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RESEARCH ARTICLE

PHENOLOGICAL AND POMOLOGICAL CHARACTERIZATION AND ELITE GERMPLASM SCREENING IN SPECIES OF *PASSIFLORA* L. (PASSIFLORACEAE) FROM KERALA

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ABSTRACT

Passiflora L. belonging to the family Passifloraceae includes more than 465 species, of which 12 are cultivated with worldwide distribution. A breeding program of the genus for developing new cultivars has therefore become much important, and diversity analysis has become a necessity to screen the elite germplasm. The present study thus aims at determining the genetic variability in the genus *Passiflora* with a view to identify the superior germplasm for the improvement of the fruit crop. Eight wild and two cultivated species of *Passiflora* L. from the state of Kerala were analysed for the phenological (onset of flowering, end of flowering, flowering period and harvesting date) and pomological (fruit size, fruit color, fruit juice aroma, and fruit juice taste) characters. Statistical analysis of the qualitative and quantitative traits revealed wide variations in the size, shape and color of the fruits and in the taste and content of juice. Phenological and pomological differentiation suggests the inter and intra specific variations in the wild and the cultivated species of *Passiflora* L. It was observed that the number of flowering times was higher (three or four times per year) in the varieties of the wild species, *P.foetida*. The study identified the cultivar, *Passiflora edulis* cv. *Panamared* and the wild species, P.subpeltata and *P.foetida* as the elite germplasm for the improvement of this fruit crop.

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INTRODUCTION

Passiflora L., a large and wide genus, belonging to the family Passifloraceae consists of approximately 465 species, distributed in the tropical and subtropical regions. Though the passion flower is a native to Brazil,it is widely cultivated in frost free areas in countries including India and Sree Lanka (Shivanna, 2012; Kishore *et al*., 2010). According to Ulmer and MacDougal (2004), South America is the home for most of the *Passiflora* species. It is an allogamous genus mainly on account of its floral morphology and sporophytic self-incompatibility (Souza *et al*., 2010).Passion vines are evergreen climbers grown for their beautiful flowers and edible fruits (Vanderplank, 1996). The flowers are hermaphrodite and are located in the leaf axils. Each flower consists of five petals, five sepals and five stamens. Ovaries borne over the androgynophore possess of three styles united at base and with three bifurcated stigmas. The fruits are indehiscent oval or round capsules containing numerous small black or brown seeds that are enclosed in a yellow, orange or white aromatic juicy pulp which has an acidic but pleasant flavor (Kamaldeep *et al*., 2004; Rodriguez-Amaya, 2003; Wohlmuth *et al*., 2010). The fruits are used to process delicious food items like juices, sweets, jellies, ice creams and liquors. Variations were observed in the fruits of *Passiflora* between and within the species. Of these the phenological and pomological features can be used to assess the genetic variability and for the screening of elite germplasm. Phenological and pomological characters in the analysis of genetic variability were suggested by Ganji *et al*., (2011); Son (2010) and Gunes (2003) in cultivars of plum. Hakan andYasar (2011) selected superior genotype in walnut by way of phenological and pomological characterization. In *Passiflora,* phenological studies were limited to floral biology (Kundan *et al*., 2010) and anomalous flower development (Shawan *et al*., 2006). Shivanna (2012) studied the effect of pollinators in the fruit settings of *P.edulis flavicarpa*. Ataide *et al*., (2012) reported varied flowering behavior in the genus. However, pomological studies were limited to the nature and extent of the physicochemical composition of the fruits in *P.edulis* (Pruthi *et al.,* 1959). Detailed information on flowering behavior, an important breeding aspect for increasing fruit set in passion fruits, is not

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readily available, especially in the wild species of *Passiflora*. The present study unveils the phenological and pomological characterization of the wild and cultivated species of *Passiflora* L. that have of immense relevance to future breeding programs.

MATERIALS AND METHODS

Plant materials and study area

As part of the investigations, Phenological characters of eight wild taxa under six species (*P. edulis* var.*edulis, P.foetida* var.*foetida, P.foetida* var.*hispida, P.foetida* var.*gossippifolia, P.quadrangularis, P.subpeltata, P.ligularis, P.leschenaultii* and *P.tripartitia)* and two cultivars of *P.edulis* viz, *P.edulis* f.*flavicarpa* and *P.edulis* cv.*panamared* were studied using randomized pattern. The species were planted under uniform environmental conditions using similar field management practices. The experiment was conducted at the Department of Botany, University of Kerala, Kariavattom, Kerala, India, during 2011-2014.The flowering time and the amount of yield were first recorded in the 2nd year after planting. Observations on phenological and pomological characters (qualitative and quantitative) were scored for five plants each, randomly selected from each population. The details of the taxa collected and the place of collection with their geographical status are provided in Table 1.

Phenotypic variation

Phenological characteristics such as onset of flowering, end of flowering, flowering period and duration of harvesting time were determined according to Maliga (1980). Onset of flowering was recorded when at least 5% of flower buds had bloomed, and the end of flowering was determined when 90% of the flower buds had bloomed and started withering. Harvesting date was determined as the day when the fruits were sufficiently colored and soft for eating (Tzoner and Yamaguchi, 1999; Funt, 1998). Pomological studies based on qualitative (fruit size, fruit color, fruit juice aroma, fruit juice color, fruit juice taste) and quantitative (fruit length, fruit diameter, weight of the fruit, number of seeds) morphological characters were also carried out during the period. Measurements of each fruit were based on 15 replicates and the mean values were used. Fruit dimensions (length and width) were measured using a digital caliper. Weight for fruit was measured using electronic balance with 0.01 g precision. Also, some characteristics such as shape, color, and size of the fruits, color, taste and aroma of the fruit juice were determined based on rating and coding (Table 2).

