × Lalit	16	GH-2017-2C	Pant Prabhat × Hisar Surkha
7	GH-2017-2A	Pant Prabhat × Lalit	17	GH-2017-3F	Lalit × Hisar Safeda
8	GH-2017-4C	Lucknow-49 × Hisar Surkha	18	GH-2017-8B (R)	Thai × Hisar Surkha
9	GH-2017-5C	Allahabad Safeda × Hisar Surkha	19	GH-2017-1F	Punjab Pink × Allahabad Safeda
10	GH-2017-7A	Hisar Safeda × Black Guava			

Table 2 Evaluation of qualitative and quantitative physical pomological parameters of the selected guava genotypes

Sl. No.	Genotype	Fruit shape	Pulp colour	Peel colour	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Pulp weight (g)	Number of seeds	Seed hardness (kg/cm^2)	Seed weight (g)	Pulp to seed weight ratio
1	Allahabad Safeda	Roundish	YW155 B	YG151 A	111.33^{fgh}	6.58^{e}	7.22^{a}	93.16^{q}	255.33^{g}	10.80^{fgh}	2.163^{l}	43.13^{i}
2	Lalit	Spherical	R49 A	YG151 A	105.33^{gh}	5.98^{f}	4.58^{p}	92.29^{r}	161.0^{k}	16.19^{bcdef}	1.44^{n}	64.50^{b}
3	Shweta	Roundish	YW8 B	Y158 D	136.29^{def}	6.86^{d}	5.52^{k}	130.49^{j}	274.0^{f}	10.74^{gh}	2.77^{g}	48.40^{f}
4	Hisar Surkha	Roundish	R54 B	Y11 A	111.33^{fgh}	5.90^{g}	5.77^{i}	104.66^{m}	252.0^{g}	8.55^{h}	2.37^{hij}	44.21^{h}
5	GH-2017-8E(R)	Roundish	R48 B	YGN144 B	160.33^{bcd}	7.61^{a}	6.52^{d}	153.83^{f}	274.66^{f}	12.81^{efgh}	2.40^{hi}	63.96^{b}
6	GH-2017-8E(W)	Roundish	YW158 B	YG154 A	163.66^{bc}	4.78^{hij}	6.20^{e}	157.10^{c}	225.0^{j}	18.27^{bcd}	2.12^{l}	72.67^{a}
7	GH-2017-2A	Spherical	R38 B	YG145 A	99.67^{h}	7.01^{c}	4.99^{o}	94.13^{p}	226.0^{j}	15.46^{bcdefg}	2.06^{m}	44.79^{h}
8	GH-2017-4C	Roundish	R38 A	YG145 A	111.67^{fgh}	4.77^{hij}	5.03^{n}	105.64^{l}	243.33^{h}	14.12^{cdefg}	3.88^{b}	27.44^{m}
