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Taxonomic Significance of Floral Morphology in *Cinnamomum* Schaeffer (Lauraceae) From South India

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Abstract: **Floral morphological characters were studied in 54 accessions belonging to 25 taxa of *Cinnamomum* Schaeffer, which include 22 wild and 3 cultivated ones. All the taxa showed variation in flower size, colour, opening of flower during anther dehiscence, presence of indumentum, number of anther locules and shape of staminodes. The first Principal Component (PC) accounted for 97.6% of phenotypic variance followed by second for another 0.95%. The unweighted pair- group method with mathematical averaging (UPGMA) clustering method revealed two principal clusters which separated all the accessions between euclidean distances of 0.109 – 0.741. Both cluster analysis and principal co-ordinate analysis revealed that *Cinnamomum travancoricum* (CT), collected from Idukki and *Cinnamomum heyneanum* accessions (CHI CH2) have morphologically distinct inflorescence and flowers. The phenogram and PCoA scatter plot showed the grouping of accessions with species delimitation, which emphasize the importance of floral morphology as a key character in identifying *Cinnamomum* at species level.**

***Index Terms: Cinnamomum*, floral morphology, PCA, UPGMA, PCoA.**

***Abbreviations*:** **CAg**- *C. agasthyamalayanum*, **CCa**- *C. cassia*, **CCh**- *C. chemungianum*, **CD**- *C. dubium*, **CF**- *C. filipedicellatum*, **CG**- *C. goaense*, **CH**- *C. heyneanum*, **CK**- *C. keralaense*, **CL**- *C. litseaefolium*, **CMa**- *C. macrocarpum*, **CM**- *C. malabatrum*, **CMt**- *C. mathewianum*, **CMtP**- *C. mathewianum* var. *ponmudianum*, **CMo**- *C. mohananii*, **CMz**- *C. moozhiyarense*, **CN**- *C. nicolsonianum*, **CNg**- *C. nilagiricum*, **CP**- *C. perrottetii*, **CR**- *C. riparium*, **CS**- *C. sulphuratum*, **CTa**- *C. tamala*, **CT**- *C. travancoricum*, **CV**- *C. verum*, **CWa**- *C. walaiwarense*, **CW**- *C. wightii*

I. Introduction

The genus *Cinnamomum* Schaeffer belongs to the family Lauraceae. The term '*Cinnamomum*' is derived from the Greek word *Kinnamon* or *kinnamomum* meaning *sweet* wood. It consists of about 350 species distributed in East Asia, South East Asia, Australia, Samoa, Fiji and Tropical America (Mabberley, 2008).To date, *The Plant List* includes 893 scientific plant names of species rank for the genus *Cinnamomum* (http://www.theplantlist.org, last accessed 11 April 2019) and 48 of these are attributed to species occurring in India, which are mainly distributed in the Western Ghats, Eastern Ghats and the Himalayas (Baruah and Nath, 2007; Geethakumary et al., 2015; Gangopadhyay, 2008). South India houses about 26 species and they constitute 20 endemics, 4 cultivated species (*Cinnamomum verum, C. cassia, C. camphora* and *C. tamala*) and two distributional records, like *C. dubium* and *C. litseaefolium* (Geethakumari et al., 2007; Geethakumari et al., 2012).

In *Cinnamomum,* inflorescences axillary or subterminal; paniculate-cymose with 1–3 order branching, flowers of the ultimate branch arranged in cyme, rarely racemiform; rachis angular; bracts caducous or persistent. Flowers bisexual, trimerous, appressed hairy; receptacle tube shallow, 0.5–3 mm deep; perianth lobes 6 in 2 whorls, equal; fertile stamens 9, in 3 whorls, filaments 1/4–3/4 the length of stamen; anthers 2- or 4-locular, if 4-locular the locules of the upper pair smaller than that of the lower pair, anther of the first and second whorls of stamens introrse, those of the third whorl extrorse-latrorse; third whorl stamens with 2 stipitate reniform glands attached on each side of the filaments; the gland stalks free or fused with the filaments; staminodes 3, in the fourth whorl, stipitate, hairy, apex sagittate or hastate; ovary superior, stigma subpeltate, peltate, discoid or trilobed. *Cinnamomum* is a highly complicated genus due to overlapping phenotypic characters in many species and become a complex of taxonomic uncertainty. The genus is usually recognised by trinerved and fragrant leaves, paniculate inflorescence, flower with nine stamens and fruits seated on a cupule. But there are a lot of taxonomic disputes regarding the identification of plants at species level (Abeysinghe et al., 2009). While studying the taxonomy of *Cinnamomum* in South India, it has been found that the some of the floral characters have greater taxonomic significance, but they were not at all taken into account for preparing keys/ classification. These floral characters along with other vegetative characters can be used in distinguishing the *Cinnamomum* species. Therefore, in the present study, floral morphology has been studied to delimit and unravel the species complexities to solve the taxonomic disputes of *Cinnamomum*.