Statistical analysis

Data on morphological variables were statistically analyzed. Single factor analysis of variance (one-way ANOVA) with post hoc Duncan's multiple range test ($P<0.05$) (Gomez and Gomez, 1983), was used to compare the mean values by the statistical software SPSS 7.5(SPSS,Inc.,Chicago,Illinois,USA). Discriminant analysis (DA) based on linear combinations of the predicted variables was used to find out the maximum separation between the studied *Passiflora* species by XLSTAT (Kovach Computing Service 2013) based on the means of the qualitative and quantitative parameters. Multivariate relationships among the cultivars were attempted through Principal Component Analysis (PCA) using a correlation matrix derived from the significant characters. The correlation studies were conducted by determining Pearson's correlation coefficient (Best and Roberts, 1975; Hollander and Wolfe, 1973). Dendrogram based on Agglomerative Hierarchical Clustering method (Ward, 1963) was followed by the computer program MVSP Mega 3.5.

RESULTS

Flower morphology and Phenology

Phenological characteristics of the investigated taxa are shown in Table 3. All the species investigated, including the wild and cultivated ones in *Passiflora* L. had the same number of petals (5), sepals (5), and stamens (5). The stamens facing towards the stigma before opening turned downwards and showed extrose condition while opening. It was observed that the species differed with regard to the time of anthesis and accordingly they were classified in to four groups: flowers opening before 6am (*P.foetida* var.*foetida, P.foetida* var.*hispida,* & *P.foetida* var.*gossippifolia*), between 7am-8am (*P.subpeltata*), 9am-10am (*p.quadrangularis, P.ligularis,* & *P.leshnoultii*) and 12-12.30 pm (*P.edulis* var. *edulis, P. edulis* f. *flavicarpa* & *P.edulis* cv. *Panamared*) (Table 2). The flowering time also varied from species to species. Flowering was observed thrice per year (January, May, and November) in *P.foetida* var.*foetida, P.foetida* var. *hispida, P.foetida* var. *gossippifolia* & *P.subpeltata* , whereas in *P.edulis* cv. *Panamared* it was twice a year (May and November). The remaining species *p.quadrangularis, P.ligularis* exhibited flowering once in a year ie, in the month of March except in *P.leshnoultii* and *P.edulis* var. *edulis* which was in July and, had prolonged for three to four months.

Differences were observed in the harvesting time among the species (Table 3). Generally the fruits ripened within 85 to 155 days. Early maturity was observed (85 days) in *P.subpeltata* compared to the other taxa. Wild varieties of *P.foetida* (*P.foetida* var.*foetida, P.foetida* var.*hispida,* & *P.foetida* var.*gossippifolia*) ripened within 90 days, while for the wild and cultivated varieties of *P. edulis*(*P.edulis* var. *edulis, P. edulis* f. *flavicarpa* & *P.edulis* cv. *Panamared*), the period was 110-120 days. Late maturity was observed in P.ligularis *(*125-130 days).

Pomological characteristics

Pomological characters, both qualitative and quantitative, of the species of *Passiflora* are given in Table 4. Variations at the inter specific and intra specific levels were evident from the qualitative characteristics of the fruits (Fig.1) studied. The fruits were yellow in color in *P.foetida* varieties, *P.edulis* f. *flavicarpa*, *P.subpeltata*,and in *P.ligularis* while in *P.edulis* var. *edulis*, *P.edulis* cv.*panamared* and *P. lesnoultii* , the color was purple. But *P. quandrangularis* was distinct by the presence of white colored fruits and the fruit weight ranged from 2±0.022gm (*P.foetida* var.*foetida*) to 95±0.031 gm (*P.quadrangularis*).

Table 1. Wild and cultivated species of *Passiflora* with their geographical distribution

Sl.no	Name of Taxon	Status	Place of collection	Latitude/Longitude	Altitude
1	*P.edulis* var. *edulis*	Variety	Idukki	10º05.322'N/77º11.210'E	717m
2	*P. edulis* f. *flavicarpa*	Forma	Trivandrum	$08^0$26.522'N/$076^0$40.984'E	17 m
3	*P.edulis* cv. *Panamared*	Cultivar	Trivandrum	$08^0$26.522'N/$076^0$40.984'E	17 m
4	*P.foetida* var.*foetida*	Variety	Kollam	$08^0$90.82'N/$077^0$05.55'E	45m
5	*P.foetida* var.*hispida*	Variety	Alappuzha	$09^0$18.906'N/$076^0$23.347'E	47 m
6	*P.foetida* var.*gossippifolia*	Variety	Trivandrum	$08^0$26.522'N/$076^0$40.984'E	17 m
7	*p.quadrangularis*	Species	Idukki	10º05.322'N/77º11.210'E	717m
8	*P.subpeltata*	Species	Pathanamthitta	$09^0$16.982'N/$076^0$46.158'E	18m
9	*P.ligularis*	Species	Idukki	10º05.322'N/77º11.210'E	717m
10	*P.leshnoultii*	species	Idukki	10º05.322'N/77º11.210'E	717m

Table 2. Phenological characteristics of the wild and cultivated species of *Passiflora*

Name of the Taxa	Sepal No	Petal No.	Stamen No.	Type of style	Position of stigma to anthers	Time of flowering	Onset of flowering	End of flowering	Flowering period (month)
P.edulis var. *edulis*	5	5	5	Strongly curved	Facing towards the stigma before opening	12-1.30	April	September	4
P. edulis f. *flavicarpa*	5	5	5	straight	Facing towards the stigma before opening	11-12	November	March	4
P.edulis cv. *Panamared*	5	5	5	Strongly curved	Facing towards the stigma before opening	11-12	May, November	August,march	3,4
P.foetida var.*foetida*	5	5	5	partially curved	Facing away from the stigma before opening	Before 6'clock (am)	January, May,November	March, August,January	3,4,4
P.foetida var.*hispida*	5	5	5	straight	Facing away from the stigma before opening	Before 6'clock(am)	January, May,November	March, August,January	3,4,4
P.foetida var.*gossippifolia*	5	5	5	Strongly curved	Facing away from the stigma before opening	Before 6'clock(am)	January, May,November	March, August,January	3,4,4
p.quadrangularis	5	5	5	Partially curved	Facing towards the stigma before opening	9 am-10am	July	November	5
P.subpeltata	5	5	5	Strongly curved	Facing away from the stigma before opening	7am-8am	January, May, November	March, August,March	3,4,4
P.ligularis	5	5	5	Strongly curved	Facing away from the stigma before opening	9 am-10am	April	November	4
P.leshnoultii	5	5	5	Strongly curved	Facing away from the stigma before opening	9am-10am	March	November	4

