ANATOMY AND UTILIZATION OF TWO CANE SPECIES OF KERALA (*Calamus travancoricus* and *C. thwaitesii*)

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree

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DECLARATION

I hereby declare that this thesis entitled "Anatomy and utilization of two oane species of Kerala (Calamus travancoricus and C. thwaitesii)" is a bonafide record of work done by me during the oourse of research work and the thesis has not previously formed the basis for the award to me of my degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara,

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CERTIFICATE

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DEDICATED TO MY alma matre COLLEGE OF FORESTRY, KAU.

C O N T E N T S

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Plate 13. L.S of *C. thwaitesii* stem showing stegmata

Plate 14. Metaxylem vessel element of *C. thwaitesii* showing simple perforation plate

Plate 15. Metaxylem vessel element of *C. travancoricus* showing simple perforation plate

Plate 16. Metaxylem vessel element of *C. thwaitesii* showing scalariform perforation plate

Plate 17. Metaxylem vessel element of *C. travancoricus* showing scalariform perforation plate

Plate 18. Protoxylem vessel element with scalariform perforation plate

Plate 19. Branched protoxylem vessel element in *C. thwaitesii*

Plate 20. Sieve tube element in *C. thwaitesii*

Plate 21. Septate Fibre with constriction in the fibre wall in *C. thwaitesii*

Plate 22. Metaxylem vessel element in the outer portion of central cylinder of the stem of *C. thwaitesii* showing relatively large number of bars

INTRODUCTION

1. INTRODUCTION

Rattan is the collective name for all climbing palms. The name "rattan" originates from the Malaysian word "rotan". Botanically rattan belongs to the family Palmae under the sub family Lepidocaryoidae comprising nearly 14 genera and about 600 species (Dransfield, 1981). Some 50 species of rattan are commercially important belonging to four genera, viz. *Calamus*, *Daemonorops*, *Korthalsia* and *Plectocomia*. Though species of rattan occur in tropical Africa, it is in South East Asia that they form a significant component of the vegetation. Rattan also is found in India, Burma, China, North Australia and Papua New Guinea. Of the 14 genera of climbing palms, only four viz., *Calamus*, *Daemonorops*, *Plectocomia* and *Korthalsia* are known to inhabit India. Only 12 species of *Calamus* are known to occur in Southern India (Fisher, 1931, Fernandez and Dey, 1970). Of those, eleven (*C. brandissi*, *C. dransfieldii*, *C. gamblei*, *C. hookerianus*, *C. huegelianus*, *C. metzianus*, *C. pseudotenuis*, *C. rheedii*, *C. rotang*, *C. thwaitesii*, and *C. travancoricus*) are known from the present geographic limits of Kerala (Renuka *et al*, 1987).

Rattan may be found from sea level upto about 2900 m on large mountains. Most species have quite a wide altitudinal range. However, few low land species transgress the vegetational boundary occurring at between 1000 m and 1400 m. Likewise few mountain species go below this boundary. Large tracts of the more easily accessible forest area containing rich resources of rattan are fast disappearing due to conversion for agricultural purposes. In some areas important species of rattan are practically gone. Some other species are being over exploited. Demand for rattan on the other hand is continually increasing. More and more immature canes are being cut to meet the increasing demand.

Rattan stems vary in thickness from a few millimeters to approximately 8 centimeters in diameter. They can grow even up to approximately 100 m in length. Some plants produce solitary stems, while majority grow in clumps and climb on trees (Plates 1 & 2). The stems are more or less enclosed by the bases of thorny leaf sheaths. Rattan matures in 6-25 years and in maturity, stem changes from green to yellow colour and increases in toughness and strength.

Rattan collection in the natural forest is done by tribals and in some cases by communities living near the remote forest areas. Collection is often an ardous job, yet it is lowly paid. Collection methods vary slightly from place to place. Generally, the stem is cut off some 30 cm above the ground with a jungle knife and dislodged from the support tree by pulling the cane (Plate 3). Most rattan

Plate 1 Habit of C thwaitesii

Plate 2 Habit of C travancoricus

Plate - 1

Plate - 2

producing areas are in difficult terrains Apart from the dificult terrain the problems in rattan harvesting include the manner in which it tangles itself through the trees and the thorny sheaths with which it is encased The cane is twisted round a convenient tree trunk to rid it of its thorny leaf sheaths and the younger parts of these are chopped off The uppermost 3-4 m of the rattan depending on the species is usually discarded being soft and immature and hence useless Larger canes are generally cut into 2-3 m length and bundled, while the smaller ones are cut into 5-7 m length bent double and bundled The very slender canes are coiled in long lengths for taking out of the forest.

