

ANALYSIS OF DIVERGENCE IN EIGHT SPECIES OF *PIPER* USING D²-STATISTIC¹

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Abstract

Analysis of variance of morphological characters was carried out in the male and female plants of eight species of *Piper* viz., *P. argyrophyllum* Miq., *P. attenuatum* Buch-Ham., *P. galeatum* C. DC., *P. hookeri* Miq., *P. longum* Linn., *P. mullesua* Buch-Ham. (= *P. brachystachyum* Wall. ex Hook.), *P. nigrum* Linn. and *P. trichostachyon* C. DC., occurring in the Western Ghat region of South India, using Mahalanobis' D²-statistic. The female plants were separated into 5 clusters on the basis of 5 morphological characters and male plants into 4 clusters on the basis of 4 characters. Distribution of the species in the different clusters were identical in both male and female plant analysis except for *P. mullesua* which stood alone as a distinct cluster in female plant analysis but merged with the species belonging to another cluster, in male plant analysis. The biometrical affinities as evidenced by the clustering pattern were in broad agreement with the relationships suggested in the classical taxonomic studies.

Key words: Analysis of divergence; *piper*; D²-statistic; biometrical affinity; morphological relationship.

Introduction

Biometrical analysis are being applied with increasing frequency in plant systematics because, these techniques have provided additional data which are useful in solving out the taxonomic problems (Prance *et al.*, 1969; Bemis *et al.*, 1970; Hilu and Wright, 1982). The genus *Piper* which includes several economic and medicinal plants such as *P. nigrum* (black pepper), *P. betle* (betel vine), *P. longum* (long pepper) and *P. cubeba* (tailed pepper) is distributed throughout the tropical and subtropical regions. Because of the large number of species and intra

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specific categories, extremely variable vegetative characters, closely packed spicate inflorescences and minute flowers, the genus has been considered as one of the most difficult genera to classify (Hooker, 1886). A survey of the central part of the Western Ghat ranges and the adjacent peninsular and coastal region in South India, by Rahiman *et al.* (1979, 1981), showed eight wild species of *Piper*. In the present study analysis of variance of morphological characters of these Western Ghat species are carried out by selecting some quantitative characters with a hope that the information may provide a better understanding of the relationships of these wild species.

Materials and Methods

Analysis of diversity based on quantitative characters was carried out on eight species of *Piper* viz., *Piper argyrophyllum* Miq., *P. attenuatum* Buch-Ham., *P. galeatum* C.DC., *P. hookeri* Miq., *P. longum* Linn., *P. mullesua* Buch-Ham. (= *P. brachystachyum* Wall. ex Hook.), *P. nigrum* Linn. and *P. trichostachyon* C.DC. All the species were unisexual. Quantitative characters were recorded from 106 specimens with fully mature male spikes or fruiting spikes, from a collection of over 300 herbarium sheets of *Piper* from the Western Ghat region of South India. Characters of male and female plants were analysed separately. Sample size varied from 6 to 14 for each of the species except for few of the species whose sample size was as low as two because of want of plant material of these species. Four characters viz., leaf length, leaf breadth, spike length and stamen number, were studied in the male plants and five characters, viz., leaf length, leaf breadth, fruiting spike length, number of stigma lobes and fruit diameter, were studied in female plants. The diversity in the characters was estimated using D^2 -statistic of Mahalanobis (1936). The D^2 values between 28 possible combinations of the eight species using male and female characters were computed with the help of a microcomputer 'HCL 2200'. Corresponding to each species, the Mahalanobis' D^2 distance was worked out for each of the species and were arranged in increasing order of D^2 . This arrangement facilitated in picking up species which are closer to each other to form one cluster. The species were grouped into different clusters based on the criterion that any two species belonging to the same cluster, at least on an average, showed a smaller D^2 than those belonging to two different clusters. The mean values between the species were tested using Wilk's Λ criterion (Rao, 1952).

Results and Discussion

The analysis of variance showed significant difference in the mean values for all the characters studied in both female and male plants of all the species. The observations are given below separately for female and male plants.