Table 3. Harvesting time of the 10 *Passiflora taxa*

Name of the Taxa	Ripening time	Harvest time
P.edulis var. *edulis*	120	First decades of march onwards
P. edulis f. *flavicarpa*	120	First decade of march onwards
P.edulis cv. *Panamared*	110	Second decade of November onwards and second decade of march onwards
P.foetida var.*foetida*	90	Second decade of November onwards and second decade of march onwards, and 1st decade of January onwards.
P.foetida var.*hispida*	90	Second decade of November onwards and second decade of march onwards, and 1st decade of January onwards.
P.foetida var.*gossippifolia*	90	Second decade of November onwards and second decade of march onwards, and 1st decade of January onwards.
p.quadrangularis	155	First decade of November onwards.
P.subpeltata	85	Second decade of November onwards and second decade of march onwards, and 1st decade of January onwards.
P.ligularis	125	First decade of July onwards.
P.leshnoultii	95	First decade of July onwards.

Table 4. Qualitative &quantitative characteristics of the fruits of *Passiflora* species

Name of the Taxa	Fruit size	Fruit color	Fruit juice aroma	Fruir juice color	Fruit juice taste	Fruit length (cm)	Fruit width(cm)	Weight of the fruit (g)	No. of seeds	Amount of fruit juice (mL)
P.edulis var. *edulis*	Medium	Purple	Pleasant smell	Orange	Sour	7.8±0.02^{d}	6.5±0.34^{e}	15±0.023^{c}	27±0.03^{d}	5±0.02^{ab}
P. edulis f. *flavicarpa*	Medium	Lemon yellow	Pleasant smell	Yellow	Sour	6.8±0.02^{c}	5.8±0.12^{d}	20±0.024^{d}	35±0.02^{f}	11±0.02^{c}
P.edulis cv. *Panamared*	Medium	Brown	Pleasant smell	Reddish orange	Sour with sweet	9.5±0.032^{c}	0.9±0.02^{cd}	26±0.021^{e}	68±0.021^{f}	19±0.02^{d}
P.foetida var.*foetida*	Small	Yellow	Light smell	White	sweet	0.8±0.02^{a}	0.4±0.02^{a}	2±0.022^{a}	6±0.402^{ab}	0.5±0.02^{a}
P.foetida var.*hispida*	Small	Yellow	Light smell	White	Sweet	1.2±0.12^{a}	0.8±0.02^{a}	3.3±0.032^{a}	8±0.023^{ab}	0.4±0.02^{a}
P.foetida var.*gossippifolia*	Small	yellow	Light smell	White	Sweet	1±0.03^{a}	0.7±0.02^{a}	2.9±0.033^{a}	4±0.022^{a}	0.5±0.02^{a}
p.quadrangularis	Large	Cremish white	Absent	White	Sweet	25±0.02^{e}	9±0.03^{f}	95±0.031^{f}	35±0.02^{d}	10±0.02^{c}
P.subpeltata	Medium	Yellow	Absent	White	Sweet	5±0.03^{c}	4±0.01^{c}	4±0.02^{a}	18±0.02^{c}	8±0.02b^{c}
P.ligularis	Medium	Yellow with red dots	Absent	white	Sweet	9±0.023^{f}	6±0.01^{e}	25±0.02^{e}	56±0.02^{g}	15±0.02^{d}
P.leshnoultii	Small	Purple	Absent	White	Sweet	3±0.012^{b}	2±0.02^{b}	6±0.02^{b}	9±0.02^{b}	1±0.02^{abc}

Table 5. Principal component of quantitative and qualitative traits of *Passiflora* species

Characters	PC1	PC2	PC3	PC4	PC5
Fruit shape	-2.506	0.257	-0.493	-0.182	-0.148
Fruit color	-2.513	0.308	-0.424	-0.347	-0.296
Fruit juice aroma	-1.708	-0.433	0.170	-0.064	0.149
Fruit juice color	-0.334	-1.631	1.215	0.192	-0.039
Fruit juice taste	-1.147	-1.045	0.701	0.026	-0.075
Fruit length	-0.389	0.547	-0.116	0.026	0.422
Fruit width	-1.053	0.314	-0.484	-0.089	0.307
Fruit weight	2.718	1.963	1.645	0.048	-0.113
Number ofseeds	7.479	-0.749	-0.877	-0.167	-0.035
Average amount of fuit juice	-0.547	0.467	-1.337	0.556	-0.171
Eigenvalue	8.183	0.913	0.793	0.054	0.045
Variability (%)	81.827	9.131	7.930	0.543	0.455
Cumulative %	81.827	90.958	98.887	99.430	99.885

Table 6. Eigen values and corresponding values of percentage of variance for each component. The table shows the contribution of each factor to the percentages of variability detected in the observation

	F1	F2	F3	F4	F5	F6	F7	F8	F9
Eigenvalue	6.241	3.027	1.110	0.292	0.244	0.049	0.035	0.001	0.000
Variability (%)	56.740	27.521	10.087	2.655	2.220	0.446	0.320	0.009	0.001
Cumulative %	56.740	84.261	94.348	97.003	99.224	99.669	99.990	99.999	100.000

Table 7 .Pearson's correlation matrix between the different characters in *Passiflora* species. With the threshold of risk of 5%

