



Research Article

EVALUATION OF AVOCADO GERMPLASM FOR YIELD AND FRUIT CHARACTERS

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Abstract: Avocado (*Persia americana*) is one the most nutritious fruits native of tropical America. In India it was brought during first decade of nineteenth century. A few seedlings of their choice varieties were also occasionally brought from different countries by Missionaries and planted in several parts of humid tropical region of south India and hill stations like Kallar, Palni, Kodaikanal, Yercaud, Coorg etc. As of results lot of variability of avocado is available in these regions. In order to identify elite lines of avocado, several accessions were collected, planted and evaluated at ICAR-IIHR-CHES, Chettalli, Karnataka, India. The growth characteristic of 38 accessions of avocado revealed that the height of the plant ranged from 2.65 to 6.46 m. It was the highest in PA-VII-1 (6.46 m). The plant girth range from 32 to 81 cm it was the highest PA-XVI-1 (81cm) and the lowest in PA-II-2 (32 cm). The accessions PA-II-3, PA-III-1, PA-IV-1, PA-VII-1, PA-XIII-1, PA-PH-1 were found vigorous growth with plant height of more than 6 meter. The canopy spread was higher (>15.0 m²) in PA-XII-1 (15.79 m²), PA-XVI-1 (17.78 m²), and PA-PH-1 (17.67). The higher plant volume was recorded in PA-PH-1 (91.62 m³), PA-XVI-1 (79.50 m³), PA-X-3 (53.18 m³) and PA-XIII-1 (63.04 m³) and PA-XVI-4 (57.51). The number of fruits per plant were the highest in PA-XIII-1 (353.3 fruits) and the lowest in PA-VIII-2 (7 fruits). The fruit yield was highest in PA-XIII-1 (149.8 kg/plant) followed by PA-III-1 (115.36 kg). The fruit weight ranged from 122g to 871g. The fruit colour of all the accessions was light green at maturity. The pulp colour was light creamish yellow in all the accessions. The fruit shape varied from round to pear shape as the fruit shape index ranged from 0.985 to 1.541. The pulp content was the highest (81.46%) in PA-VII-1. The seed content ranged from 10.25 to 29.34 percent. The total soluble solids ranged from 3.6° Brix (PA-VIII-2) to 12.8° Brix (PA-Nursery-1). The ascorbic acid content ranges from 1 mg (PA-III-4) to 10.6 mg/100g (PA-XI-2). Over all the accessions, the accessions PA-III-1, PA-XIII-1, PA-II-1, PA-X-3 were found better with respect to fruit yield and fruit size.

Keywords: Avocado, Genotype, Growth, Fruit Character, Yield

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Introduction

Avocado (*Persia americana*) is a native of tropical America. Avocadi is heterozygous deplid species with 24 chromosomes numbers [1]. It is a cross-pollinating species, with outcrossing rates ranging from 74 to 96% [2]. These taxa are considered to be botanical varieties and include *P. americana* var. *drymifolia*, *P. americana* var. *guatemalensis*, and *P. americana* var. *americana*, which are commonly referred to as the Mexican, Guatemalan, and West Indian horticultural races, respectively. The three avocado races are cross-compatible and hybridization can occur between trees of different races when grown near each other [3]. Most commercial avocado cultivars are interracial hybrids developed from chance seedlings. Avocado was introduced in India during first decade of nineteenth century by American missionaries. The plants of all three species were introduced in many parts of humid tropical region of South India and hill stations like Kallar near The Nilgiris, Palni, Kodaikanal, Yercaud, Coorg. Due to outcrossing of these introduced varieties [4-7] lot of variability of avocado is available in the region with respect to tree vigour, fruit size shape, colour and biochemical properties [8-11]. Some of the varieties such as Fuerte, Pinkerton, Green and Hass were introduced in Sikkim later on. The purposes of this research were to evaluate and select accessions that produce good fruit characters, high content of fat and continual yield along the year. Taking into account the above this study was aimed to evaluate the physico-chemical characteristics of thirty-eight avocado accessions and to select the superior ones for various purposes

