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LEAF TRAIT ANALYSIS OF FIVE ENDANGERED PLANT SPECIES OF WESTERN GHATS

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ABSTRACT
Recent studies have revealed variation of leaf traits across various plant life-forms on a global scale. This study aims to analyze and compare the leaf-trait strategies of selected RET (Rare Endangered and Threatened) plant species of Western Ghats. The present study was carried out in an experimental plot established in KFRI Nilambur, a tropical moist deciduous site on the Nilgiri biosphere of India. We selected five RET plant species to analyze and compare their leaf-trait strategies. For each species, we collected 30 healthy leaves from at least five individuals. The collected leaf samples were analyzed for various leaf functional traits using standard protocol. Leaf area was analyzed using Image J (IJ) software. Leaf thickness was measured using digital screw-gauze. The study also checks whether these five species differ in their anatomical traits. Cluster analysis was made among them to check for relationship between different leaf traits.

KEYWORDS: Anatomical traits, leaf-lamina area, leaf nitrogen, leaf thickness, leaf tissue density, specific leaf area.

INTRODUCTION
Plant functional traits are robust indicators of how plant species survive and establish in constraints of their biotic and abiotic environment using physiological, morphological and phenological adaptations (Gallagher *et al*., 2012). Globally, there is growing consensus that functional traits can provide greater insight into the diverse ecological and life-history strategies among plant species (Grime, 1977; Diaz and Cabido, 2001; Westoby and Wright, 2006; Lavorel and Grigulis, 2012) with the recognition that there are inevitable trade-offs in strategies associated with particular suits of traits (Bloom *et al.*, 1985; Grime *et al.*, 1997; Reich *et al.*, 1997; Diaz *et al.*, 2004). Therefore, as a result, plant functional traits are being largely used rather than their taxonomic identity for understanding diversity and dynamics of vegetation world-wide (Westoby and Wright, 2006; Kattege *et al.*, 2011).

In the present study anatomical, morphological and biochemical trait of five RET (Rare Endangered and Threatened) plant species *Garcinia morella (Gaertn.)Desr.*, *Kingiodendron pinnatum*(DC) Harms. *Syzygium stocksii* (Duthie) Gamble, *Knema attenuate* Warb. and *Aglaia barberi* Gamble were studied. By doing the micrometry of sections of leaf, petiole and trichomes, a comparative analysis and taxonomic importance of the selected plants were determined.

Objective
1. To assess the morphological and anatomical properties of the endemic plant species.
2. In this study, we will discuss the adaptive value of some morphological and anatomical traits in the various organs of endemic plants growing under the changing climatic conditions.
3. To analyse whether multiple species coexist with diverse leaf trait strategies within Western Ghats.
4. To study the characterisation of plant functional traits within the Western Ghats, which is vital for our understanding of key ecological processes.
5. To explore whether plants of Western Ghats exhibit similarities or dissimilarities in their traits.

MATERIALS AND METHODS
Study area
The data for this study were collected from KFRI (Kerala Forest Research Institute) sub centre Nilambur. The Kerala Forest Research Institute Sub Centre (KFRI Sub Centre) is situated in the fringe area of the Nilgiri Biosphere Reserve (76^0 15' 28" E longitude and 11^0 18' 14" N latitude).

30 healthy leaves were collected from four individuals of the selected RET plant species such as *Garcinia morella* (Gaertn.) Desr., *Kingiodendron pinnatum* (DC) Harms, *Syzygium stocksii* (Duthie) Gamble, *Knema attenuate*

Warb. and *Aglaia barberi* Gamble. each individual leaf was given a unique sequential code and the following leaf functional traits were analyzed: Leaf fresh weight (g), Leaf thickness (Lth, mm), Leaf-lamina area (LA, cm2), specific leaf area (cm2 g-1, SLA), mass based leaf nitrogen concentration (N mass, mg g-1) and leaf tissue density (Ltd g cm-3). Leaf dry weight (g) was measured after drying the leaf samples at 80°C for 48 hours. All other measurements were taken ≤ 2 hours following leaf collection from the field. Estimation of Chlorophyll Content was done by Arnon method (1949).

pH was measured with a calibrated pH meter. All the leaf functional traits were determined following Perez-Harguindeguy *et al.*, (2013). Lth was measured using digital screw-gauze at the intermediate point between border of the leaf and the midrib, avoiding secondary veins. LA (one sided area of a fresh leaf) was measured using Image J (IJ) software. SLA was calculated as fresh leaf area (cm^2) / leaf dry weight (g). LDMC was calculated as leaf dry weight (mg) / fresh leaf area (cm2). Leaf tissue density (g cm^{-3}) was calculated as LDMC (g cm^{-2}) / leaf thickness (cm). To measure leaf nitrogen, samples were dried at 80°C for 48 hours, ground to a fine powder, and analyzed on a CHNS analyser (varioEL cube V3.1.8 (e638c54) 2015-01-21, CHNS Mode, Ser. No.: 19151007 Elementar Analyser system GmbH, Germany).

pH Determination

1g Fresh leaves of each sample were collected and grinded with mortar and pestle and was extracted using distilled water.