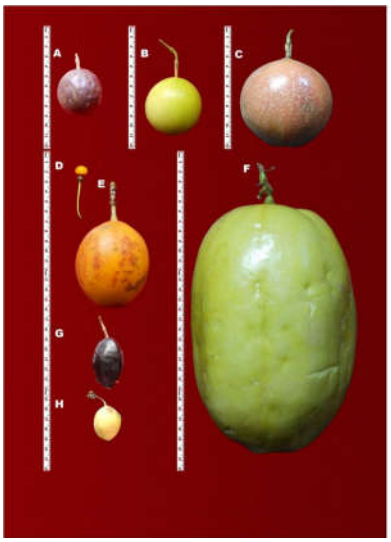
Variables	Fruit shape	Fruit color	Fruit juice aroma	Fruit juice color	Fruit juice taste	Fruit length	Fruit width	Fruit weight	Number ofseeds	Average amount of fuit juice
Fruit shape	1									
Fruit color	0.982	1								
Fruit juice aroma	0.965	0.983	1							
Fruit juice color	0.721	0.738	0.787	1						
Fruit juice taste	0.832	0.835	0.865	0.982	1					
Fruit length	0.660	0.669	0.661	0.933	0.922	1				
Fruit width	0.658	0.655	0.513	0.315	0.448	0.511	1			
Fruit weight	0.872	0.899	0.947	0.779	0.818	0.608	0.291	1		
Number of seeds	0.969	0.986	0.825	0.797	0.877	0.686	0.560	0.996	1	
Average amount of fuit juice	0.904	0.892	0.870	0.886	0.949	0.893	0.665	0.789	0.891	1

Values in bold are different from 0 with a significance level alpha=0.05

Table 8. The statistics of the whisker and box plot of the quantitative traits

Statistic	Fruit Length	Fruit Width	Weight of the fruit	Number of seeds	Average amount of fruit juice
Minimum	0.800	0.400	2.000	4.000	0.400
Maximum	25.000	9.000	95.000	68.000	19.000
1st Quartile	1.650	1.400	3.475	8.250	0.625
Median	5.900	5.800	10.500	22.500	6.500
3rd Quartile	8.700	7.750	23.750	35.000	10.750
Mean	6.910	4.836	19.920	26.600	7.040
Variance (n-1)	51.437	11.889	784.248	487.156	44.672
Standard deviation (n-1)	7.172	3.448	28.004	22.072	6.684
Minimum	0.800	0.400	2.000	4.000	0.400

Considerable variations were also observed in fruit length, fruit diameter, number of seeds, and in the amount of fruit juice among the wild and cultivated species of *Passiflora*, viz, *P.foetida* and *P. edulis* . The quantity of fruit juice was high in *P.edulis* cv.*panamared* (19 mL) followed by *P.ligularis* (15 mL). ANOVA using the mean revealed significant variations at the $P<0.05$ level (Table 4). Principal Component Analysis revealed two principal components PC1 and PC2, based on fruit morphological traits. 90% of the variations were observed in the first two Principal components (Table 5).



A. P.edulis f.flavicarpa,
B. P.edulis var.edulis
C. P.edulis cv.panamared,
D. P.foetida var.foetida,
E. P.Ligularis,
F. P.Quadrangularis
G. P.Subpeltata,
H. P.leshnoultii,

Fig.1. The morphological variation of the *Passiflora* fruit

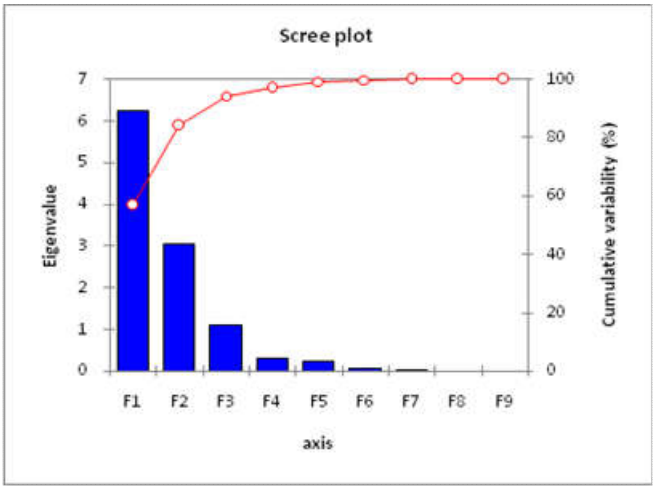


Fig.2. A Scree plot showing the relative eigenvalues for the principal components generated for the measured variables