Siliceous species are deglazed soon after harvesting as deglazing of dried canes becomes difficult If deglazing cannot be done soon enough the canes are steeped in water to keep it from drying before deglazing After deglazing the canes are dried for about 7-10 days depending on the weather In very wet weather drying is also done over a fire Quick drying is essential to prevent or reduce blemishes like fungal stains(FAO 1978)

Grading is very subjective and grade classes are derived from long trading practices established in specific localities or even by individual companies Iowever the basic factors as - size length colour hardness defects and blemishes internodal lengths and evenness of thickness along the full length of the cane are taken into consideration

As a source of cane rattans are economically important In commercial sense the term cane refers o rattans of 2 cm in diameter upwards and rattan refers to those of smaller diameter (FAO 1978) The most important use to which canes are put is manufacture of furniture Other uses of canes include production of walking sticks ski-sticks broom handles cricket bats hockey sticks etc The slender rattans are normally peeled and the skin is used for making baskets mats chair seats and handicrafts (Plate 4) The core which is resplit into smaller sections is also used for basket making and handicrafts Splitting can be done by hand or machine Rattan processing is a traditional industry which is in the form of small scale cottage units

In India rattan is found in the tropical evergreen and semi evergreen forest and locally in moist deciduous forest The best growing condition seems to be along the edges of streams and fresh water swamps or on well drained soils Cane brakes are mostly edaphic vegetational types and are found in moist hollows extending outwards to various distances and it is more conspicuous with heavier rainfall Soil is permenantly wet and usually fine clay very rich in

Plate 3 Extraction of large diameter cane, *C. thwaitesii*

Plate 4 Handicraft items of cane products

Plate - 3

Plate- 4

humus The cane brakes are impenetrable or almost impenetrable thorny thickets which sometimes have few scattered trees over them

Because of the fact that rattans have been considered as "minor forest product" little attention was given to it by way of research and development. Progress in any industry is based on a firm understanding of the characteristics and behaviour of the raw material Thus the present study was undertaken to study two important cane species of Kerala - one representing a large diameter cane viz C. thwaitesii and one representing a small diameter cane viz C travancoricus The objectives of the study are

(i) To investigate the variation in the anatomical characteristics and compare them between the two species

(ii) To correlate the physical properties such as specific gravity moisture content hardness and texture with the anatomical features.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1 Arborescent, non lianoid palms

2.1.1. Anatomy

The contributions to the anatomy of arborescent palms occured from as early as the first decade of the nineteenth century when Moldenhawer, (1812) observed a clear demarcation line between central and peripheral vascular zones in *Phoenix dactylifera*. Karsten (1847) observed that in arborescent palms, during initial stages, leaves developed for a prolonged period while the stem failed to undergo extension growth. But the stem was observed to keep pace with the production of new leaves by increasing later in radial diameter. Sohoute(1912) explained that the increase in girth through the aoivity of lateral meristem growth is an intimate continuation of terminal meristem of the shoot. It is brought by the tangential division of their primary thickening meristem which is continuous beneath successive leaf bases (Ball, 1941 Tomlinson, 1961) Cheadle (1937) referred this meristem to as 'thickening ring". Based on the quantum of girth increment the thickening ring outweighs the apical meristem in extent and importance (Ball, 1941).

2 1.1.1 Vascular bundle distribution

In *Phoenix sylvestris*, Swamy and Govindarajulu (1961) observed that in the central portion of the stem the vascular bundles were more widely separated and in the peripheral portion, they were more densely aggregated. They found a positive correlation (.51) between the distance from the periphery and the number of vascular bundles per unit area. An increase was also found from the base upto a height of 18 ft beyond which the number decreased at successive heights

All the vascular bundles in *Raphis excelsa* were observed to have essentially the same course and construction (Zimmermann and Tomlinson, 1965). No single vascular bundle was seen to be continuous from root to leaf and the continuity throughout the length of the stem was maintained by anastomoses. Tomlinson (1961) claimed that the number of vascular bundles per unit area in coconut stem was the same at all heights. However, along the stem height, Richolson and Swarup (1977) observed an increase in number of vascular bundles accompanied by a decrease in diameter of vascular bundles . A significant correlation was found between the number of vascular bundles per unit crosssectional area and their percentage in coconut stem by several authors like Richolson and Swarup (1977) and Killmann (1983).