Procedure

The pH of green leaf tissue of each sample (leaf litter), measured by grinding up the tissue and extracting it with distilled water. Shake gently with shaker and centrifuged. The extract was collected and pH was measured with pH meter.

Chlorophyll extraction

Fresh leaf of each sample (0.2 g) were collected and weighted and taken in a test tube and grinded with 10 ml of 80% acetone in mortar using pestle. It was centrifuged 3 or 4 times, supernatant was separated and 0.5 ml of it mixed with 4.5 ml of 80% acetone. Then the solution was transferred into a 1 cm cuvette, measured the absorbance on spectrophotometer at 645nm and 663nm.

Anatomical trait

The leaves and petiole of the selected five plant species were collected in the month of February 2018 from KFRI sub center nilambur, Malappuram district. Transverse section (T.S). of leaf midrib, leaf lamina and petiole were taken by free hand sectioning method with the help of razors. The sections were stained in Safranine. Trichomes were studied by scrapping. The dimensions were measured by micrometry and photographs were taken by camera. Micrometric measurements were also calculated for each leaf, trichome and petiole. Each cell layer's micrometer was also calculated. It was helpful to measure the dimensions of TS of leaf, petiole and trichomes in terms of length, breadth, diameter and thickness. The value of one division of ocular mirror micrometer can be calculated using formula;

Value of one ocular division = S/O x 0.01

Where, S = Stage micrometer division
O = Ocular micrometer division
The value of division of stage micrometer was 0.01mm / 10µm. The value obtained is known as calibration value. Each objective of the microscope is to be calibrated using the same method.

Biochemical trait

To measure leaf nitrogen, samples were dried at 80° C for 48 hours, ground to a fine powder, and analysed on a CNHS analyser (EURO VECTOR CHNS ANALYSER Model No: EA 3000).

RESULTS AND DISCUSSION

Morphology and taxonomic descriptions

Garcinia morella (Gaertn.) Desr

Evergreen trees, to 18 m high, bark 3-10 mm thick, brownish-grey or brown to dark brown, smooth; blaze dark yellow; exudation dark yellow or orange yellow, sticky; branchlets quadrangular, glabrous. Leaves simple, opposite, decussate, 6-16 x 2.5-9 cm, elliptic-obovate or elliptic-oblanceolate, apex obtuse, obtusely acuminate or caudate-acuminate, base acute or cuneate, margin entire, glabrous, coriaceous; lateral nerves 8-16 pairs, pinnate, arched towards the margin forming intramarginal nerve, slender, prominent, intercostae reticulate, faint; petiole 6-15 mm, stout, glabrous, grooved above, thickened, very shortly ligulate at base. Flowers polygamodioecious, reddish, sessile: Male flowers: 2-4 in axillary fascicles or on old wood; sepals 4 orbicular, decussate, outer pairs smaller than the inner, glabrous; petals 4, little larger than sepals, orbicular, veined, concave; stamens 10-12, monadelphous, the filaments combined in to a subquadrangular central column, anthers red, orbicular, plurilocular; pistillode absent. Female flowers: axillary, solitary, larger than male flowers; staminodes 10-12 in a ring round the ovary, connate at the base; ovary superior, greenish, globose, smooth, 4-celled, ovule one in each cell; stigma peltate, sessile, irregularly lobed, tubercled, persistent, margin dentate. Fruit a berry, 1.5-2.5 cm long, subglobose, or globose, smooth, yellowish or light pink, surrounded at the base by persistent sepals, crowned by flat tuberculate round stigmas, pulp sweet, acidic; seeds 2-4, kidney shaped, laterally compressed, dark brown, testa muriculate. It's fruiting and flowering time is February – August.

***Kingiodendron pinnatum* (DC) Harms**

Kingiodendron pinnatum(DC) Harmsisendangered, and endemic to Southern western ghat. Evergreen trees, to 30 m high, bark 5-8 mm thick, surface greyish-brown with green blotches, rough; exuding a reddish sticky resin.

Leaves imparipinnate, alternate; leaflets 5-9, alternate, 4.5-10.5 x 2-4.5 cm, ovate-lanceolate or oblong, apex acuminate, falcate or oblique, margin entire, glabrous, coriaceous; stipules minute, lateral, cauducous; rachis 10-15.2 cm, slender, pulvinate, glabrous; petiolule 5-10 mm, stout, grooved above, glabrous; lateral nerves 8-13, pinnate, slender, prominent, secondary laterals present, intercostae reticulate, prominent. Flowers are bisexual, 2-3 mm across, white, in axillary and terminal panicled racemes. Calyx tube is almost wanting, lobes 5, broadly ovate, imbricate. Petals are absent and disc very small. Stamens are 10 in number, equal, filaments filiform, villous at base; anthers versatile. Ovary is half inferior, sessile, villous at base; ovules 2; style subulate; stigma minute, oblique. Fruit a pod, 4-5 x 2-2.5 cm, ovate-ellipsoid, turgid, obtusely beaked, prominently veined, dark brown, indehiscent; seed one, pendulous. Fruiting and flowering time of *Kingiodendron pinnatum*(DC) Harms is February – December.