9	GH-2017-5C	Roundish	R39 B	YGN144 B	107.33^{gh}	7.56^{b}	5.24^{m}	102.63^{n}	281.33^{e}	16.89^{bcde}	2.72^{g}	37.12^{l}
10	GH-2017-7A	Roundish	Y11 D	YGN144 B	150.33^{bcde}	4.78^{hij}	6.02^{g}	146.83^{g}	305.67^{b}	14.04^{defg}	3.13^{e}	46.88^{g}
11	GH-2017-6C	Roundish	R39 B	YG145 A	144.66^{cde}	7.013^{c}	5.78^{i}	138.82^{h}	286.33^{d}	14.79^{bcdefg}	2.31^{jk}	60.22^{d}
12	GH-2017-8C	Roundish	R47 C	YG145 A	110.67^{fgh}	4.76^{j}	5.66^{j}	105.27^{lm}	251.67^{g}	13.78^{defgh}	2.29^{k}	46.23^{g}
13	GH-2017-4F	Roundish	R38 A	YG145 A	132.0^{efg}	7.57^{b}	5.42^{l}	126.47^{k}	301.67^{b}	15.44^{bcdefg}	3.26^{d}	38.75^{k}
14	GH-2017-8B (W)	Roundish	Y155 A	YGN144 B	175.67^{ab}	4.78^{hi}	6.88^{b}	172.08^{b}	391.33^{a}	15.33^{bcdefg}	4.70^{a}	36.61^{l}
15	GH-2017-6D	Roundish	R39 B	YG145 A	191.0^{a}	7.01^{c}	6.58^{c}	184.57^{a}	291.33^{c}	11.45^{fgh}	3.01^{f}	61.39^{c}
16	GH-2017-2C	Roundish	R39 B	YG145 A	161.33^{bcd}	4.76^{ij}	6.08^{f}	155.83^{d}	222.33^{j}	20.09^{ab}	2.41^{h}	64.67^{b}
17	GH-2017-3F	Roundish	R49 A	YG145 A	136.29^{cde}	7.56^{b}	5.76^{i}	134.33^{i}	234.00^{i}	23.72^{a}	2.34^{ijk}	57.66^{e}
18	GH-2017-8B (R)	Roundish	R55 B	YG145 A	103.0^{h}	4.79^{h}	4.53^{q}	99.48^{o}	282.67^{de}	19.45^{abc}	3.58^{c}	27.76^{m}
19	GH-2017-1F	Ovate	R39 B	YG151 A	159.33^{bcd}	7.01^{c}	5.84^{h}	154.74^{e}	295.00^{c}	17.55^{bcde}	3.81^{b}	41.05^{j}
LSD (p<0.05)					26.93	0.02	0.03	0.65	4.70	5.39	0.07	1.03
Minimum					99.67	4.76	4.53	92.29	161.00	8.55	1.44	72.67
Maximum					191.00	7.61	7.22	184.57	391.33	23.78	4.70	27.44
Mean					135.56	6.16	5.77	129.07	266.04	15.24	2.78	48.81
Standard deviation					31.14	1.16	0.71	28.63	46.00	4.46	0.77	12.88
Coefficient of Variation (%)					22.97	18.82	12.37	22.18	17.29	29.26	27.87	26.38