Materials and Methods

The avocado collections were made from different parts of Kodagu district of

Karnataka during the year 2000 through extensive surveys. The plants were planted in the field at a distance of 6x6m at the Research Farm of ICAR-IIHR-Central Horticultural Experiment Station (IIHR), Chettalli, Kodagu, Karnataka during 2001-02. Central Horticultural Experiment Station (IIHR), Chettalli, Karnataka is located at 12°26' N latitude and 75°57' E longitude at 890 m above sea level. It has humid tropical climate with annual rainfall of 150 cm. The soil is a deep, dark brown, well drained sandy loam to sandy clay loam with 28.5% clay content and pH of 5.70. The plant started to fruit in 6 year and yield stabilized from 10th year onwards. Thirty-eight collections were evaluated for 4 years for vegetative growth, flowering, fruiting and fruit characteristics. Plant height and canopy diameter were converted into plant spread and tree volume. Plant spread (sq m) was estimated using formula (Plant spread(N-S) X Plant Spread (E-W))/2. The Tree volume (cu.m) was calculated using formula: (tree spread X plant height) X 0.85. Ten mature fruits were harvested randomly from each accession to record observation on physico-chemical parameters. The fruits were washed with distilled water and the surface water was removed using blotting paper. The cleaned air-dried samples were used. The fruit weight, fruit length, fruit diameter was recorded using electric balance and digital vernier callipers. The fruit shape and fruit colours were recorded per standard fruit shape and colour charts. The fruits were cut and pulp colour was recorded. The fruits were kept for storage for one week at ambient temperature. The seed weight, pulp weight was recorded by cutting fruits. The total soluble solids (TSS) of ripe fruits were determined with Erma Hand Refractometer (0-32°Brix). The titratable acidity (%) and ascorbic acid content were estimated using procedures described by Ranganna [12].