***Syzygium stocksii*(Duthie) Gamble**

Syzygium stocksii (Duthie) Gamble is endangered and endemic to Southern western ghat. Lofty trees, to 15 m high, bark greyish-brown; branchlets tetragonus. Leaves simple, opposite, estipulate; petiole 10-20 mm long, stout, grooved above, glabrous; lamina 8.5-17 x 4-7.5 cm, elliptic, elliptic-oblong or elliptic-obovate, base narrowed and decurrent on petiole, apex rounded or obtusely acuminate, margin entire, chartaceous, glabrous; lateral nerves 9-12 pairs, parallel but very irregular, distant, prominent, curving upwards and becoming faint towards the margin forming indistinct intramarginal nerve, intercostae reticulate, obscure. Flowers bisexual, small, cymes axillary and from the leafless axils half the length of or equaling the leaves; peduncle 2.5-5 cm, branches slender angled; calyx lobes 4, rounded or subacute; no thick staminal disc; petals calyptrate; stamens many, bent inwards at the middle when in bud; ovary inferior, 2-celled, ovules many; style 1; stigma simple. Fruit a berry, pink-purple, 0.8 x 6 cm. It's fruiting and flowering time is March – June.

***Knema attenuate* Warb**

Knema attenuate Warb. is endemic to Western ghat it is seen in evergreen and semi-evergreen forests. Deciduous trees, to 18 m high, bark 6-8 mm thick, surface greenish-black to greenish-brown, mottled with green and white, smooth, exfoliations irregular; exudation watery, red; branchlets horizontal; branchlets rusty tomentose. Leaves simple, alternate, distichous, 8-20 x 2.5-7.5 cm, oblong-lanceolate, oblong or ovate, apex acuminate, base round, or acute, margin entire, glabrous, glossy above and glaucous beneath or rusty pubescent along costae beneath, coriaceous; petiole 1-1.5 cm long, stout, grooved above, rusty pubescent when young and glabrous when mature; lateral nerves 12-16 pairs, parallel, slender, prominent beneath, intercostae scalariform, slender, prominent. Flowers unisexual, in rusty pubescent fascicles on thick peduncle from the axils of leaves or of the scars of fallen leaves; male 1-6 flowered, female 1-3 flowered; pedicel 7-8 mm long; perianth larger in female, rusty tomentose; lobes 3-[4]; androecium usually stalked; filaments and connectives connate in a peltate disc; anthers 8-20, free, attached stellately to the margin of the disc, dehiscing down words. Ovary superior, ovoid, 1-celled, hairy, ovule-1; style short, thick, hairy; stigma 2, laciniate on the margin. Fruit a capsule 2-valved, 3-3.7 cm long, ovoid, apiculate, rusty tomentose; seed one; aril brilliant crimson, laciniate at apex only. It's fruiting and flowering time is December – June.

***Aglaia barberi* Gamble**

Aglaia barberi Gamble is vulnerable and endemic to western ghat. It is seen in Semi-evergreen and evergreen forests. Trees, to 15 m, bark reddish-brown, smooth; young parts covered with reddish-brown, lepidote scales. Leaves imparipinnate, alternate; leaflets 5-7, opposite or subopposite, 4.5-12 x 1.5-4 cm, elliptic-oblong, elliptic-lanceolate or lanceolate apex acuminate, base acute or obliquely acute, margin entire, coriaceous, glabrous above, reddish-brown scales present beneath; rachis 100-120 mm, slender, slightly swollen at base, covered with reddish-brown lepidote scales; lateral nerves 12-15 pairs, parallel, slender, obscure, intercostae obscure. Flowers polygamo-dioecious, yellow, in axillary panicles; peduncle densely scaly; bracts minute, cauducous. Calyx saucer shaped; lobes 5, acute, margin ciliate. Petals 5, orbicular, glabrous. Staminal tube 1 mm long, globose, not contracted at base, undulate along margins, anthers 5, included. Ovary superior, hairy, 1-2-celled; ovules 1-2 in each cell; style short; stigma capitate. Fruit a berry, depressed globose, brown puberulus, 2-3 cm across. It is fruiting and flowering time is December – June.

Anatomical analysis

Garcinia morella (Gaertn.) Desr.

T.S of petiole showed outer two layers of epidermal cell covered with cuticle. Cells of epidermis polygonal, large 2 µm. Hypodermis 2-3 layered 3 µm composed of circular to polygonal chlorenchymatic cells. Cortex 6 to 9 parenchymatic cells and some cells were filled with starch. These parenchymatic cells were circular, oval irregular cells 62 µm. Cortex was followed by 3 – 5 layered, chlorenchymatous cells. Sclernchymatous patches of bundle sheath was seen surrounding the vascular bundle. Bundle sheath cells were polygonal and compactly arranged, in patches. Then adaxial vascular strands together with the bundle sheath separated from the main vascular bundle as seen in *G. morella.* Vascular bundles were conjoint, open. Phloem 4 – 6 layered, 36 µm, cells were circular in nature. Vascular cambium 1 – 2 layered cells rectangular 36 µm. Metaxylem circular 1-2 layered 24 µm. Protoxylem circular 17 µm. Pith was composed of parenchymatous, cells.