2.1.1.2 Tracheary elements

Esau (1965) described tracheids as imperforate cells with only pit pairs on their contiguous wall and that vessel elements are perforate in certain areas of contiguity with other vessel elements. The terms 'primitive' and 'advanced were used to express the degree of resemblance of vessels to tracheids (Klotz, 1978).

In *Phoenix sylvestris*, Swamy and Govindarajulu (1961) found that the longest vessel members occured along the central axis of the stem. From the centre towards the periphery, there was a highly significant decrease in average length of vessel members. Similarly the vessel members showed shortening from the base to the top of the stem. The vessel members in the stem periphery had a significantly larger number of bars compared to the vessels in the inner regions.

Tomlinson (1961) observed that in coconut wood, the vessel elements ranged from 1160 µm to 1630 µm in length and 170 µm - 200 µm in width with a few thickening bars. In *Raphis excelsa*, the metaxylem elements were observed to be 40 µm - 60 µm wide and 600 µm - 800 µm long with mostly scalarifoam perforation plates with a few thickening bars (4-10) on oblique end walls (Zimmermann and Tomlinson, 1965). The observations in palms by Bierhorst and Zamora

(1965) revealed that the pitting of wide late metaxylem vessels was basically scalariform and that their end walls ranged from scalariform plates with many closely spaced bars to reticulate or scalariform perforation plates with fewer, more widely spaced bars

Parthasarathy and Klotz (1976) observed that smaller palms had narrower tracheary elements than larger palms. They found that wide late metaxylem elements had lengths ranging from .1 mm to more than 1 cm and width ranging from .02 mm to nearly .5 mm. The bars of the perforation plates were found to be most closely spaced in the petiole, most widely spaced in the root and intermediate in the stem.

The perforation plates in palms were found to extend the entire length or only part of the length of the end wall and rarely on lateral walls. The end walls were usually straight, but occasionally they were curved or saddle shaped" (Klotz, 1978).

2.1.1.3 Sieve elements

In cocoid palms, Tomlinson (1961) found massive fibrous phloem sheaths. In coconut palm, sieve tubes in the stem were found to range from 50-60 μm in width with slightly oblique sieve plates.

In *Raphis excelsa*, the phelem was found to be directed towards the stem periphery, partly sheathed by fibres forming a well developed fibrous phloem sheath (Zimmermann and Tomlinson, 1965) The companion and phloem parenchyma cells were however, seen to be irregularly scattered and not well differentiated from each other.

In palms the phloem strand in each vascular bundle could be divided or undivided depending on the species or organ (Parthasarathy, 1966) and based on the species or organs the sieve elements had simple or compound sieve plates. The stems and leaves were reported to have sieve elements with transverse to oblique walls.

Parthasarathy and Klotz (1976) observed that the metaphloem sieve elements had diameters ranging from 15 µm to about 50 µm and lengths ranging from .5 mm to 3.25 mm The phloem was observed to be continuous between all bundle types without any structural complexity (Zimmermann and Sperry, 1983).

2.1.1.4 Fibres

The vascular bundles in the peripheral zone of central cylinder in stems are normally associated with a massive, radially extended fibrous sheath (Zimmermann and Tomlinson, 1965). In addition fibres occur in the cortex in discrete non vascular or incomplete vascular bundles. From the way, palm stems endure hurricanes, the arrangement of fibres appears to be mechanically very effective (Richolson and Swarup, 1977).