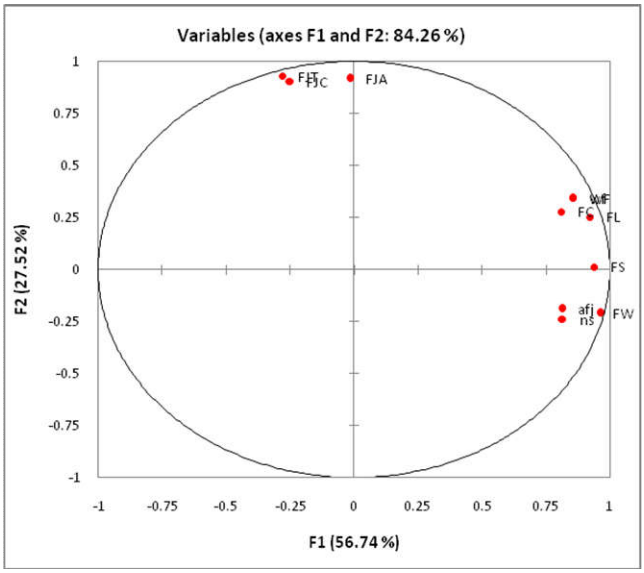


Fig 3. PCA analysis in the observed characters among the studied taxa

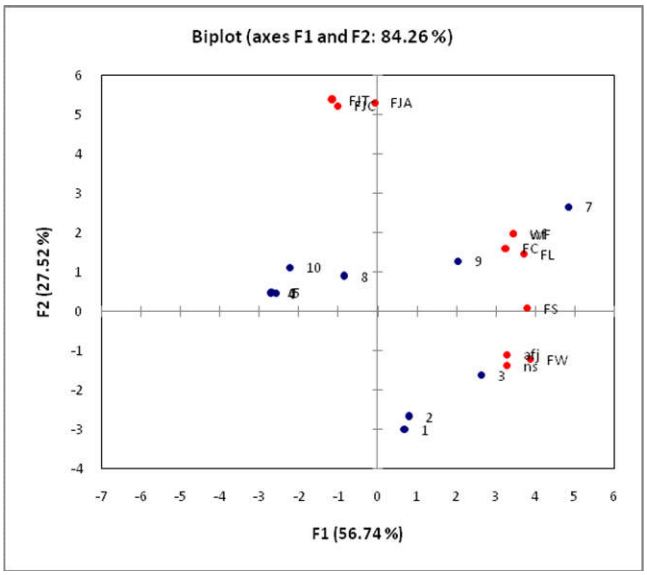


Fig. 4. The biplot generated by Principal component analysis of the studied morphological traits

The fruit weight and number of seeds had strong positive charge, while fruit shape, fruit color, fruit juice aroma, taste, fruit diameter and average amount of fruit juice showed strong negative charges in the first principal component, that explained 81 % of total variation.

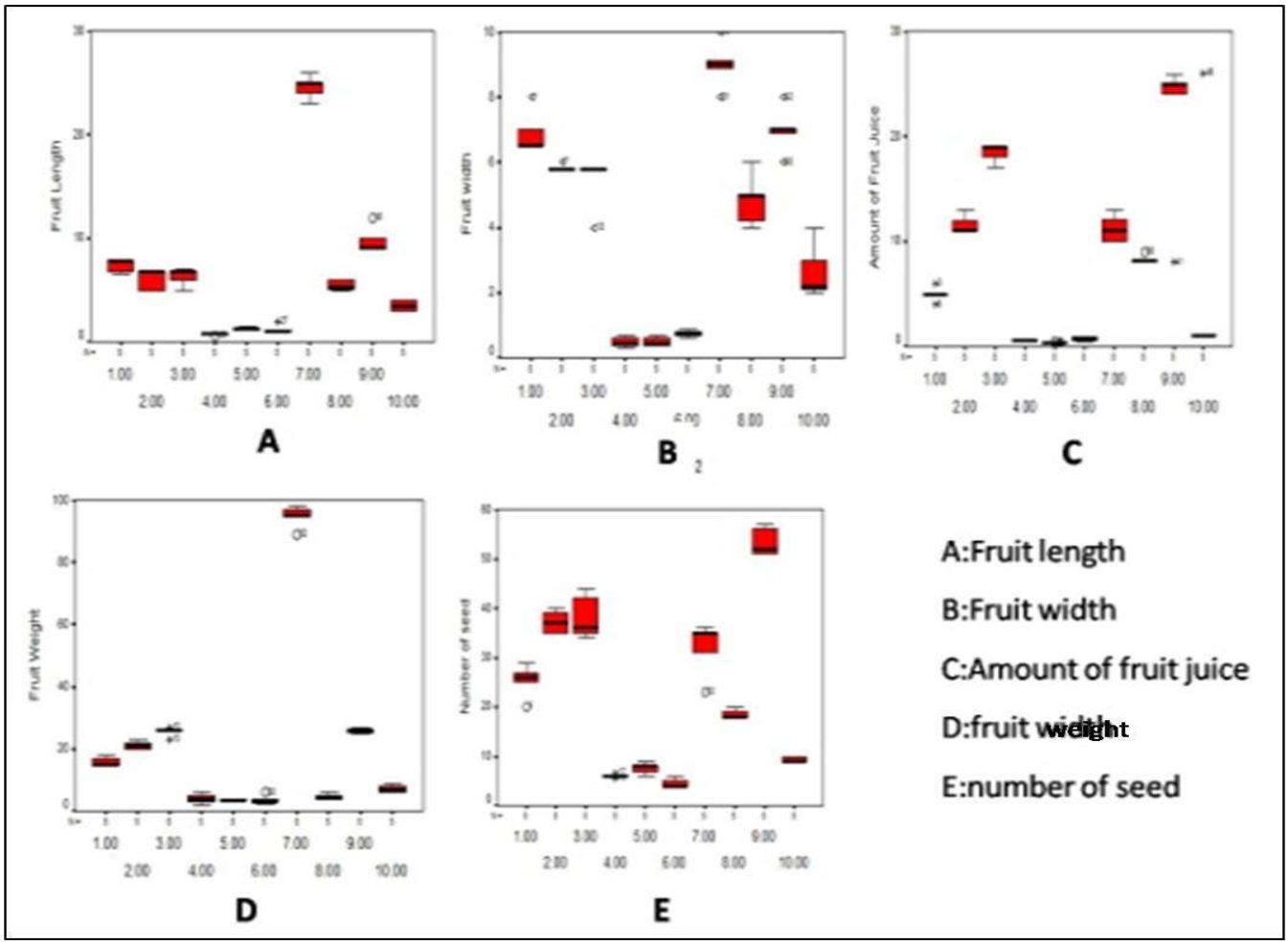


Fig. 5. Whisker and box plot generated by XLSTAT 2003. The boxes represent the inter quartile range and the solid line in the box is the median , and the circles are the outliers