T. S. of the leaf showed typical dorsiventral structure. The epidermis of both the surfaces was single layered and covered with cuticle but trichomes were absent. The cells of upper epidermis were elongated polygonal cells

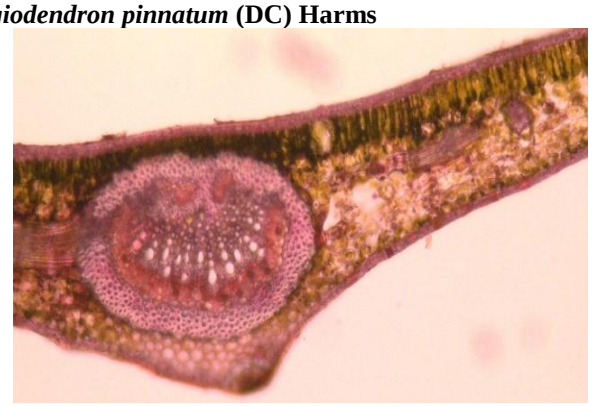
2 µm. Lower epidermal cells oval in shape 2 µm. Upper epidermis followed by vertically elongated, single layered palisade tissue 5 µm. Spongy mesophyll cells were circular, oval, and irregular, 12 µm with inter cellular spaces. Some of the mesophyll cells showed starch grains. At the midrib region, epidermis was followed by single layered hypodermis, restricted to this region. Cortex 4 – 8 layered, polygonal or irregular, collenchymatous cells some of them were filled with oil. Cortex followed by layered sclerenchymatous bundle sheath. Bundle sheath cells were circular, oval, polygonal and compactly arranged 9 µm. Bundle sheath was followed by phloem. Phloem 5 to 9 layered cells and were rectangular and polygonal 3 µm. The main vascular bundle was conjoint, collateral and closed 18 µm. Metaxylem circular to polygonal, 2 –3 layered, facing towards periphery, protoxylem circular to polygonal, situated towards center. Pith was composed of small parenchymatic cells.

***Kingiodendron pinnatum*(DC) Harms**

T.S of petiole shows outer epidermal cell 3 µm covered with thick cuticle. Cortex was parenchymatic and 13 to 15 layered 42 µm and some cells were filled with oil and starch. The resin filled cells were distributed in cortex it was 7 to 9 in numbers. The vascular bundle was different from normal dicot petiole. It has more than one vascular bundle 36 µm. Cortex was followed by collenchymatous pericycle and 3 to 6 layered and followed by sclernchymatous endodermis. Pholems 4 to 6 layered small cells cambium was broadly present. 3 to 4 layered Metaxylem towards the periphery 5 µm, 2-3 layered protoxylem towards the centre 4 µm were also observed. Medullary rays were clearly seen. Small parenchymatous central pith was present. The adjacent vascular bundle was smaller than main vascular bundle, and formation of new vascular bundle was also seen.

T. S. of the leaf showed epidermis in both surfaces single layered and was covered with thick cuticle and trichomes were absent. The cells of upper epidermis were elongated polygonal, large sized 2 µm. Lower epidermal cells were polygonal in shape 2 µm. Upper epidermis followed by vertically elongated, single layered palisade cells was seen 6 µm. Spongy mesophyll cells were circular, oval and irregular 14 µm, with inter cellular spaces. Some of the mesophyll cells showed starch grains. At the midrib region, epidermis was followed by 3 to 6 layered sclernchymatic bundle sheath surrounding the entire vascular bundle. Bundle sheath cells were circular, oval, polygonal and compactly arranged. Bundle sheath was followed by. 3 to 5 layered phloem cells and they were circular to oval in structure. The main vascular bundle conjoint, collateral and, closed 12 µm. Metaxylem circular to polygonal, 2 –3 layered, facing towards periphery4 µm, protoxylem circular to polygonal 3 µm, situated towards center. Pith was composed of sclernchymatous cells and it was the continuation of bundle sheath.