In coconut stem, in the centre, the fibres associated with the vascular bundles were seen to have relatively thin walls and large lumen while at the periphery, their walls were very thick and the lumen extremely small (Kloot, 1952, Sudo, 1980). In the stem of Raphis excelsa, Zimmermann and Tomlinson (1965) found that the fibres became sclerotic and wall thickening appeared first in inner most fibres closest to the phloem, and subsequently in centrifugal fibres. The fibres keep on depositing secondary wall, most of palm's lifetime and thus the basal part of the palm stem generally has fibres with better developed secondary walls than the top part (Parthasarathy and Klotz, 1976 and Sudo 1980). Sudo (1980) reported that in coconut stem the ratio of single cell wall thickness to tho diameter of fibres (Th/D) was the lowest in the youngest part of the stem and increased rapidly with age.

The ratio between the area of the fibrous cap and that of vascular tissues was observed to decrease gradually from the periphery towards the centre and from the bottom upwards in palms (Swamy and Govindarajulu, 1961). They found a highly significant decrease in the average length of the fibres from the centre towards the periphery and shortening of average fibre length from the base to the top.

A common association of silica-containing cells called stegmata was seen with vascular or non vascular fibres. Stegmata were seen in palms as longtitudinal file of cells adjacent to fibres (Tomlinson, 1961).

2.1.1.5 Cortex and central cylinder

Tomlinson (1961) observed that the cortex of palm stem was largely made up of unspecialised ground parenchyma having numerous small fibrous strands. The cortical vascular bundlos were always found to be few and small and the central cylinder was abruptly demarcated from the cortex by a wide peripheral sclerotic zone made of congested vascular bundles. He opined that this zone formed the main mechanical support of the palm stem and in the lower portion of the mature stem, this zone was seen to be generally hard, heavy, dark brown and 3-4 inches wide.

The cortical parenchyma in *Raphis excelsa* was found to be upto 20 cells deep, the cells isodiametric or slightly elongated vertically (Zimmermann and Tomlinson, 1965). Fibres occurring as thick walled strands were found scattered throughout the cortex. Leaf traces were also seen extending from each leaf base, into the central cylinder, across the cortex. Walford (1974) observed that in coconut stem within approximately 50 ft of the stem tho average thickness of the cortex was 9.9 mm with the thickening towards the bottom being 11.4 mm and the top 11.2 mm.

2.1.2 Physical properties

The variation in growth of palms like coconut, due to adverse growing conditions affect the physical properties and utilization value of the wood (Mc Paul, 1964).

2.1.2 1 Density

In coconut stem, Richolson and Swarup (1976) observed that the basic density decreased linearly with increase in stem height and logarithmically in the radial direction from centre to cortex. They found that for the first 12 feet, the density varied from 844 kg/m^3 in the peripheral zone to 112 kg/m^3 in the central axis of the stem. The low density wood portion was estimated to be more than 25 percent of the round wood volume of the stem. The density of coconut stem increased with age in the order of young, mature and overmature (Sudo, 1980). The values ranged from .115, the lowest value in young stem to .918, the highest value in an over mature stem. He also observed the area percentage of vascular bundles to have influence on the density

The correlation between ovendry density and number of vascular bundles per cm^2 area over the stem height was relatively low whereas for a cross section of the stem, it was high (Killmann, 1983). Thus the fibre wall thickness within a vascular bundle was observed to be more important than the number of vascular bundles per square unit area in influencing the density.

2 1.2.2 Moisture content

Moisture content is a transitory variable and the measurement depends primarily on external conditions at the time of test (Richolson and Swarup 1977)

They observed the moisture content in coconut stem to be wide ranging. It increased rapidly with stem height and logarithmically from the peripheral zone to the centre of the central cylinder.

Killmann (1983) observed in coconut palm, a high by significant negative correlation between initial moisture content and ovendry density. With increase in density the moisture content was seen to drop logarithmically. Along the stem, the moisture content was seen to increase only at a lesser rate than along the intermediate or central portion.

2 1.2.3 Shrinkage

According to McConchie (1975), the volumetric shrinkage in coconut wood decreased from the centre to the bark. He observed values of 11.1% for the axis along the cortex, 11.6% for the mid section axis and 22 4% (from green to air dry) and 23.3% (from green to ovendry) for the inner section. Radial and tangential shrinkage appeared to be low in coconut wood, but tangential shrinkage was slightly higher and longitudinal shrinkage was negligible (McConchie, 1975 and Killmann 1983).