II. MATERIALS AND METHODS

In the present study, 54 accessions of 25 taxa of *Cinnamomum* were collected from different localities of Kerala (Table 1). Herbarium specimens were submitted and voucher numbers were obtained from Kerala University Botany Herbarium (KUBH), Kerala, India. Photographs of different specimens were taken with digital camera. Specimens were identified using authentic literature and comparing with the relevant type specimens deposited at various herbaria. For morphological studies, floral parts were subjected to Light Microscopy and Scanning Electron Microscopy. The flowers were observed, measured and recorded using 20 samples for each taxon. Observations on 41 morphological traits were scored including both quantitative and qualitative characters. All data were processed using one way ANOVA and Duncan Multiple Range Test and the significance of qualitative characters were tested using Kruskal Wallis Test using SPSS 16.0. A probability value of 0.05 was used as a bench mark for significant difference between parameters. Multivariate analysis was performed by numeric taxonomic techniques using the procedure of Principal Component Analysis (PCA) (Sneath and Sokal, 1973) using MVSP Version 3.1 (Kovach computing Services, Wales, U K). To bring out the patterns of similarity and dissimilarity, data was subjected to cluster analysis based on UPGMA method to group the 25 taxa using MVSP 3.1. Principal Coordinate Analysis (PCoA) followed by construction of scatter plots based on ordination of accessions was performed using PAST 3.01.

III. RESULTS

In *Cinnamomum,* inflorescences are axillary or subterminal; paniculate-cymose in all the selected taxa except *C. travancoricum* having racemiform inflorescence. The term subterminal is used here when the inflorescences are axillary but positioned at the twig end at the axils of distal leaves. All the taxa possess branched inflorescence with *C. heyneanum* being an exception by having simple cyme inflorescence. The length and branching of inflorescences and number of flowers/inflorescence were found to differ greatly among the selected taxa. Flowers bisexual, trimerous, pubescent or glabrous; receptacle tube shallow, 0.5–3 mm deep; perianth lobes 6 in 2 whorls, equal or subequal. Flowers also showed variation in size, colour, presence of indumentum on flower, opening of flower during anther dehiscence, etc (Fig. 1).

Figure 1. Flowers of 25 taxa of *Cinnamomum.* A-*C. agasthyamalayanum,* B- *C. mathewianum* var. *ponmudianum*, C- *C. cassia*, D- *C. chemungianum*, E- *C. dubium*, F- *C. filipedicellatum*, G- *C. goaense*, H- *C. heyneanum*, I- *C. keralaense*, J- *C. litseaefolium*, K- *C. malabatrum*, L- *C. mathewianum*, M- *C. mohanani*i, N- *C. nicolsonianum*, O- *C. nilagiricum*, P- *C. macrocarpum*, Q- *C. perrottetii*, R- *C. riparium*, S- *C. sulphuratum*, T- *C. tamala*, U- *C. travancoricum*, V- *C. verum*, W- *C. walaiwarense*, X- *C. wightii*, Y- *C. moozhiyarense*

Cinnamomum travancoricum is found to have the largest flower and the longest one is that of *C. mathewianum* among the taxa under study. *Cinnamomum mathewianum*, *C. mathewianum* var. *ponmudianum*, *C. filipedicellatum* and *C. chemungianum* were found to have glabrous flowers and pedicels (Figs. 1 & 2) and they do not wide open during the time of anther dehiscence. While the rest of the taxa have pubescent flowers which fully open during anther dehiscence. In *Cinnamomum* there are 9 fertile stamens arranged in 3 whorls of 3 each. The anthers of most species are strictly 4-locular (19 spp.) but there are some species with strictly 2-locular anthers (1 sp. and 1 var.). In other species, the first and second whorl anthers are 4-locular while the third whorl anthers are 2-locular (4 spp.)