Superscript in small letters on the value of each parameter indicates significant difference at p<0.05.

hardness, seed weight/fruit, and pulp-to-seed weight ratio had >20% coefficient of variance (CV) in a selected set of guava genotypes and exhibited the large variability. The highest fruit weight (191.00 g) was observed in GH-2017-6D, whereas the lowest (99.67 g) was in GH-2017-2A. The longest fruit (7.61 cm) was recorded in GH-2017-8E (R), while the shortest (4.76 cm) was in GH-2017-8C. The maximum fruit diameter (7.22 cm) was recorded in Allahabad Safeda, which was statistically similar (6.88 cm) with the guava hybrid GH-2017-8B (W), while GH-2017-8B (R) had a minimum fruit diameter (4.53 cm). The individual fruit weight of guava genotypes is important parameter in terms of market preferences. Fruit size is the combination of fruit weight, length and width and also it is an important criteria for external fruit quality which affects consumer preference (Prudent *et al.* 2014, Shiva *et al.* 2017). The significant variations in the fruit physical parameters indicate the genotypic and phenotypic influences amongst the selected guava genotypes. Earlier, Raghav and Tiwari (2008), Shiva *et al.* (2017) and Verma *et al.* (2024) found similar observations on their guava selections for pomological traits.

High seed content and presence of hard seed coat are major concerns in guava; however, development of the seedless guava genotypes leads to misshapen fruit and reduced size. Therefore, development of the guava genotypes having low seediness with enhanced seed mellowness is fixed as guava ideotype in genetic improvement programme (Shiva *et al.* 2017, Kumar *et al.* 2020). In the present investigation, significant variations were recorded for the seed related traits among studied guava genotypes. The guava genotype, Lalit, had the minimum number of seeds/fruit (161.00), which was at par with GH-2017-2C (222.33), while it was highest (391.33) in GH-2017-8B (W). The lowest seed weight/fruit was recorded in Lalit (1.44 g) without exhibiting significant variation with GH-2017-2A (2.06 g), while guava hybrids GH-2017-8B (W) had the highest seed weight (4.7 g). The minimum seed hardness (8.55 kg/cm^2) was recorded in Hisar Surkha, which was statistically *at par* with Shweta (10.74 kg/cm^2) and Allahabad Safeda (10.80 kg/cm^2). In comparison, GH-2017-3F had hardy seeds (23.72 kg/cm^2) without having a significant difference with GH-2017-2C (20.09 kg/cm^2). The weight of pulp was recorded maximum in GH-2017-6D (184.57 g) followed by GH-2017-8B(W) (172.08 g). The minimum weight of pulp (92.29 g) was recorded in Lalit, followed by Allahabad Safeda (93.16 g) and GH-2017-2A (94.13 g). The highest pulp:seed weight ratio (72.7) was recorded in GH-2017-8E (W), Which showed no significant statistical difference to GH-2017-2C (64.66) and Lalit (64.5) while GH-2017-4C (27.44) and GH-2017-8B(R) (27.76) had lowest pulp:seed weight ratio. The formation of the seeds in guava genotypes is influenced by pollen fertility and fertilization (Patel *et al.* 2015, Shiva *et al.* 2017). The differential number of seeds among the selected guava genotypes indicated their differential genetic pollen fertility and fertilization ability.

The majority of the guava genotypes [Allahabad Safeda, Shweta, Hisar Surkha, GH-2017-8E (R), GH-2017-8E (W), GH-2017-4C, GH-2017-5C, GH-2017-7A, GH-2017-6C, GH-2017-2C, GH-2017-4F, GH-2017-6D, GH-2017-8C, GH-2017-3F, GH-2017-8B (R), and GH-2017-8B (W)] had roundish fruit shape whereas, in Lalit and GH-2017-2A, it was spherical and GH-2017-1F had ovate shape. The peel colour varies among the guava genotypes, viz. yellow green (YG151 A) (Allahabad Safeda, Lalit and GH-2017-1F), yellow group (Y11 A) Hisar Surkha and Shweta (Y158D group), yellow green (YGN144 B group) GH-2017-8E (R), GH-2017-5C, GH-2017-7A, GH-2017-8B (W) while, yellow green colour GH-2017-8E (W) (YG154 A group) and GH-2017-2A, GH-2017-4C, GH-2017-6C, GH-2017-2C, GH-2017-6D, GH-2017-8C, GH-2017-3F, GH-2017-8B (R) and GH-2017-4F (YG145 A group). The pulp colour varied among the guava genotypes, Allahabad Safeda, Shweta (YW8 B) and GH-2017-8E (W) (YW158 B group) came under yellow white (YW155 B) group, whereas, Hisar Surkha (R54 B group), Lalit (R49 A group), GH-2017-8E(R) (R48 B group), GH-2017-2A (R38 B group), GH-2017-4C, GH-2017-4F (R38 A group), GH-2017-5C, GH-2017-6C, GH-2017-6D, GH-2017-2C and GH-2017-1F (R39 B group), GH-2017-8C (R47 C group), GH-2017-3F (R49 A group) and GH-2017-8B (R) (R55 B group) had various shades of red colour. Only hybrids, GH-2017-7A (Y11 D group) and GH-2017-8B (W) (Y155 A group) fall under the yellow group. A substantial variation was noticed for the qualitative and quantitative physical pomological traits amongst the selected guava genotypes. Previous studies by Alam *et al.* (2018), Golam *et al.* (2021) and Verma *et al.* (2024) also observed the variations for physical pomological parameters like weight, surface, shape, peel colour and pulp colour. Thus, the variability available in the selected guava genotypes could provide ample opportunities for the selection of the desirable guava phenotypes. The hybrid progenies, viz. GH-2017-6D, GH-2017-2C, GH-2017-8E (W) were found superior in terms of physical pomological traits and its appearance in terms of peel and pulp colours.