Shrinkage was observed to have poor correlation with stem height, basic density and vascular bundle number (Richolson and Swarup, 1977). Contrarily, Killmann (1983) observed that shrinkage had a direct correlation with ovendry density, initial moisture content and vascular bundles per cm^2. The shrinkage increased to the greatest extent with increasing amounts of vascular bundles/square unit area . A similar trend was observed for oven dry density with a shrinkage of 3% at 200 kg/m^3 and 6% at 800 kg/m^3. This however contradicted the results of McConchie (1975) as a decrease in shrinkage was found from bark to centre.

2.2. Palm 'Wood' VS Conventional Wood

Wood is the principal strengthening and water conducting tissue of stems and roots characterised by the presence of tracheary elements (IAWA, 1964). Palm stem may also therefore be referred to as wood as it has water conducting xylem elements and mechanical fibrous tissue

However palm stem differs from conventional wood in the following respects.

2.2.1 Anatomy

(a) As there is no vascular cambium, no regular girth increase (secondary thickening) takes place in palm stems. However, diffuse secondary growth often occurs due to the cell division and enlargement of parenchymatous cells or ground tissue (Tomlinson, 1961).

(b) The apical meristem contributes little to stem tissues but is a leaf producing meristem (Tomlinson, 1961). Internodal elongation begins only when the primary thickening ends.

(c) The wood of dicotyledons is mostly secondary xylem whereas, the wood of palms consists of primary vascular bundles embedded in a parenchymatous ground tissue (Parthasarathy and Klotz, 1976).

(d) In palms, the sieve elements formed during early life are long lived and remain functional throughout the lifetime of the plants, whereas in most dicotyledons, sieve elements are short lived (Parthasarathy and Klotz, 1976).

(e) The wood cells of palms are not dead as in normal forest trees and the walls continue to increase in thickness

2.2.2 Physical properties

The physical properties that help in differentiating conventional wood and palm wood are the following.

(1) As a result of periodic radial growth, conventional timbers have a distinct grain pattern and shrinkage in tangential direction is double that in radial direction. Palm stem has no such grain differentiation and hence the material will dry uniformly without cross sectional distortion (Kinnimonth, 1977)

(2) Conventional woods, generally exhibit density gradients from the centre of the stem towards the outside and from bottom of the trunk towards the top, whereas a palm wood does not show a definite trend, as it consists of a number of scattered vascular bundles (Meylan, 1978).

2.3 Lepidocaryoid lianoid palms (Canes)

2.3.1 Anatomical properties

Literature reveals relatively little information on anatomy and physical properties of lepidocaryoid palms particularly rattans. The brittleness often observed in some cane species is mostly due to their peculiar anatomy (Anon, 1939).

2.3.1.1 Perforation plates

Tomlinson (1961) reported that among the Lepidocaryoid palms, the lianoid ones are the "most specialised . In the genus *Calamus*, the end wall in the tracheary elements of the stem was observed to be simple and transverse.

The lepidocaryoid palms were seen to inhabit tropical areas (Moore, 1973) and their advanced perforation plates were related to the high moisture demand that accompanied such areas. The late metaxylem tracheary elements in the stem of genera *Calamus* and *Daemonorops* were seen to have simple perforation plates (Parthasarathy and Klotz, 1976).

The lepidocaryoid lianas were seen to be relatively homogeneous in the form of their perforation plates (Klotz, 1978). The end walls were less oblique than in other lepidocaryoid palms, and the slope index was estimated to be 12.6.

Bhat *et al*. (1988) showed for the first time, the occurrence of mixed, multiple and simple perforation plates in the stem of more than one species of *Calamus* occuring in the Western Ghats of peninsular India. Occasional presence of reticulate perforation plate was also observed in *C pseudotenuis* and *C. tranvancoricus*. The wide metaxylem vessels in the stem of *Calamus* mostly have simple perforation plates with occasional mixed, multiple and simple type

2.3.1.2 Vessel diameter

Among the group of palms, lepidocaryoid lianas had generally the widest vessels Maximum diameter of over .4 mm were observed in four species of the lianas. Wide vessels have greater conducting efficiency which is especially true for the lepidocaryoid lianas some of which reach a length of over 100 metres (Klotz, 1976).

The wood of rattans is light due to the porous nature caused by the presence of wide vessels (Parthasarathy and Klotz, 1976). Generally, the smaller palms have narrower tracheary elements but, the stems of many lianas have very wide vessels, relative to their stem diameter.