The number of anther locules have evolutionary significance, since they vary between species. Hence, based on the number of anther locules, all the taxa under study were categorized into three groups (Table 1). The number of anther locules together with other vegetative characters were useful in delimiting species. In 4-locular stamens, the locules of the upper pair were found to be smaller than that of the lower pair. Anther of the first and second whorls of stamens are introrse, those of the third whorl extrorse/latrorse; third whorl stamens with 2 stipitate reniform glands attached on each side of the filaments; the gland stalks free or fused with the filaments. The 3 staminodes in the fourth whorl also showed variation in size and shape (Fig. 3). Ovary superior, stigma subpeltate, peltate, discoid or trilobed.

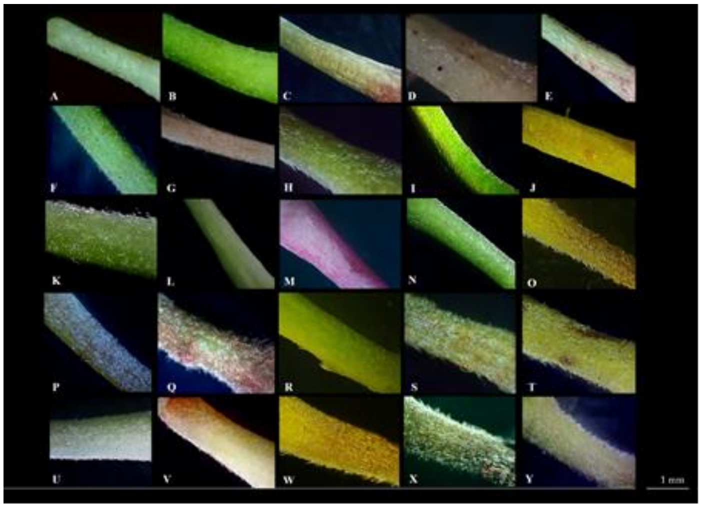

Figure 2. Pedicels of 25 taxa of *Cinnamomum* Schaeffer. A-*C. agasthyamalayanum*, B- *C. cassia* C- *C. chemungianum*, D- *C. dubium*, E- *C. filipedicellatum*, F- *C. goaense*, G- *C. heyneanum*, H- *C. keralaense*, I- *C. litsaeafolium*, J- *C. macrocarpum*, K- *C. malabatrum*, L- *C. mathewianum*, M- *C. mathewianum* var. *ponmudianum*, N- *C. mohananii*, O- *C. nicolsonianum*, P- *C. nilagiricum*, Q- *C. perrottetii*, R- *C. riparium*, S- *C. sulphuratum*, T- *C. travancoricum*, U- *C. tamala*, V- *C. verum*, W- *C. walaiwarense*, X- *C. wightii*, Y- *C. moozhiyarense*

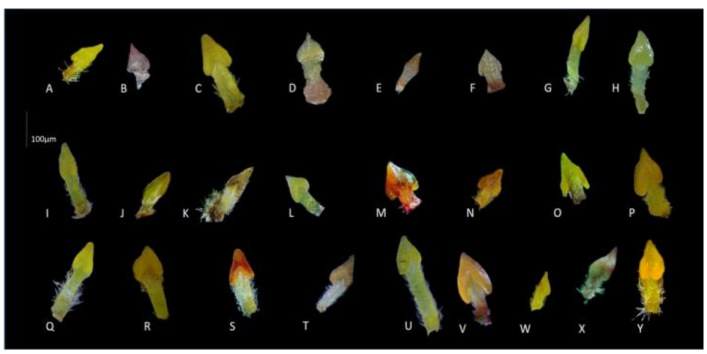

Figure 3. Staminodes of *Cinnamomum* Schaeffer. A-*C. agasthyamalayanum*, B- *C. mathewianum* var. *ponmudianum*, C- *C. cassia*, D- *C. chemungianum*, E- *C. dubium*, F- *C. filipedicellatum*, G- *C. goaense*, H- *C. heyneanum*, I- *C. keralaense*, J- *C. litseaefolium*, K- *C. malabatrum*, L- *C. mathewianum*, M- *C. mohananii*, N- C. *nicolsonianum*, O- *C. nilagiricum*, P- *C. macrocarpum*, Q- *C. perrottetii*, R- *C. riparium*, S- *C. sulphuratum*, T- *C. tamala*, U- *C. travancoricum*, V- *C. verum*, W- *C. walaiwarense*, X- *C. wightii*, Y- *C. moozhiyarense*.