Biochemical parameters: Among the different variables affecting fruit quality, bio-chemical compounds play a vital role in determining the guava fruits for its suitability for the dessert and processing purposes (Shiva *et al.* 2017, Verma *et al.* 2024). In the current research, fruit biochemical parameters, viz. TSS, TA, AAC, TPC, TFC, total carotenoids and TS were significantly varied among the selected guava genotypes (Table 3). The biochemical parameters like TA, TPC, TFC, AA-CUPRAC and total carotenoids showed >20% of the coefficient variations in selected guava genotypes which indicated substantial variation amongst them. The fruit biochemical parameters like TSS, TA, AAC, and TSC are important components of the fruit quality of guava (Patel *et al.* 2015) and determined the dessert quality of fruits. The TSS ranged from 8.89–12.54°Brix in the selected guava genotypes, the guava hybrid, GH-2017-1F, had a higher (12.54°Brix) TSS,

Table 3 Evaluation of fruit biochemical parameters of the selected guava genotypes

Sl. no.	Genotype	TSS (°Brix)	Titratable acidity (%)	Ascorbic acid (mg/100 g of pulp)	Total Phenols (mg GAE/100 g of FW)	Total flavonoid (mg/100 g of FW)	Total antioxidant (µmol/g TE FW)	Total carotenoid (mg/100 g of FW)	Total sugar (%)
1	Allahabad Safeda	12.14^{e}	0.51^{a}	244.33^{b}	110.93^{ghi}	24.74^{l}	12.88^{b}	0.16^{gh}	8.72^{ab}
2	Lalit	9.21^{p}	0.42^{abcd}	166.47^{h}	283.67^{a}	41.27^{hi}	5.73^{efg}	0.68^{a}	6.58^{hi}
3	Shweta	9.82^{o}	0.50^{a}	215.50^{c}	112.33^{ghi}	81.137^{c}	15.06^{a}	0.21^{fg}	6.97^{gh}
4	Hisar Surkha	10.86^{m}	0.42^{abc}	145.77^{m}	137.00^{efg}	30.19^{k}	5.63^{efg}	0.58^{b}	7.88^{cde}
5	GH-2017-8E(R)	10.21^{n}	0.24^{f}	154.30^{l}	121.57^{fgh}	84.53^{bc}	6.40^{ef}	0.33^{de}	7.19^{fgh}
6	GH-2017-8E(W)	12.41^{b}	0.31^{cdef}	169.44^{f}	86.33^{i}	68.47^{d}	8.67^{c}	0.32^{de}	8.43^{bc}
7	GH-2017-2A	11.69^{h}	0.34^{cdef}	169.21^{fg}	105.73^{hi}	84.33^{c}	6.40^{ef}	0.16^{gh}	7.89^{cde}
8	GH-2017-4C	11.34^{i}	0.26^{ef}	162.27^{ij}	195.53^{b}	37.43^{ij}	6.80^{de}	0.16^{gh}	7.41^{efg}
9	GH-2017-5C	11.07^{k}	0.29^{ef}	208.64^{d}	148.77^{def}	88.53^{ab}	4.86^{fgh}	0.46^{c}	7.27^{efg}
10	GH-2017-7A	12.24^{d}	0.32^{cdef}	169.60^{f}	151.43^{def}	62.53^{e}	5.40^{efg}	0.38^{d}	8.34^{bcd}
11	GH-2017-6C	12.29^{c}	0.33^{cdef}	161.33^{j}	141.47^{efg}	92.53^{a}	3.37^{hi}	0.18^{gh}	8.64^{ab}
12	GH-2017-8C	8.89^{q}	0.34^{cdef}	193.87^{e}	186.53^{bc}	84.63^{bc}	6.20^{ef}	0.27^{ef}	6.21^{i}
13	GH-2017-4F	11.01^{l}	0.49^{ab}	285.03^{a}	97.37^{hi}	63.33^{e}	8.40^{cd}	0.16^{gh}	7.13^{fgh}
14	GH-2017-8B (W)	11.34^{i}	0.35^{cdef}	163.46^{i}	112.67^{ghi}	43.60^{gh}	5.20^{efg}	0.18^{gh}	7.89^{cde}
15	GH-2017-6D	11.22^{j}	0.30^{def}	158.97^{k}	125.73^{fgh}	53.33^{f}	2.70^{i}	0.46^{c}	7.33^{efg}
16	GH-2017-2C	11.97^{g}	0.35^{cdef}	163.62^{i}	194.97^{b}	35.63^{j}	6.30^{ef}	0.14^{h}	7.76^{def}
17	GH-2017-3F	12.07^{f}	0.35^{cdef}	167.72^{gh}	162.53^{cde}	33.47^{jk}	4.27^{ghi}	0.45^{c}	8.49^{abc}
18	GH-2017-8B (R)	12.24^{d}	0.37^{bcde}	209.67^{d}	122.40^{fgh}	45.33^{g}	4.80^{fgh}	0.45^{c}	8.91^{ab}
19	GH-2017-1F	12.54^{a}	0.23^{f}	214.43^{c}	175.53^{bcd}	52.83^{f}	4.20^{ghi}	0.54^{b}	9.09^{a}
LSD (p<0.05)		0.034	0.12	1.71	30.91	4.02	1.72	0.06	1.03
Minimum		8.89	0.23	145.77	86.33	24.74	2.70	0.14	6.21
Maximum		12.54	0.51	285.03	283.67	92.53	15.06	0.68	9.09
Mean		11.29	0.35	185.45	145.92	58.31	6.49	0.33	7.80
Standard deviation		1.07	0.14	35.18	48.33	22.07	3.12	0.17	0.81
Coefficient of Variation (%)		9.46	38.54	18.97	33.12	37.86	48.07	50.83	10.39