Table-1 Growth and yield characteristics of avocado accession

Collections	Plant height (m)	Plant Girth(cm)	Plant spread (E-W)(m)	Plant spread (N-S) (m)	Tree spread(sq m)(E-W*N-S/2)	Tree Volume (m ³)(TS*Ht*0.85)	Tree shape Index (Ht/SP)	No. of fruits/tree	Fruit yield (Kg/tree)	Fruit yield (Kg/tree vol)
PA-I-3	3.80	42.20	3.30	3.19	5.26	17.00	1.17	66.50	20.74	1.22
PA-II-1	4.85	52.60	2.94	3.10	4.56	18.79	1.61	49.30	52.55	2.80
PA-II-2	3.13	32.00	1.98	2.14	2.12	5.64	1.52	12.00	9.08	1.61
PA-II-3	5.14	57.40	3.56	4.04	7.19	31.42	1.35	9.80	2.00	0.06
PA-II-4	2.65	33.90	1.91	2.39	2.28	5.14	1.23	14.50	5.64	1.10
PA-III-1	5.15	68.60	5.50	5.74	15.79	69.10	0.92	292.30	115.36	1.67
PA-III-2	4.26	65.40	3.34	3.35	5.59	20.26	1.27	196.70	15.25	0.75
PA-III-4	4.80	74.80	5.26	5.26	13.83	56.44	0.91	116.00	61.83	1.10
PA-IV-1	6.04	79.40	4.03	4.04	8.14	41.79	1.50	27.30	9.38	0.22
PA-V-1	4.95	65.80	4.33	4.59	9.94	41.81	1.11	48.30	14.01	0.34
PA-VI-1	4.53	63.00	4.94	4.45	10.99	42.32	0.96	52.30	23.74	0.56
PA-VI-2	5.26	68.20	4.71	4.81	11.33	50.65	1.11	37.00	11.06	0.22
PA-VI-4	4.11	64.60	3.73	4.15	7.74	27.04	1.04	62.00	24.37	0.90
PA-VII-1	6.46	63.80	4.08	3.73	7.61	41.78	1.65	239.50	57.18	1.37
PA-VII-2	4.66	59.60	3.80	3.95	7.51	29.73	1.20	41.80	7.73	0.26
PA-VII-3	4.38	45.60	3.84	3.66	7.03	26.16	1.17	59.00	29.62	1.13
PA-VII-4	5.11	57.30	3.94	4.73	9.32	40.47	1.18	180.00	54.81	1.35
PA-VIII-2	4.80	63.00	3.76	3.83	7.20	29.38	1.26	7.00	1.55	0.05
PA-IX-2	4.91	54.50	3.73	3.95	7.37	30.75	1.28	84.00	31.64	1.03
PA-IX-4	5.34	64.00	3.79	3.18	6.03	27.35	1.53	7.30	0.00	0.04
PA-X-2	4.48	62.50	4.54	5.64	12.8	48.75	0.88	47.50	17.28	0.35
PA-X-3	4.56	68.30	4.98	5.51	13.72	53.18	0.87	311.30	63.11	1.19
PA-X-4	4.30	43.60	3.88	3.68	7.14	26.09	1.14	56.50	16.15	0.62
PA-XI-1	5.18	59.30	3.81	3.11	5.92	26.09	1.50	74.50	32.98	1.26
PA-XI-2	4.28	53.60	3.36	3.11	5.22	19.01	1.32	59.80	15.58	0.82
PA-XI-4	3.96	51.00	3.73	3.00	5.60	18.83	1.18	133.50	60.61	3.22
PA-XII-1	3.95	53.30	3.78	3.54	6.69	22.46	1.08	36.30	11.87	0.53
PA-XIII-1	6.36	63.80	4.75	4.91	11.66	63.04	1.32	353.30	149.80	2.38
PA-XIII-2	4.08	59.00	3.84	4.19	8.04	27.90	1.02	34.30	10.29	0.37
PA-XIII-3	5.16	60.30	3.98	4.56	9.07	39.80	1.21	53.00	13.50	0.34
PA-XIII-4	5.25	60.00	4.29	4.73	10.15	45.28	1.16	166.5	65.47	1.45
PA-XVI-1	5.26	81.00	6.61	5.38	17.78	79.50	0.88	157.8	56.76	0.71
PA-XVI-2	5.01	61.50	3.73	3.23	6.02	25.65	1.44	58.00	18.31	0.71
PA-XVI-4	5.26	64.60	3.84	6.70	12.86	57.51	1.00	49.80	17.83	0.31
PA-XVII-2	4.85	49.90	3.16	0.92	1.45	5.99	2.38	7.50	2.51	0.42
PA-XVII-3	3.80	55.30	2.98	5.03	7.49	24.21	0.95	22.00	4.85	0.20
PANur-1	4.30	54.00	4.10	3.24	6.642	24.28	1.17	143.00	50.90	2.10
PA-PH-1	6.10	73.00	5.70	6.20	17.67	91.62	0.95	127.00	29.66	0.32
AV.	4.75	59.20	3.99	4.08	8.49	35.58	1.22	91.95	31.22	0.92
Max	6.46	81.00	6.61	6.70	17.78	91.62	2.38	353.3	149.80	3.22
Min	2.65	32.00	1.91	0.92	1.45	5.14	0.87	7.00	1.20	0.04
SD	0.80	10.72	0.91	1.17	3.92	19.52	0.29	88.8	31.84	0.76

Table-2 Correlation matrix of growth characteristics of avocado

Characters	Tree height	Tree girth	Tree Spread (E-W)	Tree Spread (N-S)	Tree Spread	Tree volume	Tree shape Index
Tree height	1	-	-	-	-	-	-
Tree girth	0.69	1	-	-	-	-	-
Tree Spread (E-W)	0.58	0.79	1	-	-	-	-
Tree Spread (N-S)	0.40	0.65	0.71	1	-	-	-
Tree Spread	0.49	0.74	0.91	0.91	1	-	-
Tree volume	0.65	0.76	0.9	0.86	0.97	1	-
Tree shape Index	0.16	-0.31	-0.51	-0.77	-0.69	-0.54	1

Data analysis

The data analysis was performed in R software. Principal component analysis was done using the 'pca' function [13].