A. Analysis of variance

Both quantitative and qualitative data showed significant variation (P <0.05) in the analysis of variance and Kruskal Wallis Test performed among the 25 taxa of *Cinnamomum*.

Table 1. Summary of the number of anther locules in the '25' Taxa of *Cinnamomum* Schaeffer

Sl. No.	No. of Anther Locule	Taxa
1.	2-locular anther in all stamens (**2**)	*C. mathewianum, C. mathewianum* var. *ponmudianum*
2.	4-locular anther in all stamens (**19**)	*C. cassia, C. chemungianum, C. filipedicellatum, C. goaense, C. heyneanum, C. keralaense, C. malabatrum, C. mohananii, C.nicolsonianum,C. macrocarpum, C. perrottetii, C. riparium, C. sulphuratum, C. tamala, C. travancoricum, C. verum, C. wightii, C. walaiwarense, C. moozhiyarense*
3.	The first and second whorl anthers 4-locular, the third whorl anthers 2-locular (**4**)	*C. agasthyamalayanum, C. dubium, C. litseaefolium, C. nilagiricum,*

Cinnamomum cassia (CCa) found to have the highest values for Inflorescence Length, Number of Flowers and Number of Branches indicating the presence of largest inflorescence. Whereas *C. dubium* have the shortest inflorescence and *C. heyneanum* have the least number of flowers and no branches since having simple cyme inflorescence. Flower length and pedicel length was found to be highest in *C. mathewianum* (CMt1) attributing to the longest flower and the lowest value was observed in *C. malabatrum* (CM2). *Cinnamomum travancoricum* have the highest values for length of outer tepal, inner tepal, outer, middle and inner stamen, anther filaments, staminode, pistil and style and thus clearly indicates having the largest flower among the taxa. Breadth of outer and inner tepals were highest in *C. perrottetii* (CP2) and *C. cassia* respectively whereas the lowest value was observed in *C. dubium*. Length and Breadth of Gland was observed high in *C. perrottetii* and low in *C. filipedicellatum* which also have lowest values for length of staminode, pistil and style. Breadth of Ovary was high in *C. perrottetii* and low in *C. malabatrum.* Breadth of outer and middle stamens were high in *C. macrocarpum* and the same for inner stamens is high in *C. cassia.* While the same variables recorded lowest values in *C. dubium, C. malabatrum* and *C. filipedicellatum* respectively.

B. Principal Component Analysis

In the PCA of inflorescence and floral characters, 99.7% of the phenetic variance was accounted by the first principal component, followed by 0.1% in the second and 0.055% of the variance in the third component (Table 2). Length, breadth and apex angle of tepals, length and breadth of stamens, filaments, glands and staminodes; length of pistil, style and breadth of ovary were found influential in the most variable first principal component. The highly loaded traits in second and third principal components were found to be Inflorescence Length, Peduncle Length, Number of Branches/Inflorescence, Number of Flowers, Flower Colour, Type of Inflorescence, Locules of Stamen, Shape of Staminode, Presence of Indumentum on Flower and Opening of Flower During Anther dehiscence.

Table 2. PCA variable loadings of inflorescence and floral morphological characters

