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Leaf Architecture in Indian Coffee (*Coffea arabica* L) Cultivars and Their Adaptive Significance

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Astract: Leaf architecture including venation pattern was studied in ten different Indian arabica (*Coffea arabica* L.) cultivars. In general, the leaves are simple opposite with moderate mid-vein and entire margin. The major venation pattern is camptodromous type with festooned brochidodromous secondaries. The angle of divergence of secondary veins is obtuse and more or less uniform. Intersecondary veins are noticed in all cultivars. The marginal ultimate venation is either incomplete or incompletely looped. The leaf size, areole size, number of vein endings entering the areole and vein islets termination number showed variation in different cultivars and is attributed to their origin involving different parents and selection pressure. The adaptive significance of leaf architecture is discussed. The study further indicated that the cultivars, Sln.7.3, Sln.9, Sln.11 and Sln.5 have inherent structural advantage over other arabica cultivars to cope with the water distribution during stress conditions.

Key words: *Coffea arabica*, Leaf architecture, Minor venation, Adaptation

INTRODUCTION

The angiosperm flora exhibits a wide range of leaf architecture. Although foliar architecture as a taxonomic tool has been in use since along time, the coherent classification of dicotyledonous leaf architecture by Hickey [1] has stimulated a wider interest in the subject. In the recent past, a large number of workers have successfully used these characters in classifying both extinct and extant plant materials of complex taxonomic groups [2-8]. A perusal of literature reveals that the study on leaf architecture in coffee received little attention. The present investigation is therefore undertaken to study the leaf architecture patterns in ten different cultivars of *C. arabica*.

MATERIALS AND METHODS

Ten Indian arabica (C. *arabica*) cultivars/hybrids constituted the material for the present study and details of their parentage/origin are given in Table 1. Fully expanded third pair of leaves from the terminal part of the branch were collected from ten representative plants. Leaves were immersed in 80% ethanol for 48-72 hrs with several changes of the solvent in order to remove chlorophyll pigments. The leaf samples were then washed and treated with 3-5% Na OH at 60° for 24-36 hrs. The digested leaf tissue was carefully brushed apart to obtain the leaf skeleton. These are further hardened by treating with saturated chloral hydrate solution for several days, washed, dehydrated and preserved. Major venation pattern was studied with the help of a photographic enlarger. For study of minor venation patterns, small bits were cut from the central part of the leaf skeletons (excluding mid rib and marginal parts), stained with safranin and mounted in euparol. Absolute vein islet number and absolute vein termination number were calculated by Gupta [13]; the terminology of Hickey [1] is followed for the description of leaf architecture.

Table1: Details of Coffee selections/cultivars studied and their parentage

Selections/Hybrids	Origin/Parentage
Sln.3 (S.795)	F4 of S.288 x Kents
Sln.4	Agaro (Ethiopian origin)
Sln.5	Devamachy x S.881(Rume Sudan)
Sln.6	*C. canephora* (S.274) x *C. arabica* (Kents)
Sln.7.3	San Ramon x S.795 x Agaro x Hybrido de Timor
Sln.8	Hybrido de Timor (HDT)
Sln.9	HDT x Tafarikela
Sln.10	(Caturra x Cioccie) x (Caturra x S.795)
Sln.1	*C. liberica* x *C.eugenioides*
Sln.12	(Cauvery)Caturra x HDT

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The minor venation pattern viz. vein islet number/mm^2 , vein let's entering areoles/ mm^2 , vein lets termination number/ mm^2 and average size of areoles (mm^2) were critically analyzed microscopically from 50 different slides prepared from leaves from ten different plants to capture the possible variability since observed variability were considered as indicators of drought adaptation. Raw data on these characters is classified using the expression level e.g. maximum observed value was considered as full expression of the character (+++), in the case of vein islet number/ mm^2 , veinlets entering areoles / mm^2 and vein lets termination number/ mm^2 where as the lowest value of the average size of the areoles is desirable and therefore considered as full expression (+++). For classifying the varieties, range (high value – low value) was divided in to three classes of equal intervals (+++, ++ and +) and varieties were assigned to different classes based on observed value. Considering moderate (++) or full (+++) expression of the character as its presence and poor expression (+) as its absence, the above data were converted in to binary data (1=presence, 0 = absence). These data was subjected to hierarchical cluster analysis using squared euclidean co-efficient as a measure of distance and the between groups linkage option was used to generate the dendrogram to understand the relationship of coffee selections with reference to drought adaptation.