Results and Discussion

Growth characteristics

The growth characteristics of the avocado collections revealed that there was lot of variation in the plant girth, plant height and canopy area. The growth characteristic of 38 accessions of avocado revealed that the height of the plant ranged from 2.65 to 6.46 m. It was the highest in PA-VII-1 (6.46 m). The accessions PA-XIII-1, PA-IV-1 and PA-PH-1 also were found more vigorous with more than 6 m plant height. The plant girth range from 32 to 81 cm it was the highest PA-XVI-1 (81cm) and the lowest in PA-II-2 (32 cm). The accession PA-VII-1 also recorded higher plant girth(79.4cm). Plant spread (East-West) ranged from 1.91 to 6.61m. The plant spread(North-South) ranged from 0.92m to 6.7m and it was more than 4 m in accessions like PA-III-1, PA-III-4, PA-X-2, PA-X-3 and PA-XVI-1. Canopy spread ranged from 1.45 m² to 17.78 m². The canopy spread was higher (>12m²) in PA-XVI-1(78.78 m²), PA-PH-1(17.68 m²), PA-XIII-1 (15.79m²), PA-III-4(13.93 m²), PA-XVI-4(12.86m²) and PA-X-2(12.80m²). The plant volume ranged from 5.14 m³ to 91.62 m³. The higher plant volume was recorded in PA-PH-1(91.62m³), PA-XVI-1(79.50m³), PA-III-1 (69.10m³), PA-XIII-1 (63.04m³). Lower plant value was recorded in accessions like PA-II-2 (5.64m³), PA-II-4 (5.12 m³) and PA-XVII-3(5.99m³; [Table-1]. Most of the accessions were semi spreading type with tree shape index between 1.0 to 1.5 but some accessions such as PA-II-4, PA-VI-1, PA-XVI-1, PA-XVII-3 were spreading type with tree shape index less than

1.0. The tree volume of some of the PA-PH-1(91.62m³), PA-XVI-1(79.50m³), PA-III-1 (69.10 m³), PA-XIII-1 (63.04m³) was higher than others collections. This difference may be due to parentage of these plants. The flowering time of different accessions was found in the month of February-March and October in all four years. The initiation of panicle emergence was started in the month of February and September and flowering started almost after 2-3 week later [9]. The flowering continued for almost 3-4 weeks in all the accessions.

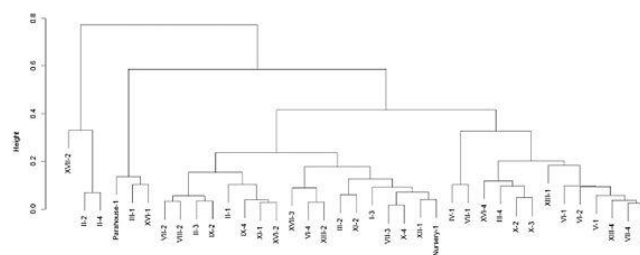


Fig-1 The grouping of Avocado accessions on the basis of growth characters

Cluster analysis

Clustering of the all the thirty eight accessions were done based on the growth characters. Two major clusters were observed, these were consisting of 2 and 36 accessions, respectively. The first cluster consisted of the 2 accessions and cluster 2 consisted 5 sub clusters. The minimum distance was found between the accessions like PA-X-4 and PA-XII-3 while the maximum distance was observed between accessions like PA-PH-1 and PA-II-2 [Fig-1].

Table-4 Correlation matrix of yield and fruit characteristics of avocado

The biplot analysis of components based on PC1 and PC2 has scattered accessions in all 4 quarters of the biplot. Projections of the variables on the factor plane with individual genotypes revealed diversity among them in terms of variables measured. [Fig-2]. The correlation matrix shows that the plant height was positively correlated with Plant girth, plant spread, tree spread and tree volume [Table-2].