Sl. No.	Variables	PC 1	PC 2	PC 3
1.	Inflorescence Length	0.062	**0.31**	**-0.13**
2.	Peduncle Length	0.044	**0.236**	-0.05
3.	Flower Length	0.018	-0.05	-0.06
4.	Pedicel Length	0.013	-0.072	-0.08
5.	Primary Pedicel Length	0.023	**0.216**	-0.09
6.	Number of Flowers	0.093	**0.614**	**-0.22**
7.	Number of Branches	0.052	**0.324**	**-0.18**
8.	Length of Outer Tepal	**0.227**	-0.041	**0.115**
9.	Breadth of Outer Tepal	**0.217**	-0.078	**-0.11**
10.	Apex Angle of Outer Tepal	**0.138**	-0.049	**-0.14**
11.	Length of Inner Tepal	**0.227**	-0.037	0.065
12.	Breadth of Inner Tepal	**0.216**	-0.071	-0.09
13.	Apex angle of Inner Tepal	**0.139**	-0.041	-0.13
14.	Length of Outer Whorl stamen	**0.216**	-0.01	0.06
15.	Breadth of Outer Whorl Stamen	**0.193**	-0.032	-0.07
16.	Length of Filament of Outer Whorl Stamen	**0.191**	0.041	0.299
17.	Breadth of Filament of Outer Whorl Stamen	**0.175**	-0.095	-0.17
18.	Length of Middle Whorl stamen	**0.215**	-0.019	0.059
19.	Breadth of Middle Whorl Stamen	**0.193**	-0.028	-0.06
20.	Length of Filament of Middle Whorl Stamen	**0.191**	0.018	0.245
21.	Breadth of Filament of Middle Whorl Stamen	**0.174**	-0.104	-0.17
22.	Length of Inner Whorl stamen	**0.22**	-0.008	0.029
23.	Breadth of Inner Whorl Stamen	**0.189**	-0.016	-0.07
24.	Length of Filament of Inner Whorl Stamen	**0.203**	0.013	**0.141**
25.	Breadth of Filament of Inner Whorl Stamen	**0.178**	-0.088	**-0.24**
26.	Length of Gland	**0.189**	0.049	**0.176**
27.	Breadth of Gland	**0.18**	0.001	0.043
28.	Length of Staminode	**0.212**	0.001	0.045
29.	Breadth of Staminode	**0.186**	-0.061	**-0.11**
30.	Length of Pistil	**0.228**	-0.023	0.012
31.	Length of Style	**0.202**	0.084	**0.231**
32.	Breadth of Ovary	**0.199**	**-0.129**	**-0.19**
33.	Flower Colour	0.05	**0.242**	**0.23**
34.	Type of Inflorescence	0.042	**0.146**	**-0.22**
35.	Locules of Stamen	0.028	0.057	**0.219**
36.	Length of Peduncle	0.008	**0.172**	-0.03
37.	Shape of Staminode	0.042	0.036	0.23
38.	Presence of Indumentum on Ovary	0.004	0.08	0.024
39.	Presence of Indumentum on Flower	0.016	**0.107**	**0.247**
40.	Length of Inflorescence	0.02	**0.286**	-0.06
41.	Opening of Flower During Anther dehiscence	0.004	**-0.128**	**-0.25**
	Eigenvalues	233.03	0.307	0.129
	Percentage	99.703	0.132	0.055
	Cum. Percentage	99.703	99.835	99.89

C. Cluster Analysis

UPGMA phenogram based on inflorescence and floral characters separated the accessions into 2 principal clusters beween the Euclidean distance 0.024-2.135 (Fig. 4). The first principal cluster constitutes *C. travancoricum* and *C. heyneanum* while the rest of the taxa constitute the second principal cluster. The most diverged species was found to be *C. travancoricum* at a distance of 1.709. The closely related species were found to be *C. agasthyamalayanum* and *C. nilagiricum* with a Euclidean distance 0.347.

D. Principal co-ordinate Analysis

PCoA gave true species co-ordination (Fig. 5). In the scatter plot, the distantly placed taxa were found to be *C. travancoricum* and *C. heyneanum.* The closely associated species were *C. agasthyamalayanum* and *C. nilagiricum.* This implies that the results are harmonious with the cluster analysis.

IV. DISCUSSION

Three groups were distinguished in *Cinnamomum* based on the type of inflorescence- 1) Racemiform 2) Simple cyme 3) Panicle of cyme. The first type of inflorescence is the identifying feature of *C. travancoricum*. The second type of inflorescence is observed in *C. heyneanum*, while the rest of the other taxa found to have the third type of inflorescence, which is the most predominant one within the genus. Even though the panicle of cyme inflorescence is the predominant one, it is further categorized into three groups - short (<5 cm), long (5-10cm) and elongated (>10cm). The short inflorescence is exhibited by *C. chemungianum*, *C. dubium*, *C. filipedicellatum*, *C. mathewianum*, *C. mathewianum* var. *ponmudianum*, *C. mohananii* and *C. perrottetii*. The long inflorescence is present in *C. agasthyamalayanum*, *C. nicolsonianum*, *C. nilagiricum*, *C. riparium*, *C. sulphuratum* and *C. verum* The elongated inflorescence is seen in species like, *C. cassia*, *C. goaense*, *C. keralaense*, *C. litseaefolium*, *C. macrocarpum*, *C. malabatrum*, *C. moozhiyarense*, *C. tamala*, *C. walaiwarense* and *C. wightii*.