RESULTS

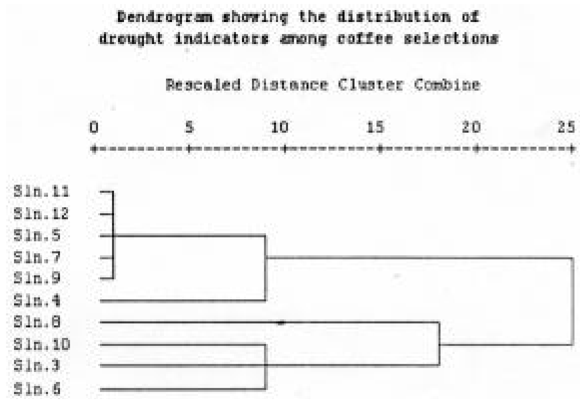
The leaves of all the cultivars studied were simple, opposite with moderate mid-vein and entire margin. In general, the leaf shape was variable and found to be elliptic in Sln.3, Sln4, Sln.5, Sln.6, Sln.8, Sln.9 and Cauvery. wide-elliptic in Sln. 7.3 and mostly elliptic but occasionally narrow elliptic in Sln.11. In all cases the leaf apex was acuminate but in Sln. 7.3 mucronate apex was occasionally observed. The leaf base was either acute or obtuse (Table 2).

Major Venation Pattern: The venation pattern conformed to pinnate camptodromous type with festooned brochidodromous secondaries. The secondary veins are produced on both sides of the primary vein in an alternate or sub-opposite fashion. The number of secondary veins showed little variation (Table) and their angle of divergence was obtuse and more or less uniform in different selections studied. It was observed that the secondaries upturned and joined together in a series of prominent arches to form brochidodromous pattern (Fig 1) instead of terminating at the margin. Secondaries were found to be inconspicuous towards the tip portion.

The intersecondary veins as the name indicates were found to be intermediate in thickness between the second and third order veins and were observed in all selections

Table 2: Qualitative features of leaves of different cultivars of *Coffea arabica*

Cultivars	Leaflet shape	Apex	Base	Margin	Venation Type	Inter Primary Vein	Tertiary Secondary Vein	Marginal vein pattern	ultimate venations	Areole	Areole shape
Sln.3	Elliptic	Acuminate	Obtuse	Entire	Campto-brochido dromus	Moderate straight	Composite	Random reticulate	Incomplete	Imperfect	Irregular
Sln.4	Elliptic	Acuminate	Obtuse /Acute	Entire	Campto-brochido dromus	Moderate straight	Composite	Random reticulate	Incomplete	Imperfect	polygonal
Sln.5	Elliptic	Acuminate	Obtuse /Acute	Entire	Camptobrochido dromus	Moderate straight	Composite	Random reticulate	Incomplete	Well developed	Irregular
Sln.6	Elliptic	Acuminate	Obtuse	Entire	CamptoBrochido dromus	Moderate straight	Composite	Random reticulate	Incompletely looped	Well developed	Pentagonal/ polygonal
Sln.7.3	Wide Elliptic/ Elliptic	Acuminate /mucronate	Obtuse	Entire	Campto-brochido dromus	Moderate straight	Composite	Random reticulate	Incomplete	Well developed	Quadrangular/ penta - gonal
Sln.8	Elliptic	Acuminate	Obtuse	Entire	Campto- brochido dromus straight	Moderate	Composite reticulate	Random looped	Incompletely	Imperfect	Irregular
Sln.9	Elliptic	Acuminate	Obtuse	Entire	Campto -brochido dromus	Moderate straight	Composite	Random reticulate	Incomplete	Imperfect	Variable
Sln.10	Wide Elliptic	Acuminate	Obtuse	Entire	Campto- brochido dromus	Moderate straight	Composite	Random reticulate	Incomplete	Imperfect	Variable
Sln.11	Narrow Elliptic	Acuminate	Obtuse	Entire	Campto- brochido dromus	Moderate straight	Composite	Random reticulate	Incompletely looped	Well developed	Irregular
Sln.12	Elliptic	Acuminate	Obtuse	Entire	Campto-brochido dromus	Moderate straight	Composite	Random reticulate	Incomplete	Imperfect	Irregular