***Kingiodendron pinnatum* (DC) Harms**

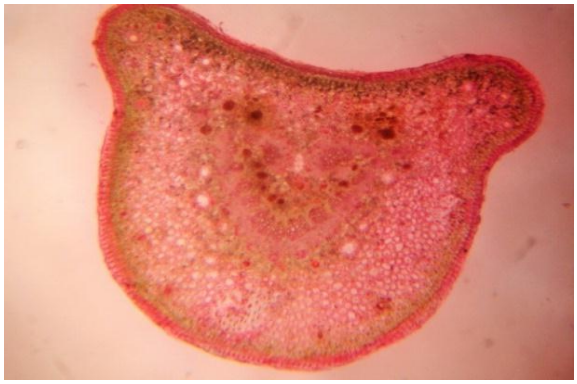


T.S of leaf

T.S of Petiole

***Garcinia morella* (Gaertn.) Desr**

T.S of Leaf



T.S of Petiole

***Syzygium stocksii* (Duthie) Gamble**

T.S of petiole showed heart shaped outline with outer single layered epidermal cells covered with cuticle. Hypodermis 2-3 layered, composed of circular chollenchymatic cells. In the hypodermal region some resin cells were observed. Cortex 9-12 parenchymatic cells and some cells were filled with starch. This parenchymatic cells were circular, oval irregular cells 65.5 µm. Cortex was followed by 3 – 5 layered, sclerenchymatous cells. Inner to this collenchymas cells were also present in two, three layered patches. Sclerenchymatous patches of bundle sheath was seen surrounding the vascular bundle. The stelar region was ovoidal and folded towards the interior side and at the upper side it was widely opened. This folded region was composed of compactly arranged parenchymatous cells with starch deposited cells. Bundle sheath cells were polygonal and compactly arranged 8.0 µm, in patches. Vascular bundles were conjoint, open. Phloem 3-5 layered, 9.0 µm, and cells were circular in nature. Vascular cambium 2-3 layered and cells were rectangular in shape. Metaxylem circular 1-2 layered 14.4 µm. Protoxylem circular and 10.1 µm in size. Primary medullary rays were seen in between xylem vessels.

The transverse section of the leaf exhibited the anatomical characters of a typical dorsiventral leaf. Single layered upper and lower epidermis covered with thick cuticle with polygonal epidermal cells bearing stomata at both sides. The epidermal tissue was 3 µm it followed by chlorenchymatous palisade tissue in a single layer which was absent at the midrib region 7 µm. Mesophyll tissue was seen in 3-4 layers with intercelular spaces. Certain oil cells were observed in between the mesophyll tissues. Mesophyll cells were polygonal / oval and irregularly distributed 24 µm. Stomata were present at the upper epidermis. At the midrib region a large sized stele was observed. The stelar region was composed of a prothallic shaped structure with conjoint collateral closed vascular bundles at the centre 36 µm. Large number of xylem vessels 9 µm was present in 4-6 rows and below the xylem were phloem cells 6 µm in 3-4 layers. The vascular tissues were protected by a bundle sheath composed of sclerenchyma cells. Instead of Palisade and spongy tissues, chollenchyma cells followed by parenchyma cells 15 µm containg starch cells were seen at the mid rib region.

***Knema attenuate* Warb**

T.S of petiole showed a wavy outline with outer single layered epidermal cells covered with cuticle. Cells of epidermis were rectangular in shape, small and 2.0 µm in size. Large number of epidermal hairs was present. Glandular hairs were multicellular and with varying size. Hypodermis 2-3 layered, composed of circular chollenchymatic cells. They were compactly arranged. Wide area of cortex was seen at the underside of the semi-circular stele with parenchyma cells and some cells were filled with starch and other crystal deposits. But the upper side of the stele a narrow region of collenchymas cells were present. The parenchyma cells were circular, oval irregular cells 65.5 µm. Cortex was followed by 3 – 5 layered sclerenchyma cells with resin canals here and there. Sclerenchymatous patches of bundle sheath was seen surrounding the vascular tissues together with some sclerids. Medullary rays were seen in between vascular bundles. Bundle sheath cells were polygonal and compactly arranged 10.1 µm, in patches. Vascular bundles were conjoint, open. Phloem 4 – 6 layered, 8.0 µm, and cells were circular in nature. Vascular cambium 3– 4 layered cells and were rectangular in shape. Metaxylem circular 1-2 layered 14.2 µm. Protoxylem circular and 10.5 µm in size.

T.S. of the leaf showed typical dorsiventral structure. The epidermis of both the surfaces was single layered and covered with cuticle, trichomes were present. The cells of both upper epidermis and lower epidermis were polygonal, in shape. Upper epidermis 3 µm was followed by vertically elongated, double layered palisade tissue 8 µm, at the midrib region but single layered at other places. Some elongated glandular cells were seen at the midrib region extending towards each side of the midrib. Spongy mesophyll cells were circular, oval, rectangular and irregular, with inter cellular spaces 15 µm. Some of the mesophyll cells showed starch grains and also some glandular cells. At the midrib region, epidermis was followed by a single layered palisade tissue. At the lower side, cortex consisted of 4-6 layered, polygonal or irregular, collenchymatous cells followed by 4-6 parenchymatous cells 25 µm, some of them were filled with oil glands. Cortex followed by multilayered sclerenchymatous bundle sheath 9 µm. Bundle sheath cells were polygonal followed by phloem at the lower side of the xylem. Phloem 3 to 4 layered cells and were rectangular and polygonal 9 µm. The main vascular bundle was conjoint, collateral and closed. Metaxylem circular to polygonal, 2 –3 layered, facing towards periphery 12 µm, protoxylem circular to polygonal, situated towards centre 6 µm. Pith was composed of small chollenchyma cells 9 µm. Stomata were present at the upper and lower epidermis.