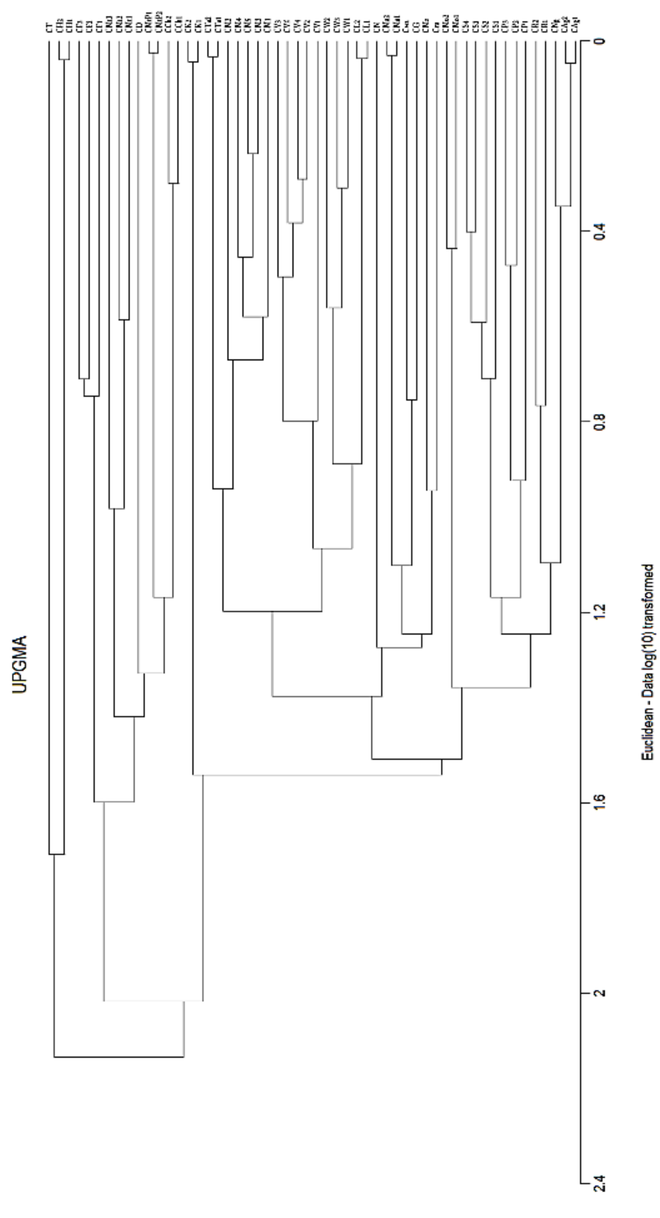

Figure 4. UPGMA phenogram based on qualitative and quantitative floral characters (MVSP 3.1)

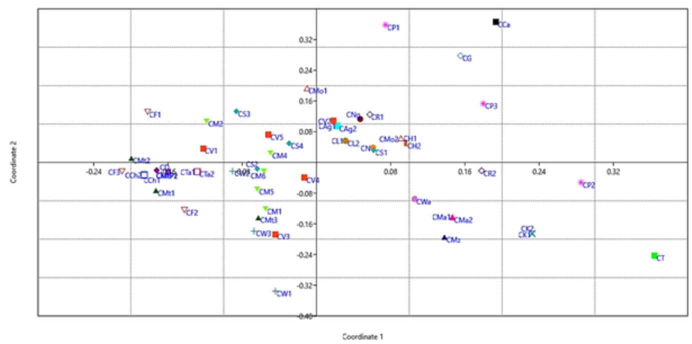

Figure. 5. UPGMA phenogram based on qualitative and quantitative floral characters (PAST 3.01)