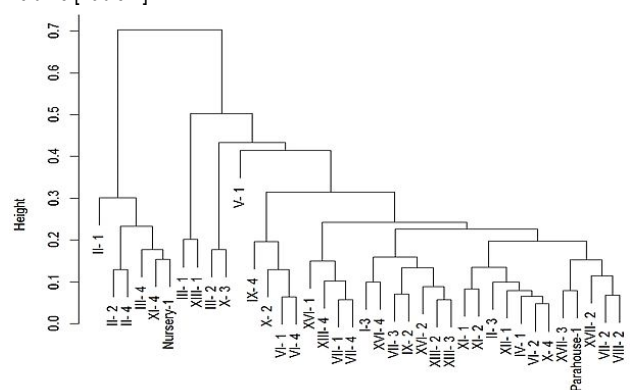


Fig-3 The grouping of Avocado accessions on the basis of yield characters

Characterisation for fruit traits and evaluation for yield

The fruits started maturing in the month of April -June and August- October. The fruits did not mature at one time and several picking were done continuously as per maturity of the fruit. There was due to long flowering period of different collections. The number of fruits per tree ranged from 7.0 to 353.3. It was highest in PA-XIII-1 and lowest in PA-VII-2. The accessions like PA-XIII-1 (353.3 fruits), PA-X-3 (311.3 fruits) and PA-III-1 (292.3 fruits) produced higher number of fruits per tree. The lowest number of fruits were produced by PA-VIII-2 (7 fruits), PA-IX-4 (7.3 fruits) and PA-XVII-2 (7.5 fruits). The fruit yield was the highest in PA-XIII-1 (149.8 kg/tree) followed by PA-III-1 (115.36 kg), PA-X-3 (63.11 kg) and PA-II-1 (52.55 kg). The yield per unit plant volume ranged from 0.92 kg/m³ to 3.22 kg/m³. It was the highest in PA-XI-4 (3.22 kg/m³) followed by PA-XIII-1 (2.38 kg/m³) and PA-Nur-1 (2.10 kg/m³). Some of the vigorously growing accession viz. PA-PARA-1, PA-III-4, PA-XVI-1 and PA-X-2 produced less fruits for unit plant volume [Table-1]. It seems the vigorous accessions were utilized more photosynthates for their vegetative growth and failed to produce more number of fruits. Thus, the conversion into fruits was lower. The average fruit weight ranged from 137.88 g to 871.0 g. The fruit weight was the highest in accession PA-II-1 (871.0g). The other accessions with higher fruit weight were PA-II-1 (681.3g), PA-IX-4 (596.4g), PA-III-4 (563.8g), PA-X-2 (545.8g) and PA-II-4 (528.8g). There was no relationship between vigour of the plant and fruit weight. The fruit length and fruit diameter were to the tune of fruit weight of all the accessions. The fruit colour of all the accessions was light green at the time of maturity. The pulp colour was light creamish yellow in all the accessions. The fruit shape varied from flat round to pear shaped. The fruit shape index varied from 0.726 to 1.524. This shows that there was large variability among the accessions with respect to fruit shape. The pulp content was higher in big fruited accessions. It was the highest 81.46 % in PA-VII-1 and lowest in PA-III-2 (56.72%). The accessions PA-II-1, PA-V-1, PA-XII-1 and PA-VII-3 were found to have more than 80 % pulp content. The rind content ranged from 5.11 % to 14.17 percent. The accession PA-XVII-1 had the highest rind content (14.17%) and it was lowest in PA-II-1 (5.11 %). These accessions had thicker rind which may be a good character suitable for distant transport and higher storage life. The seed content ranged from 10.25 % to 29.33 percent. It was the lowest in PA-XIII-2. The accessions PA-VII-1, PA-VII-3, PA-IX-2, PA-IX-4, PA-XIII-1, PA-XIII-3, PA-XIII-4 were found to have less than 12 percent seed content. Higher seed content was observed in accessions such as PA-II-3 (29.37%), PA-III-2 (29.37%) and PA-XI-4 (26.13%). In general, small fruit accession had higher seed content [Table-3]. Rich diversity in physico-chemical characteristics of the fruits of different accessions indicated the presence of genetic diversity in avocado accessions maintained at field gene bank in IIHR-CHES, Chettalli. Variations in the germplasm of avocado with regard to physico-chemical characters and fruit yield corroborates the earlier findings of Juma *et al* (2020) [3] in Tanzania and high degree of genotypic and phenotypic variability reported by Sánchez-González *et al.*, (2020) [14], Tripathi *et al.*, (2020) [11], Borrone *et al.*, (2008) [2] and Senthil kumar, *et al.*, (2022) [15].