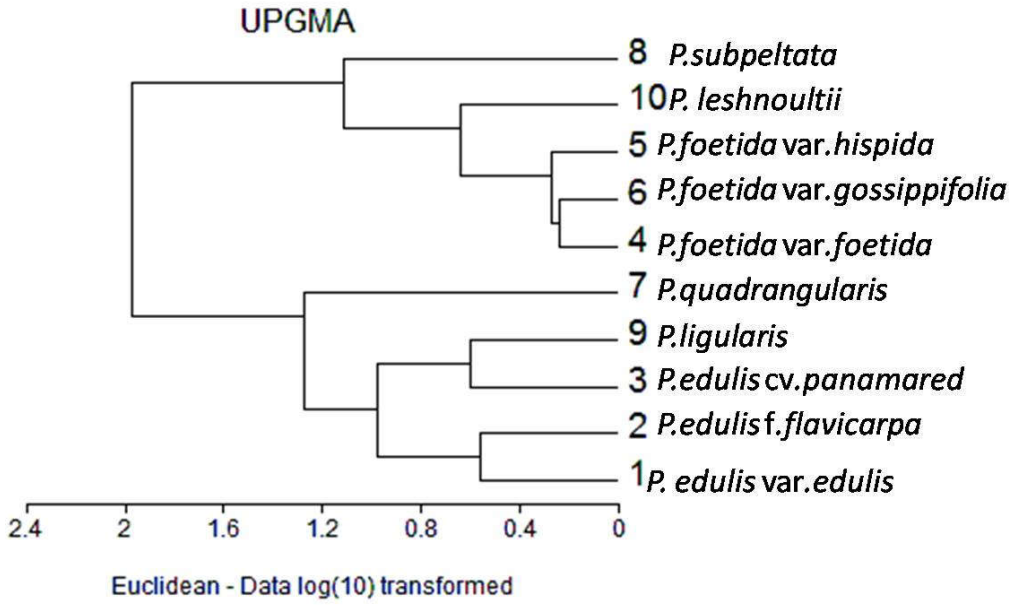


Fig. 6. Dendrogram generated by using morphological characters

The second principal component, explained 9 % of the negative charges exhibited for characters like fruit juice color, fruit juice taste, and number of seeds, whereas, fruit length and fruit weight showed strong positive charges. Factor analysis showed that the first two factors (Table.6) with Eigenvalues greater than 2, accounted for 85% of the total variation. The residual 15% of the variation was contributed by the remaining seven components and is reflected in the Screeplot (Fig.2). The analysis of the plot revealed that the first two factors contributed much to the variability. It was observed that the total variation among the taxa was 84.26% and the variability of PC1 and PC2 was 56.74% and 27.52% respectively (Fig.3). The first two principal componets in the biplot generated from the PCA explained cumulative variability at 84.26% and the pomological traits were grouped in to 4 main clusters (Fig.4).

The correlation among the first cluster was associated with traits like fruit juice aroma, fruit juice color, fruit juice taste, whereas the second cluster comprised of traits like fruit weight, fruit length, and fruit color. But the character, fruit shape solely formed the third cluster and the average amount of fruit juice, number of seeds and fruit diameter formed the fourth cluster. It was obsedved that the taste of the fruit juice was highly correlated to fruit juice color meanwhile the fruit color was inversely correlated to average amount of fruit juice. Banu *et al*., (2009) reported the same phenomenon in passion fruits in Bangladesh. Blooming patterns of the wild varieties of *P. foetida twice* or thrice in a year suggested the influence of climatic factors like temperature and humidity in the flowering of the species. Miller-Rushing and Inouye (2009), Crimmins *et al*. (2009), Inouye (2008), Crimmins *et al*. (2010) have opined that the phenological responses of flowering plants are closely related to the variation in temperature and altitude. Reports by Soeimani *et al*. (2014) and Reni (2014) speaks of the influence of temperature in the fruit morphological traits in *Populus euphratic and Baccaurea dulcis* respectively. Dearth of flowering in *P.edulis* var. *edulis*, *P.ligularis, P. subpletata and P.leshnoultii* in the experimental garden of the Department of Botany, also supports the above view. Pearson correlation of the pomological traits revealed high positive correlation (Table 7) between fruit shape and fruit color and in the number of seeds (0.969) and low correlation was assessed between fruit shape and fruit length (0.660). It was observed that the correlation between fruit juice color and fruit diameter was the least (0.315), while with fruit weight and the number of seeds it was highly correlated (0.966). The Box and Whisker plot developed to estimate the frequency distribution of the quantitative characters, such as fruit length, fruit diameter, amount of fruit juice, and number of seeds among the wild and cultivated species of *Passiflora* is shown in Fig.5 and Table 8. It was noted that approximately 99% of the data contributed inside the whiskers. The data outside the whiskers are indicated by vertical lines (the lines extending from the top and bottom of the boxes). The median (22.5%) and average (26.6%) numbers of the seeds were significantly higher ($P<0.001$) than that of the other traits. The median of the fruit diameter among the species of *Passiflora* was, 5.8% and average (4.8%) was significantly lower ($P<0.001$) than that of the other pomological quantitative traits. UPGMA dendrogram based on pomological characters revealed two principal clusters (Fig.6) at an Euclidean distance of 2. At high similarity level the first principal cluster included, *P.ligularis and P.quadrangularis* and the accessions of *P.edulis*. The varieties of *P.foetida* together formed the second cluster along with *P.subpeltata* and *P.leshnoultii*. The cultivated variety *P.edulis cv.panamared* and the wild species *P.ligularis* were clustered together taking in to account their size and taste of fruit juice at an Euclidian distance of 0.5. However, the *P.edulis cv.panamared* was kept apart from the wild varieties.

DISCUSSION

Phenological characteristics of the investigated taxa (Table 1) revealed that the flowering time varied from species to species. Altitudinal variations play a vital role in the change in flowering time. The species such as *P.edulis* var. *edulis*, *P.ligularis, P. subpletata and P.leshnoultii*, habitating in high altitude areas bloomed from April to September. The present study categorized the species of *Passiflora* in to four groups depending on the period of blooming. The time of anthesis revealed intra specific relationships in *P. foetida* and *P. edulis* and inter specific relationship in *P.ligularis, P.quadrangularis and P.leshnoultii.* Relationships among the taxa were noticed in *P.foetida,* on anthesis. According to Ullah *et al*. (2009) *P.foetida* is a long day plant and that required more than 10.5 hr. for blooming, whereas Banu *et al*. (2009) suggested that full blooming occurred within 11.00 hr. to 12.30 hr. in *P.edulis*. Kishore *et al*. (2010) reported that different species of cultivated *Passiflora* species respond differently to environmental factors. Adjaloo *et al*. (2012) had of the opinion that radiation of the sun, which can be characterized by its quality, duration and intensity, remains the basic factor for plant development and flower production. Analysis of Table 3 will enable to identify the variations noted in the harvesting time of the species of *Passiflora*. Occurrence of flowering twice in a year and the two time harvest in *P.edulis* cv.*panamared* pointed out the increase in the yield of the species.