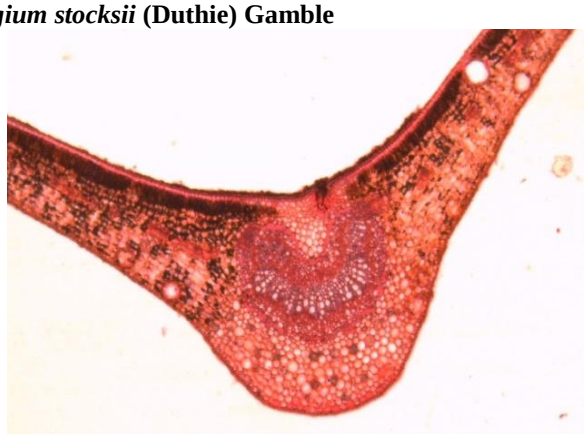
***Aglaia barberi* Gamble**

T.S of petiole showed a wavy outline with a projection at one side and the outer single layered epidermal cells were covered with cuticle. Cells of epidermis were rectangular in shape, small and 2.0 µm in size. Hypodermis 2-3 layered, composed of sclerenchyma cells. Below the hypodermis, outer cortex composed of collenchyma cells 4-5 layers followed by inner cortex having 6-7 layers of parenchyma cells. Starch cells were present in the inner cortex. The parenchyma cells were circular, oval irregular cells 65.5 µm. Sclerenchymatous bundle sheath was seen surrounding the vascular tissues together with some sclerids. Vascular bundles were conjoint, open. Phloem 3-4 layered, 8.0 µm, and cells were circular in nature. Vascular cambium 3– 4 layered cells rectangular. Metaxylem circular 1-2 layered 14.2 µm. Protoxylem circular and 8.5 µm in size. The central

region of the stele was composed of compactly arranged parenchyma containing resin cells.

T.S. of the leaf showed typical dorsiventral structure. The epidermis of both the surfaces was single layered 3 µm and covered with cuticle but trichomes were present. The cells of upper epidermis were polygonal and Lower epidermal cells oval in shape 2 µm. Upper epidermis was followed by vertically elongated, double layered palisade tissue 6 µm. Spongy mesophyll cells were circular, oval, rectangular and irregular, with inter cellular spaces 21 µm. Some of the mesophyll cells showed starch grains. At the midrib region, epidermis was followed by single layered hypodermis, followed by a single layered palisade tissue. At the lower side, cortex consisted of 4-6 layered 9 µm, polygonal or irregular, collenchymatous cells followed by 4-6 parenchymatous cells 9 µm, some of them were filled with oil glands. Cortex followed by multilayered sclerenchymatous bundle sheath 6 µm. Bundle sheath cells were circular, oval, polygonal and compactly arranged. Bundle sheath was followed by phloem at the lower side of the xylem. Phloem 5 to 7 layered cells and were rectangular and polygonal 9µm. The main vascular bundle was conjoint, collateral and closed. Metaxylem circular to polygonal, 2 –3 layered, facing towards periphery 8 µm, protoxylem circular to polygonal 4, situated towards centre. Pith was composed of small chollenchyma cells.