Superscript in small letters on the value of each morphological parameter indicates significant difference at p<0.05.

while it was recorded the lowest (8.89°Brix) in hybrid GH-2017-8C. The titratable acidity varied from 0.23–0.51%. The maximum TA (0.51%) was measured in the guava genotype, Allahabad Safeda, which was statistically at par with Shweta (0.50%). In comparison, it was minimum (0.23%) in the guava hybrid genotype, GH-2017-1F, which is statistically at par with GH-2017-8E(R) (0.23%). The AAC varied from 145.77–285.03 mg/100 g of pulp FW amongst the guava genotypes. The maximum AAC (285.03 mg/100 g) was measured in guava hybrid, GH-2017-4F, while it was minimum (145.77 mg/100 g) in Hisar Surkha. The TPC was measured at a maximum (283.67 mg/100 g FW) in the guava cultivar Lalit, and it was a minimum (86.33 mg/100 g) in hybrid, GH-2017-8E (W). The guava hybrid showed a significant variation in TFC, ranging from 24.73 mg/100 g FW (Allahabad Safeda) to 92.53 mg/100 g FW (GH-2017-6C). The guava cultivar, Shweta, exhibited a higher antioxidant potential (15.06 µmol/g TE FW) while, hybrid GH-2017-6D had a minimum AA-CUPRAC (2.70 µmol/g TE FW). The guava cultivar, Lalit, has the highest total carotenoid content (0.68 mg/100 g FW) while, the lowest in GH-2017-2C (0.14 mg/100 g FW). The TS varied from 6.21–9.09%, and the maximum total sugars content was measured in the guava hybrid, GH-2017-1F, whereas it was lowest in GH-2017-8C. Similar findings for various fruit biochemical parameters in guava genotypes were reported by Shiva *et al.* (2017) and Verma *et al.* (2024). It was also reported that the selections were made for the improved level of biochemical parameters TSS, TA, reducing sugar, TPC, TFC and antioxidant activities (Verma *et al.* 2024). On this basis, some the hybrids, viz. GH-2017-1F, GH-2017-4F and GH-2017-6C were found superior for the biochemical traits.