Cluster analysis

Clustering of the 38 accessions was done based on the yield and yield contributing characteristics. Two major clusters were observed consisting of 6 and 32 accessions, respectively. The first cluster consisted of the six accessions. Cluster 2 consisted of 6 sub clusters. Minimum distance was observed between PA-X-4 and PA-VI-2 while maximum distance was found between PA-X-3 and PA-II-1 [Fig-3].

Principal Component Analysis

The biplot analysis of components based on PC1 and PC2 has scattered accessions in all 4 quarters of the biplot. Projections of the variables on the factor plane with individual genotypes revealed diversity among them in terms of variables measured. [Fig-4]. The correlation matrix shows that the plant was positively correlated with fruit weight was highly co-related with pulp content, seed content, rind weight, fruit length and fruit diameter [Table-4].

Fruit biochemical analysis

It was observed that the fruit of all the accessions of avocado were not ripped at the time of harvesting. The total soluble solids ranged from 3.6° Brix to 12.8° Brix. It was highest in PA-Nur-1 and lowest in PA-VIII-2. Higher TSS (>10° Brix) was recorded in accessions such as PA-III-2, PA-XVII-2, PA-XVII-3. There was no relation observed between Total Soluble solids and fruit size. The vitamin - C content ranged from 1 mg/100g pulp to 10.6 mg/100g pulp. Higher vitamin-C content (>9 mg/100g pulp) was recorded in accessions such as PA-IV-1, PA-V-1, PA-VII-2, qPA-IX-2 and PA-XI-2. There was no relation observed between vitamin C content and fruit size [Table-3].

Conclusion

It was observed that based on the performance of the avocado accessions over a period of four years for growth, fruit yield and other desirable attributes studied, the accessions PA-III-1, PA-XIII-1, PA-II-1, PA-X-3 were found better with respect to fruit yield and fruit size over all the accessions.

Application of research: The selected lines may be used as varieties for cultivation after identification and release.

Research Category: Horticulture

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Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Kodagu District of Karnataka

Cultivar / Variety / Breed name: Avocado (*Persia americana*)

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

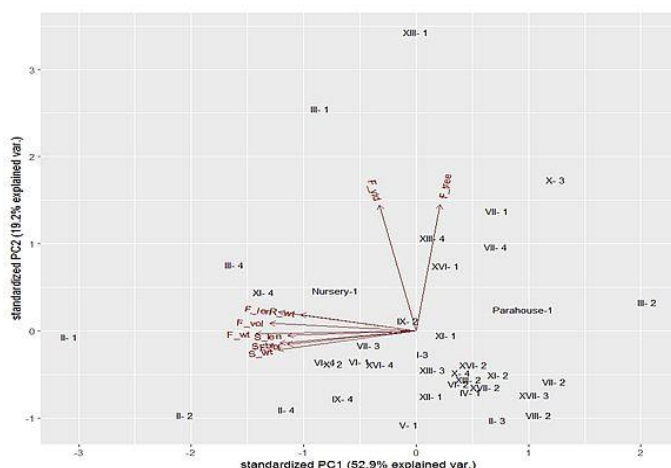


Fig-4 The Standardised PC2 of avocado accessions on basis of yield characters

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