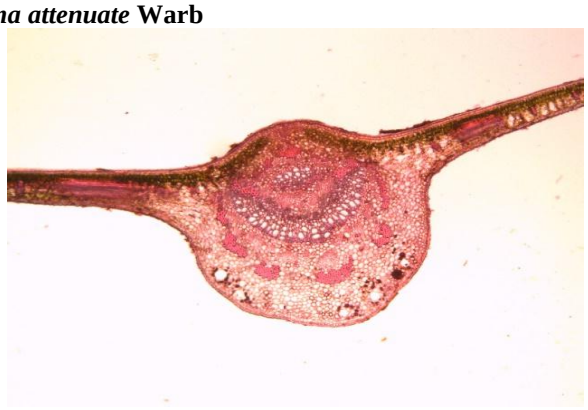
***Syzygium stocksii* (Duthie) Gamble**



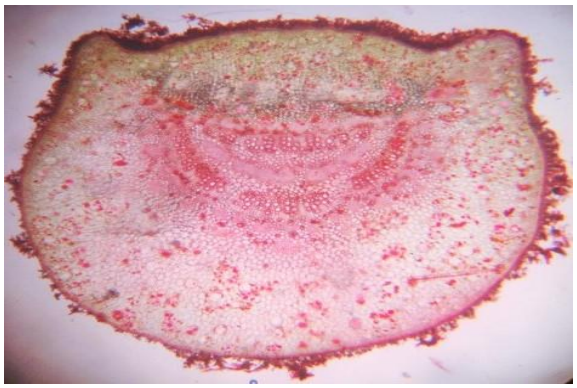
T.S of leaf

T.S of petiole

***Knema attenuate* Warb**

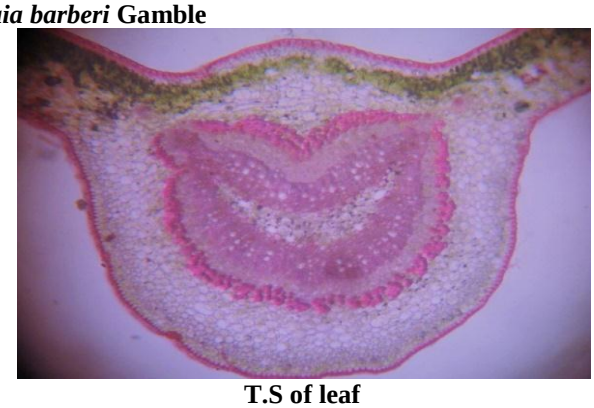


T.S of leaf



T.S of petiole

***Aglaia barberi* Gamble**



T.S of leaf

T.S of petiole

Morphological and biochemical traits

Leaf trait variability among species

Across the studied species, there was a strong variability in the leaf traits; for example Specific leaf area (SLA) varied four fold, from 58 g m-2 (*Garcinia morella*) to 224.12 g m-2 (*Kingiodendron pinnatum*) (Table 4). In general, micronutrients and non-essential elements exhibited a greater inter-specific variability (Tables 4). The N concentration was also high in *Kingiodendron pinnatum* and lowest in *Garcinia morella*.In the multivariate analysis of leaf traits (by Correspondence analysis), the first axis (explaining a 64.31 % of the variance) was positively related to Ltd, SLA (Fig. 1). *Kingiodendron pinnatum* and *Garcinia morella* are strongly associated than other species. Ltd and SLA are positively associated with *Kingiodendron pinnatum* as well as *Aglaia barberi* but negatively associated with *Garcinia morella*. *Syzygium stocksii* dissimilar to *Kingiodendron* and *Garcinia*. Nitrogen content, pH, Carbon content, Lth and LDMC are positively associated with *Garcinia morella*. *Knema attennuata* is not positively associated with any of the leaf traits. *Syzygium stocksii* is strongly associated with Leaf area.

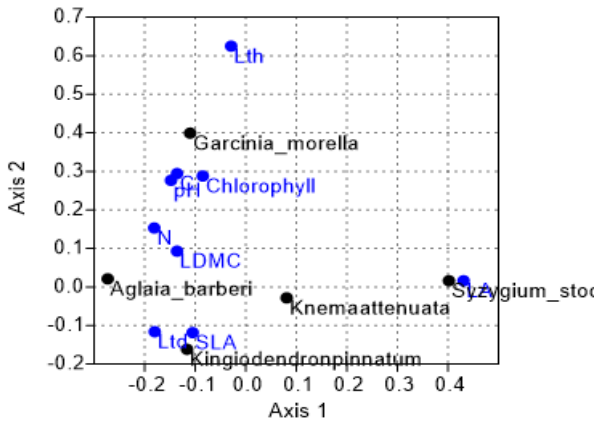
Fig. 1: Correspondence analysis scores – the diagram is given separately based on the table.

Table 1.

Axis	Eigen value	% of total
1	0.049863	64.31
2	0.0265005	34.178
3	0.00103108	1.3298
4	0.000141242	0.18216

Links among leaf traits at the species level

The relationships among leaf traits were not always consistent at the species level. In most cases, the species-level similarity was stronger in three species. For example, in cluster analysis analysis *Syzygium stocksii* (Duthie) Gamble, *Knema attenuate* Warb. and *Aglaia barberi* Gamble were significantly related, whereas no significant relationship was found in *Garcinia morella(Gaertn.)Desr* and *Kingiodendron pinnatum*(DC) Harms. (Fig. 2).



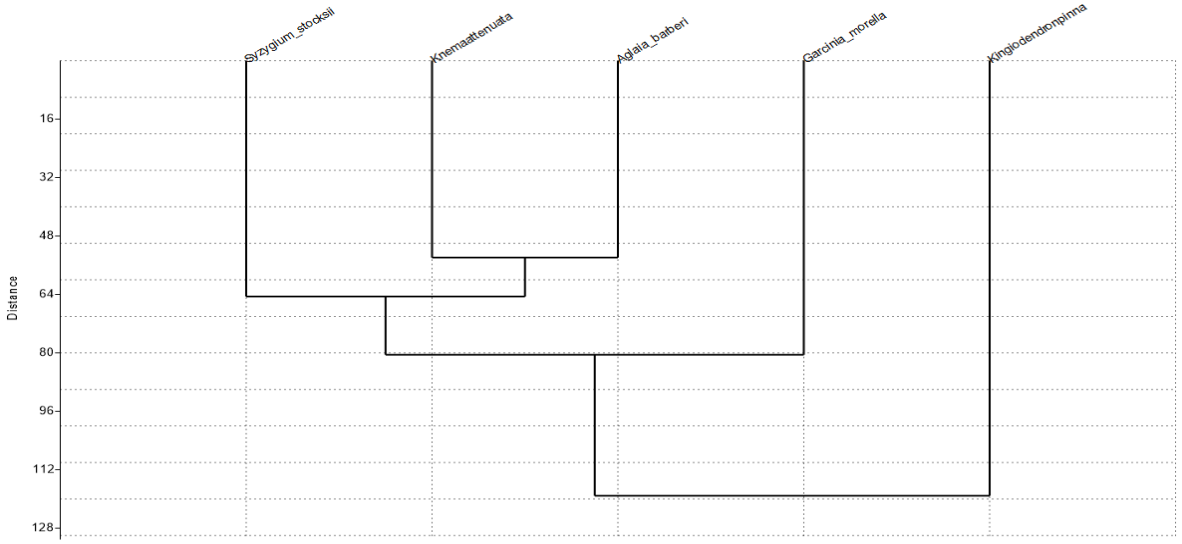


Fig. 2: Cluster analysis between five endangered plant species of Western Ghats.