Pearson's correlation studies: Understanding the degree of relationship among the different parameters is essential for the selection of fruit traits, especially when the prevailing environmental conditions are highly influencing them. In the

Table 4 The correlation studies among the morpho-biochemical parameters in guava genotypes

Particular	Fruit weight	Fruit length	Fruit diameter	Number of seeds	Pulp weight	Seed hardness	Seed weight	Pulp seed ratio	TSS	Acidity	Ascorbic acid	Total phenols	Total flavonoid	Total antioxidant	Total carotenoid	Total sugar
Fruit weight	1.000															
Fruit length	0.002	1.000														
Fruit diameter	0.655**	0.036	1.000													
Number of Seeds	0.460*	0.012	0.431	1.000												
Pulp weight	0.993**	-0.007	0.599**	0.491*	1.000											
Seed hardness	0.050	-0.071	-0.293	-0.181	0.100	1.000										
Seed weight	0.323	-0.243	0.113	0.794**	0.368	0.035	1.000									
Pulp seed ratio	0.471*	0.131	0.295	-0.438	0.431	0.125	-0.653**	1.000								
TSS	0.267	-0.046	0.227	0.232	0.278	0.395	0.281	-0.076	1.000							
Acidity	-0.353	0.084	-0.015	-0.102	-0.397	-0.292	-0.242	-0.106	-0.238	1.000						
Ascorbic acid	-0.258	0.292	-0.070	0.190	-0.275	-0.005	0.154	-0.426	0.013	0.528*	1.000					
Total phenols	-0.244	-0.210	-0.410	-0.522*	-0.254	0.216	-0.223	0.123	-0.372	-0.151	-0.277	1.000				
Total flavonoid	0.018	0.314	-0.156	0.135	0.054	-0.111	-0.177	0.149	-0.249	-0.253	0.047	-0.267	1.000			
Total antioxidant	-0.206	0.018	0.152	-0.130	-0.256	-0.361	-0.171	-0.052	-0.209	0.655**	0.485*	-0.302	0.002	1.000		
Total carotenoid	-0.089	0.116	-0.284	-0.251	-0.084	0.083	-0.177	0.134	-0.154	-0.180	-0.224	0.427	-0.209	-0.431	1.000	
Total sugar	0.159	-0.032	0.215	0.218	0.163	0.322	0.229	-0.104	0.918**	-0.146	0.015	-0.330	-0.298	-0.156	0.018	1.000

TSS, Total soluble solids. **Correlation is significant at the 0.01 level (2-tailed) and *Correlation is significant at the 0.05 level (2-tailed).

genetic improvement program, the breeders' attempt to select multiple traits and identifying their associations through correlation studies is a crucial step (Maan *et al.* 2023). The analysis of pearson's correlation revealed significant positive and negative correlations among quantitative, physical and biochemical parameters of guava genotypes (Table 4). The fruit weight was significantly positively correlated with the fruit diameter (0.655**), number of seeds (0.460*), pulp weight (0.993**) and pulp seed ratio (0.471*). The number of seeds/fruit was positively correlated with pulp weight (0.491*), seed weight (0.794**) and negatively with TPC (-0.522*). The number of seeds was negatively correlated with the pulp seed ratio (-0.653**), while TSS was positively correlated with the TS (0.918**) in guava genotypes. The fruit acidity was positively correlated with AAC (0.528*) and AA-CUPRAC (0.655**) while AAC content was positively correlated with AA-CUPRAC (0.485*). Earlier, Gangappa *et al.* (2022) reported a significant positive correlation among the physical pomological parameters like fruit length, diameter, pulp weight, pulp thickness and fruit weight which are congruent with findings of the present study. Similarly, Maan *et al.* (2023) deciphered the TSS, which was positively correlated with the TS, indicating that both traits share common genetic control. Recently, Verma *et al.* (2024) have also studied the association of the various morpho-biochemical parameters in guava genotypes and established the degree of association amongst them.

Cluster plot analysis: The multivariate analysis such as cluster analysis was performed in many perennial fruit crop species including the guava to establish the phylogenic relationships and classification of the genotypes (Verma *et al.* 2024). Earlier, various multivariate analyses were performed using the morpho-biochemical parameters and established the relationship amongst the guava genotypes (Gangappa *et al.* 2022, Verma *et al.* 2024). The cluster plot analysis revealed three major clusters and one outlier (Fig. 1). The cluster-1 have genotypes of GH-2017-2A, GH-2017-5C, GH-2017-8B_R, GH-2017-4C, GH-2017-8C and Hisar Surkha whereas cluster 3 represents genotypes of GH-2017-7A, GH-2017-6D, GH-2017-8E_R, GH-2017-6C, GH-2017-2C, GH-2017-1F and GH-2017-8B_W then cluster 2 contains only 1 genotype, Lalit, and cluster 4 contains 3 genotypes which has Allahabad Safeda, GH-2017-4F and Shweta. The hybridizations between two heterozygous parents in guava often produce progenies with transgressive segregating (Patel *et al.* 2005, Singh 2020). In the present investigation, separate clustering of the hybrid progenies from their parental genotypes indicated the existence of transgressive segregation in guava.