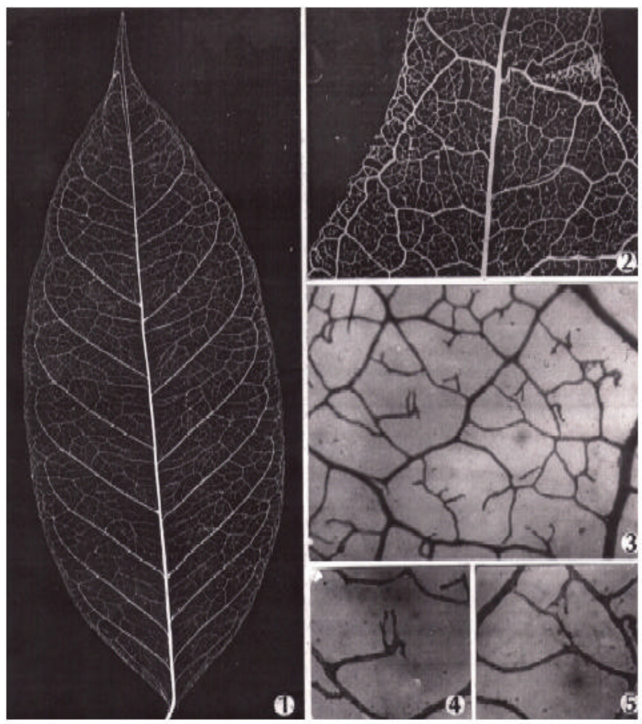


Fig. 1-5: *Coffea Arabica*

1. Cleared whole leaf of Sln.3 showing venation pattern
2. Incompletely looped marginal ultimate venation in Sln.6
3. Portion of cleared leaves showing areoles and minor venation pattern in Sln.6
4. Dichotomously branched veinlets (Sln.6)
5. Areoles without veinlets and areoles with curved veinlets (Sln.6)

(Fig 1). They originated from the medial primary vein and were interspersed between the secondary veins. Intersecondary veins were usually shorter in length than the secondary veins and parallel to the latter in position.

Tertiary veins were the next order of finer branches originating from the secondary veins. These were found to be random reticulate and oblique to mid-vein without any definite pattern.

Minor Venation Pattern: The fine order of veins originating from the tertiaries and those of same size originating from the primary and secondaries constituted the quaternary veins. In all the selections studied, the highest order of veins was identified upto 5° and the higher order veins too have no definite pattern of origin. The marginal ultimate veins were incomplete in majority of the cases except in Sln.6, Sln.8 and Sln.11 where incomplete looping was seen (Fig 2).

Table 3: Numerical data on the venation patterns of the leaves of different Arabica coffee cultivars

Cultivar	Leaf area (mm^2)	No. of veins on one side	Angle and between 1° 2° veins	Vein islets (Areoles)/ mm^2	Veinlets entering areoles/ mm^2	Veinlets termination number/ mm^2	Average size of areoles (mm^2)	Absolute vein islet number (000s)	Absolute vein islet termination number (000s)
Sln.3	9671	8-12	45° - 66°	4.85	3.75	5.7	0.52	46.904	55.124
Sln.4	7979	9-14	45° – 67°	4.65	5.45	8.1	0.51	37.102	64.629
Sln.5	9404	9-14	50° – 60°	7.25	6.05	7.9	0.35	68.179	74.291
Sln.6	10876	9-15	45° - 68°	6.60	4.95	6.2	0.44	71.781	67.431
Sln.7.3	7756	8-15	50° - 75°	7.90	6.45	8.9	0.34	61.272	69.028
Sln.8	8665	9-13	50° - 66°	2.50	3.65	6.0	0.62	21.662	51.990
Sln.9	9184	9-13	45° -75°	6.55	6.05	9.5	0.40	60.155	87.248
Sln.10	7477	8-12	45° - 65°	3.30	5.00	6.2	0.60	24.674	46.357
Sln.11	5976	9-12	45° - 65°	7.55	7.65	9.1	0.33	45.118	54.082
Sln12	8823	8-13	48° - 70°	4.45	6.95	8.7	0.45	39.262	76.760