Female Plants

The Λ value for the dispersion between the species was 496.04 which was greater than χ^2_{35df} ($P=0.01$), indicating that the differences in the mean values of these characters were highly significant. The high significance suggested that these species could be grouped into different clusters. Making use of the D^2 values, these species were grouped into the following clusters: Cluster I—*P. argyrophyllum*, *P. attenuatum* and *P. hookeri*, Cluster II—*P. nigrum*, Cluster III—*P. galeatum* and *P. trichostachyon*, Cluster IV—*P. longum* and Cluster V—*P. mullesua*. The maximum distance was between cluster III and V, followed by cluster III and IV, cluster II and V, cluster II and IV, cluster I and III, cluster I and II, cluster I and IV, cluster I and V, cluster II and III and cluster IV and V, in the sequential order. The analysis of variance for female characters is given in Table 1a, cluster means of the same in Table 2 and the average intra- and inter-cluster distances based on D^2 values in Table 3a. Grouping of the eight species is diagrammatically represented in Fig. 1a.

Male Plants

The Λ value was found to be 586.08 and was greater than χ^2_{28df} ($P=0.01$), indicating that the differences in the mean values in the males were also highly significant. By making use of D^2 values, male plants could be grouped into four clusters: Cluster I, II and IV consisted of the same species of the female plants.

Table 1a. ANOVA for 5 female characters

Source	df	Mean squares				
		Leaf length (cm)	Leaf breadth (cm)	No. of stigma lobes	Spike length (cm)	Berry size (mm)
Between species	7	66.59**	21.74**	1.24**	112.29**	23.19**
Error	38	4.97	2.06	0.19	5.85	0.33

** Significant at 1% level

Table 1b. ANOVA for 4 male characters

Source	df	Mean squares			
		Leaf length (cm)	Leaf breadth (cm)	Stamen number	Spike length (cm)
Between species	7	40.49**	8.43**	2.74**	138.63**
Error	52	4.72	1.68	0.001	22.72

** Significant at 1% level

Table 2. Cluster means of different female and male characters

Species	Sample size		Leaf length (cm)		Leaf breadth (cm)		No. of stigma lobes	Spike length (cm)	Berry size (mm)	Stamen No.		Spike length (cm)
	Female	Male	Female	Male	Female	Male				Female	Male	
Cluster I												
<i>P. argyrophyllum</i>	6	12	14.17	11.92	6.17	4.54	4.00	8.58	3.60	3.00	14.58	
<i>P. attenuatum</i>	6	9	15.58	14.17	6.75	6.06	4.00	15.33	3.12	3.00	14.89	
<i>P. hookeri</i>	3	8	11.83	12.81	5.40	5.15	3.67	12.67	3.33	3.00	10.88	
Cluster mean			13.86	12.96	6.10	5.25	3.89	12.26	3.35	3.00	13.45	
Cluster II												
<i>P. nigrum</i>	6	14	20.92	17.41	10.50	6.93	4.67	7.50	5.13	2.00	13.07	
Cluster III												
<i>P. galeatum</i>	6	4	15.33	14.50	5.17	4.50	3.33	5.50	6.80	2.00	4.25	
<i>P. trichostachyon</i>	10	5	16.15	13.80	5.25	5.50	3.50	7.20	6.07	2.00	6.00	
<i>P. mullesua</i>	—	6	—	12.00	—	4.30	—	—	—	2.00	3.92	
Cluster mean			15.74	13.43	5.21	4.76	3.42	6.35	6.43	2.00	4.72	
Cluster IV												
<i>P. longum</i>	3	2	8.33	11.50	6.33	6.75	4.00	3.17	1.70	4.00	8.50	
Cluster V												
<i>P. mullesua</i>	6	—	11.50	—	4.28	—	3.33	1.05	1.25	—	—	

Table 3a. Average intra- and inter-cluster D^2 values for female characters

The figures in the parentheses indicate square-root of average D^2 values.

Clusters	I	II	III	IV	V
I	6.87 (2.62)	51.97 (7.21)	59.56 (7.72)	43.99 (6.63)	43.09 (6.56)
II		0.00	28.87 (5.37)	99.87 (9.99)	102.85 (10.14)
III			2.57 (1.60)	118.42 (10.88)	146.97 (12.12)
IV				0.00	23.37 (4.83)
V					0.00

However, the cluster III was found to possess three species viz., *P. galeatum*, *P. trichostachyon* and *P. mullesua*. The maximum distance was between cluster II and IV, followed by cluster III and IV, cluster I and IV, cluster I and II, cluster I and III and cluster II and III, in that order. The analysis of variance for the male characters is given in Table 1b, cluster means in Table 2 and the average intra-

and inter-cluster distances in Table 3b. Grouping of the species based on male characters is diagrammatically represented in Fig. 1b.

Table 3b. Average intra- and inter-cluster D^2 values for male characters

The figures in the parentheses indicate square-root of average D^2 values.