Based on the findings of this study, it can be concluded that the selected guava genotypes exhibit significant variation in the context of physical pomological and bio-chemical parameters. The novel recombinants in the form of hybrid progenies, GH-2017-4F, GH-2017-2C, GH-2017-6C, and GH-2017-1F showed notable superiority in terms of various pomological, biochemical and antioxidant. This study provided valuable and fundamental insights

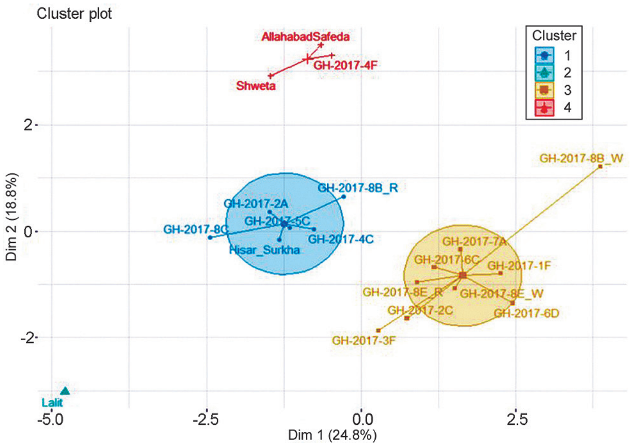

Fig. 1 Cluster plot of guava genotypes including the hybrids and parents based on the pomological and biochemical parameters.

for developing and selecting elite guava hybrids utilizing heterozygous parents. The developed unique recombinants will serve as genetic resources for the guava improvement program and some of the promising progenies will be released for commercial cultivation after clonal and multilocation trails.

REFERENCES

Alam F, Islam K D and Rahman S M. 2018. Variability among selective guava (*Psidium guajava* L.) varieties revealed by morphology and RAPD marker. *Jahangirnagar University Journal of Biological Sciences* **7**(2): 89–98.

AOAC. 1970. *Methods of Analysis of the Association of Official Agricultural Chemists*. Washington D C.

Apak R, Guclu K, Ozyurek M, Esin Karademir S and Ercag E. 2006. The cupric ion reducing antioxidant capacity and polyphenolic content of some herbal teas. *International Journal of Food Sciences and Nutrition* **57**(5–6): 292–304.

Gangappa N D, Singh C, Verma M K, Thakre M, Sevanthi A M, Singh R, Srivastav M, Raghunandan K, Anusha C, Yadav V and Nagaraja A. 2022. Assessing the genetic diversity of guava germplasm characterized by morpho-biochemical traits. *Frontiers in Nutrition* **9**: 1017680.

Golam A, Uddin M S, Chowdhury S K H, Rashid A S M H, Haimonti B and Rozina A C. 2021. Variability studies of guava (*Psidium guajava* L.) genotypes for growth, yield and quality attributes in Chattogram region of Bangladesh. *Journal of Agricultural Science and Engineering Innovation* **1**: 3–9.

Kumar C, Kumar R, Singh S K, Goswami A K, Nagaraja A, Paliwal R and Singh R. 2020. Development of novel g-SSR markers in guava (*Psidium guajava* L.) cv. Allahabad Safeda and their application in genetic diversity, population structure and cross species transferability studies. *PLOS One* **15**(8): e0237538.

Lombard K A, Geoffriau E and Peffley E. 2002. Flavonoid quantification in onion by spectrophotometric and high-performance liquid chromatography analysis. *Hort Science* **37**(4): 682–685.