Areoles: The areoles are the smallest areas of the leaf tissue surrounded by major veins and form a contiguous field over most of the leaf area. In the present study, areoles were well developed or imperfect (Table 2) areoles may be quadrangular, pentagonal or irregular in shape (Fig 3). and the size of the areoles varied in different selections (Table 3).

Observations on ultimate veins revealed both simple and branched type of veins. The simple vein endings were found to be linear or curved (Fig 5), while the branched ones divided dichotomously at one, two and sometimes at three different places (Fig 4). The vein lets were uniseriare, biseriate or even multiseriate. The number of vein endings and veinlet terminations per areole varied without any correlation in different selections. Areoles without any veinlets were also observed(Fig 5).

DISCUSSION

From the present study, it is apparent that leaves in all selections of *Coffea arabica* are simple with camptobrochidodromous type of venation. In all cases composite intersecondary veins were observed. In many woody perennials of Cunoniaceae and Bignoniaceae brochidodromous venation pattern and intersecondary veins are commonly observed [9,4]. Basing upon the size class, the leaves of all the arabica cultivars belong to the mesophyll type. Despite general nature of mesophyll type of leaves in *C. arabica* variation was observed among different cultivars. The small and large sized leaves encountered in Sln.11 and Sln.6 respectively could be attributed to the interspecific origin of these cultivars involving different parents (Table 1).

In all the cultivars examined, marginal ultimate venation is either incomplete or incompletely looped. A similar situation was also observed in many woody species of Cunnoniaceae (Dickison 1975), Bignoniaceae [4] and *Onchotheca balansae* [10]. The main function of marginal venation in leaf is to avoid desiccation [11]. Hence, the cultivars with incompletely looped margined leaves have an adaptive advantage in drought prone areas.

An important aspect of foliar architecture is the minor venation pattern contrasting reports are available regarding the taxonomic utility of minor venation pattern in different plant species. According to Levin [12], Gupta [13] and Varghese [14] the vein islet number is more or less constant for a species and could be used as a specific character. In contrary, Banerjee and Das [15], Sehgal and Paliwal [2]. Singh, Jain and Sharma [16] and Jain [4] suggested that the size of the areole, the number of vein endings and vein islet termination number are highly variable and can not be used as reliable taxonomic criteria, particularly in genera with large number of species. In the present study, though the basic minor venation pattern is same in all the cultivars, notable differences in the size and number of areoles, vein islet number and their termination number were observed. Although all the cultivars studied belong to the tetraploid species *C.arabica*, the quantitative differences in minor venation pattern could be attributed to their differential genetic architecture.

Minor veins serve both mechanical and conducting functions of the leaf. Hence, quantitative differences in the minor venation pattern may reflect on physiological or adaptive significance. The proliferation of terminal veinlets within individual vein islets increase mesophyll contact area and thus facilitate the leaf water movement. The present study indicated that in Sln.5,Sln.7.3,Sln 9 and Sln.11 vein islets are very small and veinlet proliferation inside the areole is more extensive compared to other selections. This may provide an added advantage to combat drought and better field performance of these cultivars in marginal areas.

From the foregoing discussion, it can be inferred that the cultivars falling in the first two clusters are likely to be highly adaptable in drought prone areas. This draws support from the earlier studies that implicated leaf thickness, praline accumulation in leaf tissues and the stability of nitrate reductase activity as indicators of drought tolerance [17,18,19]. Field performance data also indicated the adaptation of Selections-5, 9 and 11 in drought prone areas [20]. An important conclusion that can be drawn from this study is that minor venation pattern is an indicator of drought adaptation in coffee and can be effectively used in recommending cultivars for exploitation in drought prone areas.

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