This phenomenon recommends the cultivar for commercial purpose. Ataide *et al*. (2012) were of the opinion that fruit production and harvesting time varied throughout the year as a consequence of the variation in flowering behavior in the species of *Passiflora* L. Present study suggests the transfer of the yield contributing trait, early maturity of fruits, in *p. subpeltata* to the cultivar so as to enhance the yield of the fruit crop. The progress in breeding program for economic characters like pomological features often depend on the availability of a large germplasm representing diverse genetic variations. Wide variations within and among the species were observed in qualitative (fruit size and fruit color) as well as quantitative (length, width and weight of the fruit) pomological characters at the time of the present investigation (Table 3) .The wide range in the mean fruit weight (2±0.022 to 95±0.031 g) reflected the basic differences in the species of *Passiflora*. Vieira and Carneiro, (2006) had used fruit characteristics for the selection of yield potential of yellow passion fruit. ANOVA using the mean revealed significant variation at $P<0.05$ level (Table.3) for characters like fruit length, fruit weight and average amount of fruit juice. The high variability accounted by the three PCs (92.2%) was based on fruit traits. Studies on morphological and pomological traits in pomegranate

(49.29 %) and peach (63%) founded only a moderate level of variability (Mars, 2001 and Perez *et al*.,1993). The enhanced diversity among the species of *Passiflora* found in the present investigation suggests that it may be mainly due to the characteristics of fruits. Such phenotypic variations in fruits were the targets of selection in breeding programs. Neto *et al*. (2011) also had the same opinion in *Spondias tuberose* Arrunda.

The Scree plot, biplot and observation plot generated from Principal Component Analysis (Figs. 2, 3, 4) using Pearson correlation coefficient revealed 9 principal components for total variations, (Table 5). The first component explained 81% of the total variability and included fruit shape, fruit weight, and number of seeds as the characters with significant variation, which in turn pointed out the implication of those characters at the inter and intra specific phenological and pomological variations. According to Faruq *et al*., (2013) phenological traits contributed much for the variation in *Hibiscus cannabinus* L. The present study also showed high positive correlation between fruit size with the number of seeds, and low with fruit length. Souza *et al*.,(2004) and Shivanna, (2012) had noticed a high correlation between fruit weight and the characters like seed number, fruit length and diameter in *P. edulis*. In Whisker and Box plot the maximum frequency of the quantitative pomological characters were distributed inside the whisker. The average and the median of the number of seeds were significantly higher ($P<0.001$) than that of the other traits. Shivanna (2012), used whisker box and plot to explain the frequency distribution in the average size of fruits obtained in manual pollination and found that the same was significantly higher compared to those obtained in natural autogamous pollination in *Passiflora*.

High degree of fruit diversity was evident from the UPGMA dendrogram which separated the species of *Passiflora* in to two main clusters. The first principal cluster consisted of *P. edulis* varieties along with *P.quandrangularis* and *P.ligularis* having large fruits. This indicated that the fruit size of cultivated variety dominates over the wild varieties. Dominance of the cultivar was earlier reported in *Momordica charantia* by Beevy and Bai (2012). Eventhough the large size of the fruit remains a primitive nature, it can be used as a desirable trait to improve fruit production in the breeding program. The study concludes that the inter and intra specific phenological and pomological variations observed may be attributed to changes in environmental factors such as temperature and altitude.

Conclusion

The present investigation noticed wide variations in fruit morphology, along with the phenological characteristics like the time of anthesis, period of flowering and harvesting time in the species of *Passiflora*. Diverse statistical analysis of the pomological traits revealed that, inter and intra specific variations in the genus is mainly attributed by the significant variations in fruit shape, fruit weight and number of seeds. The study emphasizes the significance of phenological and pomological features in the delimitation of the taxa at inter and intra specific levels. The study suggests *Passiflora edulis* cv. *Panamared* as the promising cultivar for commercial purpose and identified *P.subpeltata* and *P.,foetida* with short term flowering as the elite germplasm for future breeding programme.

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REFERENCES

Adjaloo, M.K., Odouro, W., Banful, B.K. 2012 Floral phenology of upper Amazon Cocoa Trees: Implications for Reproduction and Productivity of Cocoa. *ISRN* Agronomy 2012, 1-8

Ataide, E.M., Oliveira, J.C.D. and Ruggiero, C. 2012. Flowering and Frutification of wild Passionfruit (*Passiflora setacea* D.C. grown in Jaboticabal, SP. Sp. Rev. Bras. Frutic 34, 377-381.

Banu, M.B., Matin, M.Q.I., Hossain, T. and Hoassain, M.M. 2009. Flowering behavior and flower morphology of passion fruit (*Passiflora edulis* Sims). *Int.J.Sustain. Crop. Prod.* 4, 05-07.

Beevy, S.S. and Bai, H.N. 2012. Characterization of Intraspecific F1 Hybrids of *Momordica charantia* L.based on Morphology , Cytology and Palynology. Cytologia 77(3), 301-310.

Crimmins, T.M., Crimmins, M.A. and Bertelsen, C.D. 2009. Flowering range changes across an elevation gradient in response to warming summer temperatures. *Global Change Biology* 15, 1141-1152.

Crimmins, T.M., Crimmins, M.A. and Bertelsen, C.D. 2010. Complex responses in onset of spring flowering across a semi-arid elevation gradient. *Journal of Ecology*, 98,1042-1051.