Maan S S, Brar J S, Mittal A, Gill M I, Arora N K, Sohi H S, Chhuneja P, Dhillon G S, Singh N and Thakur S. 2023. Construction of a genetic linkage map and QTL mapping of fruit quality traits in guava (*Psidium guajava* L.). *Frontiers in Plant Science* **14**: 1123274.

Menaka M, Asrey R, Vinod B R, Meena N K, Sethi S and Ahmed S. 2024. Pre-storage melatonin treatment maintains cell membrane integrity, reduces fruit browning and decay incidence in guava (*Psidium guajava*). *The Indian Journal of Agricultural Sciences* **94**(4): 387–92.

Mitra S K, Devi H L, Chakraborty I and Pathak P K. 2012. Recent development in postharvest physiology and storage of guava. (*In*) *3rd International Symposium on Guava and other Myrtaceae* **959**: 89–95.

NHB. 2022. National Horticulture Board. Minstry of Agriculture and Farmers' Welfare, Government of India. https://static.pib.gov.in/WriteReadData/specificdocs/documents/2022/mar/doc202232832101.pdf

Padilla-Ramirez J S, Gonzalez-Gaona E, Perez-Barraza M H, Osuna-Garcia J A, de la C Espindola-Barquera M and Reyes-Aleman J C. 2012. Phenological behaviour of guava trees (*Psidium guajava* L.) under different climatic conditions of Mexico. (*In*) *3rd International Symposium on Guava and other Myrtaceae* **959**: 97–102.

Patel R K, Maiti C S, Deka B C, Deshmukh N A, Verma V K and Nath A. 2015. Physical and biochemical changes in guava (*Psidium guajava* L.) during various stages of fruit growth and development. *International Journal of Agriculture, Environment and Biotechnology* **8**(1): 75–82.

Patel R K, Yadav D S, Babu, K D, Singh A and Yadav R M. 2005. Growth, yield and quality of various guava (*Psidium guajava* L.) hybrids/cultivars under mid hills of Meghalaya. (*In*) *I International guava symposium* **735**: 57–59.

Prudent M, Dai Z W, Genard M, Bertin N, Causse M and Vivin P. 2014. Resource competition modulates the seed number–fruit size relationship in a genotype-dependent manner: A modeling approach in grape and tomato. *Ecological Modelling* **290**: 54–64.

Pommer C V and Murakami K R. 2009. Breeding guava (*Psidium guajava* L.). *(In) Breeding Plantation Tree Crops: Tropical Species,* pp. 83–120. Springer, New York.

Raghav M and Tiwari J P. 2008. Genetic variability and correlation analysis in guava. *Indian Journal of Horticulture* **65**: 263–70.

Rajan S, Misra A K and Ravishankar H. 2011. *Guava descriptors*. Central Institute for Subtropical Horticulture, Lucknow, Uttar Pradesh.

Shiva B, Nagaraja A, Srivastav M, Kumari S, Goswami A K, Singh R and Arun M B. 2017. Characterization of guava (*Psidium guajava*) germplasm based on leaf and fruit parameters. *The Indian Journal of Agricultural Science***s** **87**(5): 634–38.

Singh A. 2020. “Generating a linkage map and molecular mapping of fruit quality traits in guava (*Psidium guajava* L.)”. MSc Thesis. Punjab Agricultural University, Ludhiana, Punjab.

Singleton V L and Rossi J A. 1965. Colourimetry of total phenolics with phosphor molybdic phosphotungstic acid reagents. *American Journal of Enology and Viticulture* **16**(3): 144–58.

Thimmaiah S K. 1999. *Standard Methods of Bio-Chemical Analysis*. Kalyani Publishers.

Usman M, Samad W A, Fatima B and Shah M H. 2013. Pollen parent enhances fruit size and quality in intervarietal crosses in guava (*Psidium guajava* L.). *International Journal of Agriculture and Biology* **15**: 125–29.

Verma V K, Rymbai H, Deshmukh N A, Bhattacharjee B, Jha A K, Patel R K and Mishra V K. 2024. Genetic diversity and stability analysis of the improved cultivars of guava and their related species. *Scientia Horticulturae* **333**: 113260.