In the opinion of Chuang and Heckard (1976), the evolutionary pathway in inflorescences is from elongate more-flowered type to the reduced few number of flowers and ultimately to one. From this evolutionary point of view, the species *C. cassia*, *C. goaense*, *C. keralaense*, *C. litseaefolium*, *C. macrocarpum*, *C. malabatrum*, *C. moozhiyarense*, *C. tamala*, *C. walaiwarense*, and *C. wightii*. might be primitive and *C. agasthyamalayanum*, *C. nicolsonianum*, *C. nilagiricum*, *C. perrottetii*, *C. riparium*, *C. sulphuratum* and *C. verum* may be in the transitional stages, while *C. chemungianum*, *C. dubium*, *C. filipedicellatum*, *C. heyneanum*, *C. mathewianum*, *C. mathewianum* var. *ponmudianum*, *C. mohananii* and *C. travancoricum* may be the evolved ones.

The perianth evolution in angiosperms is a debated subject concerning the origin of flower (Jaramillo and Kramer, 2004). The genus *Cinnamomum* have undifferentiated perianth with 6 perianth units arranged in 2 whorls of three each. Undifferentiated perianth is one that lacks clear distinction between the outer and inner whorls; these have been traditionally recognized as tepals (Cronquist, 1988; Takhtajan, 1997). From the evolutionary point of view, undifferentiated perianth is considered as the primitive form. The genus *Cinnamomum* shows a trimerous pattern in merosity in all the taxa. Perianth merosity has been of particular interest with regard to the origin of trimerous flowers (Kubitzki, 1987). The ancestral character state for the large clade including magnoliids is with trimerous perianth. So *Cinnamomum* shows an ancestral condition with trimerous pattern in flower merosity.

Based on floral morphology, there are two groups-1) flowers do not wide opened during anther dehiscence 2) flowers wide opened during anther dehiscence. The first group of flower type was observed in *C. mathewianum*, *C. mathewianum* var. *ponmudianum*, *C. filipedicellatum* and *C. chemungianum*, while the rest of the species have widely opened flowers. These species also observed to have a low fruit set which may be due to the unopened nature of flowers which reduces the chances of successful cross-pollination. These species also have glabrous flowers differing from the other species with pubescent flowers. Regarding perianth colour, there is great diversity exhibited by *Cinnamomum* species. Perianth is dark pink coloured in *C. chemungianum* and *C. mathewianum* var. *ponmudianum*; light pink colour in *C. filipedicellatum*; yellow in*C. goaense, C. riparium, C. tamala* and *C. walaiwarense*, greenish yellow in *C. heyneanum, C. keralaense, C. malabatrum, C. macrocarpum, C. cassia, C. nicolsonianum* and *C. mohananii*; green in *C. travancoricum*; white in *C. dubium*; brown in *C. perrottetii* and *C.wightii*; Brownish yellow in *C. sulphuratum*; pale yellowish green in *C. litseaefolium* and *C. verum*; whitish yellow in *C. agasthyamalayanum* and *C. nilagiricum*; green with maroon top in *C. mathewianum*. The new species also have yellow flowers.

The stamens of *Cinnamomum* also offer groupings based on the number of anther locules. Out of the 26 taxa studied, the newly reported species, *C. mathewianum* and the new variety *C. mathewianum* var. *ponmudianum* were the only taxa which are reported to have 2-locular stamens in all the three whorls, so far. *C. agasthyamalayanum*, *C. litseaefolium* and *C. dubium* have 4-locular stamens in the first two whorls and 2-locular stamens in the inner whorl. As per the species protalogue, *C. nilagiricum* have 4-locular stamens in all the three whorls, but after thorough and repeated examination of flowers, it was found that the 2-locular inner whorl stamens are predominant in the species and the authors might have made an erroneous description regarding the character. All the other species have 4-locular stamens in all the three whorls. The anther locules have evolutionary significance also. Drinnan *et al.* (1990) pointed out that bisporangiate anthers are primitive within the Lauraceae since all close outgroups have bisporangiate anthers and the earliest known fossil lauraceous flowers have bisporangiate anthers as weIl. But according to Rohwer (1994), it is difficult to interpret a change from the bisporangiate to the tetrasporangiate condition. He doubts about the kind of selective pressure which favor the advent of additional, initially non-functional pollen sacs either distally or proximally from the existing, functional ones and questions that why should the end products, tetrasporangiate anthers in both cases, look so similar? If more pollen sacs were advantageous then hexa- or octosporangiate anthers should also arise in the same way. In this context he suggested that reduction from four pollen sacs to two, on the other hand, appears much more likely and it can be interpreted as both more economical and allowing an even more precise presentation of the pollen. Hence, Rohwer (1994) opinioned that the 2-locular stamens are developed by the degeneration of either the upper two locules or the lower two locules. In this regard, this may be the fact that the species with 2-locular stamens may have originated from the species with 4-locular stamens through the species with 4+2-locular stamens which may be the intermediate ancestors.