Faruq, G. Alamgir, M.A., Rahman, M.M., Motior, M.R., Zakaria, H.P., Marchalina, B. and Mohamed, N.A. 2013. Morphological characterization of kenaf (Hibiscus cannabinus L.) in Malaysian tropical environment using Multivariate Analysis. *J. Anim.Plant Sci.* 23(1), 60-67.

Ganji Moghaddam, E., Hossein Ava, S., Akhavan, S., Hosseini, S. 2011. Phenological and pomological characteristics of some plum (*Prunus* spp.) cultivars grown in Mashhad, Iran. *Crop Breeding Journal* 1(2), 105-108.

Gomoez, K.A. and Gomez, A.A. 1983. Statistical Procedures for Agriculture Research. 2nd edition, paperback, pp, 680.

Gunes, M. 2003. Some local varieties grown in Tokat province. Pak.J.of Appl.Sci 3(5), 291-295.

Hakan Karadag and Yasar Akca. 2011. Phenological and pomological properties of promising walnut (*Juglans regia* L.) genotypes from selected native population in Amasya Province. *African Journal of Biotechnology,* Vol. 10(74):16763-16768.

Hollander, M. and Wolfe, D.A. 1973. Non Parametric Statistical methods. New York: John Wiley &Sons. Pp185-194.

Inouye, D.W. 2008. Effect of climate change on phenology, frost damage, and floral abundance of montane wild flowers. *Ecology,* 89,353-362.

Kamaldeep, D., Dahuan, S. and Sharma, A. 2004. *Passiflora*: A review update. J. Ethnopharmacol. 94, 1-23.

Kishore, K.A., Pathak, R., Shukla, and Bharali, R. 2010. Studies on floral biology of Passion fruit (*Passilflora* spp.). *Pak. J. Bot.* 42, 21-29.

Kundan Kishore, Pathak, K.A., Rohit Shukla and Rinku Bharali. 2010. Studies on Floral Biology of Passion Fruit (Passiflora species). *Pak. J. Bot.* 42(1), 21-29.

Mars, M. 2001. Ressources genetiques du grenadier (*Punica granatum* L.)Ten Tunisie: prospection, conservation et analyse de la diversite [These Doctorat d'Etat Es Science Naturelles], Faculte des Science, Univeriste Tunis EL Manar.

Miller-Rushing, A.J. and Inouya, D.W. 2009 Variation in the impact of climate change of flowering phenology and abundance: An examination of two pairs of closely related wildflower species. *American Journal of Botany,* 96, 1821-1829.

Perez, S., Montes, S. and Mejia, C. 1993. Analysis of peach germplasm in Mecxico. *Journal of the American Society for Horticultural Science,* Vol.118 pp, 519-524.

Pruthi, J.S., Sankaran, A.N. and Lal Girdhari, 1959. Physico-chemical composition of Passion fruit (*Passiflora edulis* IV. Effect of date of picking and plant o plant variation on some physico-chemmical aspects. *Indian Journal of Horticulture,* Vol.16 (4),243-251.

Reni Lestari, 2014. Morphological variation and species distribution of *Baccaurea dulcis* (Jack) Mull.Arg. in West Java, Indonesia. *International journal of Biology,* 6(1), 17-28.

Rodriguez-Amaya, D.B. 2003. Passion fruits. In Encyclopedia of Food Sciences and Nutrition; Calballero, B., Trugo, L., Finglas, P. Eds; Elsevier Science: Londo., 4368-4373.

Shawn E. Krosnick, Elizabeth M. Harris and John V. Freudenstein, 2006. Patterns of Anomalous floral development in the Asian *Passiflor*a (Subgenus Decaloba:supersection Disemma). *American Journal of Botany*, 93(4), 620-636.

Shivanna, K.R. 2012. Reprodictive assurance through unusal autogamy in the absence of pollinators in *Passiflora edulis* (passion fruit). *Current Science,* Vol 103. No.9.

Soleimani, A., Etemad, V., Calagari, M., Namiranian, M., Shirvani, A. 2014. Influence of climatic factors on fruit morphological traits in *Populus euphratica* Oliv. Ann. For. Res. 57(1), 31-38.

Son, L. 2010. Determination of quality characteristics of some important Japanese plum (*Prunus salicina* Lindl.) cultivar grown in Mersin-turkey. *Afri.J. O Agric. Res.* 5(10), 1144-1146.

Souza, M.M., Pereira, T.N.S., Viana, A.P., Pereira, M.G., Do Amaral Jr. and Madureira, H.C. 2004. Flower Receptivity and Fruit characteristics Associated ot Time of Pollination in the Yellow Passion Fruit *Passiflora edulis* Sims F. *Flavicar*pa Dengener (Passifloraeae). Scientia Horticulturae Vol.101,No. 4 ,373-385.

Souza, M.M., Viana, A.P. and Pereira, T.N.S. 2010. A putative mutant of self-compatible yellow passion fruit with the corona color as a phenotypic marker. Bragantia.

Ullah, M.M., Rouf, M.A., Alam, A. , Das, C.K. and Ahmed, I. 2009. Modern Cultivation of Passion Fruit (InBengali).1st Edn., Hill *Agricultural Research Station,* BARI, Khagrachari.

Ulmer, T. and MacDougal, J.M. 2004. Passiflora: passion flowers of the world. Timber Press, Portland.

Vanderplank, J. 1996. Passion flowers, Cambridge Press , London, UK.

Vieira, M.L.C. and M.S. Carneiro, 2004. Passiflora spp. Passonfruit, In R.E.Litz(ed.). Biotechnology of fruit and nut crops. CAB Inrl. Publ., Oxfordshire, U.K. ,435-453.

Ward, J.H. 1963. Hierarchial grouping to optimize an objective function. *J.Am.Stat.Assoc.* 58, 238-244.

Wohlmuth, H., Penman, K.G., Pearson, T. and Lehmann, R.P. 2010. Pharmacognosy and Chemotypes of Passion flower (*Passiflora incarnate* L.). Biol.Pharm. Bull. 33(6), 1015-1018.

XLSTAT, 2013. Addinosoft TM Version 2012. www.xlstat.com/

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