Clusters	I	II	III	IV
I	2.58 (1.61)	435.78 (20.88)	418.46 (20.46)	445.89 (21.12)
II		0.00	12.50 (3.55)	1,743.89 (41.76)
III			2.38 (1.54)	1,708.72 (41.34)
IV				0.00

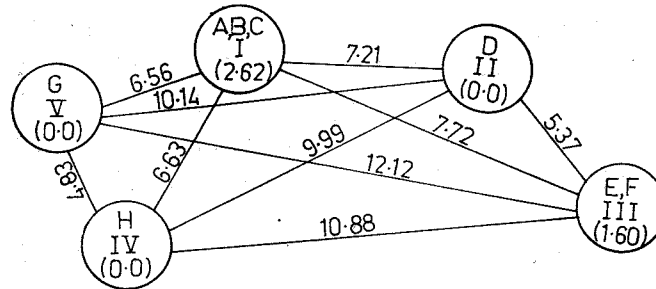


Fig. 1a. Distribution of clusters based on female characters.

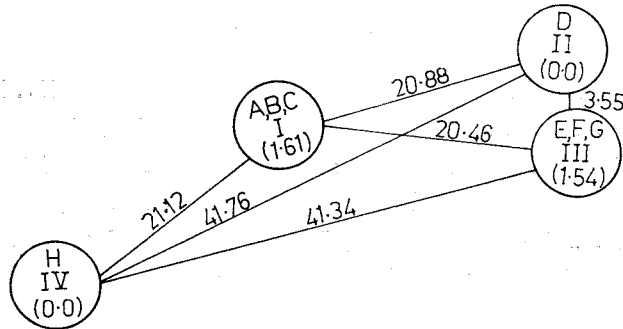


Fig. 1b. Distribution of clusters based on male characters.

- A—*P. argyrophyllum*
- B—*P. attenuatum*
- C—*P. hookeri*
- D—*P. nigrum*
- E—*P. galeatum*
- F—*P. trichostachyon*
- G—*P. mullesua*
- H—*P. longum*

Study of Indian Floras giving detailed account of the systematics of the Western Ghat *Piper*, viz., Flora of British India (Hooker, 1886), Flora of Madras (Gamble, 1925), Flora of Bombay (Cooke, 1903) and Flora of Hassan District (Saldanha and Nicolson, 1976) and the monographs having the original descriptions of these species, such as De Candolle's *Prodromus* (1869) and Miquel's *Systema Piperacearum* (1843), showed that, among the eight species under investigation, *P. argyrophyllum*, *P. attenuatum* and *P. hookeri* showed close morphological relationships. Similarly, *P. galeatum* and *P. trichostachyon* also showed close relationships. On the other hand, *P. nigrum* showed very little relationship with other species. *P. longum* and *P. mullesua* were found to resemble each other only in some floral characters and these two species showed very little relationship with other species.

In both male and female character analysis *P. attenuatum*, *P. argyrophyllum* and *P. hookeri* formed one cluster (cluster I) and therefore are biometrically related. Similarly *P. galeatum* and *P. trichostachyon* formed another cluster (cluster III) and therefore are related. *P. longum* remained separate as a cluster by itself (cluster IV), indicating that this species is distinct from all the other species. So also was *P. nigrum* (cluster II). The biometrical affinity of *P. mullesua* could not be assumed as it showed different relationship in male and female character analysis. Except for this inconsistent grouping of *P. mullesua* the grouping obtained in the intra-cluster D² analysis of both male and female plants are in close agreement with the relationship suggested by the classical taxonomists based on morphological characteristics. Because of the existence of discrepancies in the inter-cluster distances of male and female plant analysis, the affinities of the different cluster of species could not be assumed.

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八種胡椒之 D^2 -Statistic 分散分析

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以 Mahalanobis 的 D^2 -Statistic 對南印度 Ghat 西部地區之八種 (Species) 胡椒 (*P. argyrophyllum* Miq., *P. attenuatum* Buch-Ham., *P. galeatum* C. DC., *P. hookeri* Miq., *P. longum* Linn., *P. mullesua* Buch-Ham., *P. nigrum* Linn. 及 *P. trichostachyon*) 其雌株和雄株之形態性狀做變方分析。雌株依五種形態性狀分離為五羣 (cluster)，雄株則依四性狀分離為四羣。分佈於不同羣內之種，其雌雄株之分析均相同，唯有 *P. mullesua* 例外，其雌株分析獨立為一羣，但其雄株却與另一羣合併。由羣式 (cluster pattern) 證實之生統親和力與傳統分類提出之親源關係大致符合。