The presence of staminodes is considered as a secondary derived character in basal angiosperm (Leins *et al*. 1988). Species of *Cinnamomum* also exhibit great variation in the size and shape of staminodes also. Ovary is hypogynous or epigynous in nature. Based on the indumentum on ovary, there are two categories in *Cinnamomum*. One group has indumentum present on the ovary surface and the other group didn’t have indumentum on ovary. The first group includes *C. malabatrum, C. tamala* and *C. sulphuratum* while, the rest of the other taxa have glabrous ovary. From evolutionary point of view, hypogynous nature of ovary is a primitive character. According to Jaramillo *et al*. (2004), the ancestral state of carpel fusion among magnoliids is syncarpy (85%) rather than apocarpy (15%). Therefore, syncarpous gynoecium in *Cinnamomum* is primitive in nature.

Based on morphometric analysis, the most loaded characters in PCA were, Flower Colour, Type of Inflorescence, Locules of Stamens, Shape of Staminode, Presence of Indumentum on Flower, Length of Inflorescence and Opening of Flower During Anther dehiscence, which can be successfully used for delimiting the species. Applying the same in quantitative characters, Inflorescence Length, Peduncle Length, Number of Flowers and Branches of Inflorescence, Length and Breadth of Outer and Inner tepals, Stamens, Glands, Staminode; Length of Pistil, Style and Breadth of Ovary were the taxonomically significant traits.

The UPGMA clustering provided two principal clusters in which *C. travancoricum* and *C. heyneanum* constitutes the first principal cluster and *C. travancoricum* also constitute the most distantly placed taxa among the others. This may be due to the racemiform inflorescence and largest flower and floral whorls. The second most diverged species was found to be *C. heyneanum* due to the short simple cyme inflorescence. The species with unopened glabrous flowers were clustered together which demonstrates their close relationship based on floral characters. In the dendrogram, the closely associated species were found to be *C. agasthyamalayanum* and *C. nilagiricum* with a very low Euclidean distance (0.35). This attributed the indistinguishable floral features of both the species.

In the phenogram, it is clear that the accessions showed species delimitation and it confirms the floral characters being species specific. These distinguishing morphological features observed in the study are of systematic value because they are consistently different between the species and still consistent within the species studied.

V. CONCLUSION

Cinnamomum species are readily identified by the trinerved and fragrant leaves, paniculate inflorescences, flower with nine stamens and the fruits seated on a cupule. The overlapping morphological characters make the identification a burdensome task at the species level. In order to identify the key reproductive characters that are valuable in identifying the species and to clarify the phylogenetic relationship among them, a cladistics approach was made in the present study using fifty-four accessions belonging to the 26 South Indian species. All the species have panicle of cyme inflorescence except *C. travancoricum* and *C. heyneanum* which have racemiform inflorescence and simple cyme inflorescence respectively. The species viz. *C. chemungianum, C. filipedicellatum, C. mathewianum* and *C. mathewianum* var. *ponmudianum* have glabrous flowers and pedicels and are unopened during anther dehiscence. While, rest of the species have pubescent flowers which are wide open during anther dehiscence. The species also showed variations in the size and shape of staminodes. *Cinnamomum mathewianum* and *C. mathewianum* var. *ponmudianum* are the only taxa with 2-locular anthers in all the three whorls of stamens and are considered as evolved species. UPGMA dendrogram constructed based on all the floral characters resulted in the clustering of *C. agasthyamalayanum* and *C. nilagiricum* as the most closely related species. Therefore, evidence provided by the floral morphological characters, if properly interpreted, can help to support and strengthen the newly emerging molecular phylogeny of the genus and facilitate understanding of the evolution of taxa in the family.

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