Leaf trait variability among species

Across the studied species, there was a strong variability in the leaf traits; for example Specific leaf area (SLA) varied four fold, from 58 g m-2 (*Garcinia morella*) to 224.12 g m-2 (*Kingiodendron pinnatum*) (Table 4). In general, micronutrients and non-essential elements exhibited a greater inter-specific variability (Tables 1). The N concentration was also high in *Kingiodendron pinnatum* and lowest in *Garcinia morella*.In the multivariate analysis of leaf traits (by Correspondence analysis), the first axis (explaining a 64.31% of the variance) was positively related to Ltd, SLA (Fig. 1). *Kingiodendron pinnatum* and *Garcinia morella* are strongly associated than other species. Ltd and SLA are positively associated with *Kingiodendron pinnatum* as well as Aglaia barberi but negatively associated with Garcinia Morella. Syzygium stocksii dissimilar to Kingiodendron and Garcinia. Nitrogen content, pH, Carbon content, Lth and LDMC are positively associated with Garcinia spicata. Knema attennuata is not positively associated with any of the leaf traits. Syzygium stocksii is strongly associated with Leaf area.

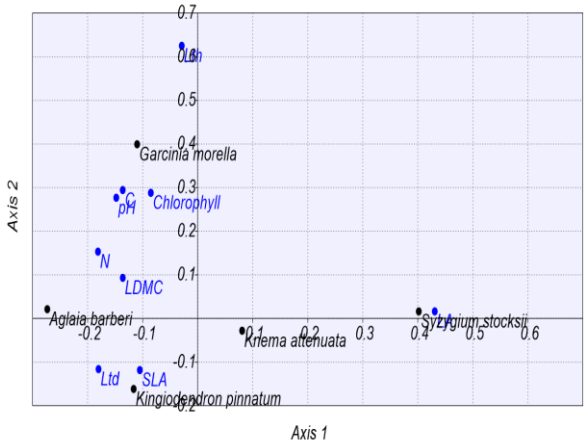


Fig 3: Correspondence analysis plot of the scores with normalisation is based on the scores table given. Eigen value and the percentage of variance the axes covered are given on Table 2.

Table 2.

Axis	Eigen value	% of total
1	0.049863	64.31
2	0.0265005	34.178
3	0.00103108	1.3298
4	0.000141242	0.18216

Table: 3.

0	Axis 1	Axis 2	Axis 3	Axis 4
Garcinia morella	-0.11015	0.39935	0.013818	-0.012546
Kingiodendron pinnatum	-0.11643	-0.1614	0.0018429	-0.01295
Syzygium stocksii	0.40167	0.016296	-0.033784	-0.0010636
Knema attenuata	0.080699	-0.027939	0.047164	0.011626
Aglaia barberi	-0.27339	0.021404	-0.039893	0.015669
SLA	-0.10518	-0.11813	0.0057544	-0.00071337
LA	0.43074	0.016364	-0.0024483	0.00051721
LDMC	-0.13618	0.093264	-0.11065	-0.015081
Lth	-0.029012	0.62508	0.063327	-0.099694
pH	-0.14805	0.27686	-0.11244	-0.04647
Chlorophyll	-0.085189	0.28812	0.0087706	-0.038251
Ltd	-0.18026	-0.11589	-0.20723	0.0041282
N	-0.18124	0.15324	-0.14614	0.086661
C	-0.13628	0.29442	0.018705	0.0048943

Table 4. Leaf trait analysis of five endangered plant species of Western Ghats.

Species Name	SLA(cm^2)	LA(cm^2)	LDMC(mg/cm^{-2})	Lth(mm)	pH	Chlorophyll	Ltd($g\ cm^{-3}$)	N%	C%
Garcinia morella	58.85	24.07	0.35	0.34	5.34	1.82	1.02	1.65	44.68
Kingiodendron pinnatum	224.12	54.911	0.68	0.16	6.41	2.02	4.25	2.626	47.993
Syzygium stocksii	97.38	82.781	0.39	0.193	4.3	1.41	2.02	1.679	30.423
Knema attenuata	152.47	67.0976	0.42	0.223	4.2	1.82	1.88	1.962	46.555
Aglaia barberi	125.48	20.588	0.53	0.17	5.83	1.62	3.11	2.858	43.756

CONCLUSION

The observed leaf trait diversity among the five RET species showed that within the Western Ghats multiple species coexisted with diverse leaf trait strategies. In addition, certain plant traits are reflecting similarity within in this region. The anatomical features of the studied endangered plant species provided information on their taxonomic significance. These diverse leaf trait strategies of individual species should be investigated in more detail in future. Additional key traits such as rooting depth, nitrogen fixing abilities, and interactions with mycorrhiza, light use strategy, photosynthetic

capacity and leaf life span should be measured. It is clear that many more leaf trait data are needed to be studied, so future research should expand the sampling size and multiple forest sites during different periods. The characterisation of plant functional traits within the Western Ghats forest is vital for our understanding of key ecological processes.

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