Bhat (Unpublished data) reported that diameter of metaxylem was correlated with stem diameter among the species while it increased more with a raise in stem height with a higher correlation coefficient of .900.

2.3.1.3 Diagnostic characters

Teoh (1978) reported that qualitatively, the rattans have similar anatomy. Of the 8 genera of rattans studied, *Calamus* exhibited the most variation in its anatomy. He observed that the anatomical characters of diagnostic value at generic level were different from those at specific level. Good quality canes had an even distribution of vascular bundles and even hardness through out the stem whereas useless canes had a spongy centre and a sclerotic peripheral region.

Leise and Weiner (1987) concluded that the composition of vascular bundles, their arrangement in subepidermal zone, the peripheral parenchyma arrangement and the morphological variation in ground tissue parenchyma receive high priority from diagnostic point of view whereas epidermis and special features have lesser importance.

2.3.1.4
(d) Fibres

Studies on the fibre wall architecture in stem of *Calamus manan* by Parameswaran and Leise (1985) revealed that the lignified secondary wall showed alternating broad and narrow layers with a lignin rich isotropic transition zone between them. The fibrillar orientation and lignin distribution in the various layers of polylamellate wall showed resemblences to the fibre structure in coconut stem and bamboo culms.

Of the 3 *Calamus* species growing naturally in Indonesia, *Calamus inops* had 43 9% of its total cross section covered with sclerenchyma cells, *C. symphysipus* had

25 8% and a third species of _Calamus_ had 28 4% (Yudodibroto, 1985).

2.3.2 _Physical properties_

Three most important characteristics used in grading and assessing the utilization of rattans are stem thickness (diameter), internode length and weight (specific gravity) (Badhwar _et al_, 1961). The highest specific gravity in the lowest internode indicates that the bottom portion is strong and rigid (Bhat and Renuka, 1986).

The 10 species of rattans found in Kerala have been divided into large diameter (>18mm), medium sized (10-18 mm) and small diameter (<10 mm) based on the mean values of stem diameter (Bhat and Renuka, 1986). From among the ten species according to them stem height varied from 1.8 m to 10.2 m. It was greater in _C. thwaitesii_ than in other species and _C travancoricus_ had the shortest stem.

The stems of _C. travancoricus_ were found to be as slender as 3 mm in diameter and thickest stem measured upto 23.5 mm in _C. thwaitesii_. There was found to be a small, but significant decreasing trend in diameter from bottom to 95% of stem height, indicating considerable stem taper. Small diameter canes were found to have both highest and lowest mean values for specific gravity. _C thwaitesii_, a thick cane had relatively low speific gravity. They observed that the specific gravity showed a tendency to decline with an increase in height level from bottom to 95% of stem height. There was found to be no consistent relation between stem height, diameter internodal length and specific gravity The within-and between-stem variations in diameter internode length and specific gravity were found to be significant in most of the species Although large diameter rattan species were taller the mean diameter within the species in general was not significantly related to height of stem The internode length increased initially upto 15% to 25% or 50% of stem length and then decreased towards the top. The physical characteristic that could be used in identification was the diameter of the cane (Bhat and Renuka 1987).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study was carried out on two cane species of Kerala - one representing large diameter canes viz. *C thwaitesii* and one representing small diameter canes viz., *C. travancoricus* (Plate 5).

Collection of stems

The stems were collected in December 1987 during field trips organised to the different forests.

(a) *C travancoricus* - This species was collected from Rajakkad in Aryankavu forest area coming under Thenmala forest division in Kerala.

(b) *C. thwaitesii* - was collected from Pallivasal area in Achencoil cane preservation plot The leaf sheaths and thorns were removed and the stems were cleaned. *C thwaitessi* was found growing to 40 metres height on semul trees. The extraction was done with special care by cutting in the rhizome portion itself to ensure that the first internode was intact. The upper most portion of the rattan stems was discarded being soft and immature. Only the mature and utilizable portions of the stems were taken for the study.

Materials for study - Five stems of more or less similar length were selected from each of the two species. Soon

Plate 5 Largest diameter (A *C. thwaitc ii*) and smallest diameter (B *C travancoricus*) canes of Kerala

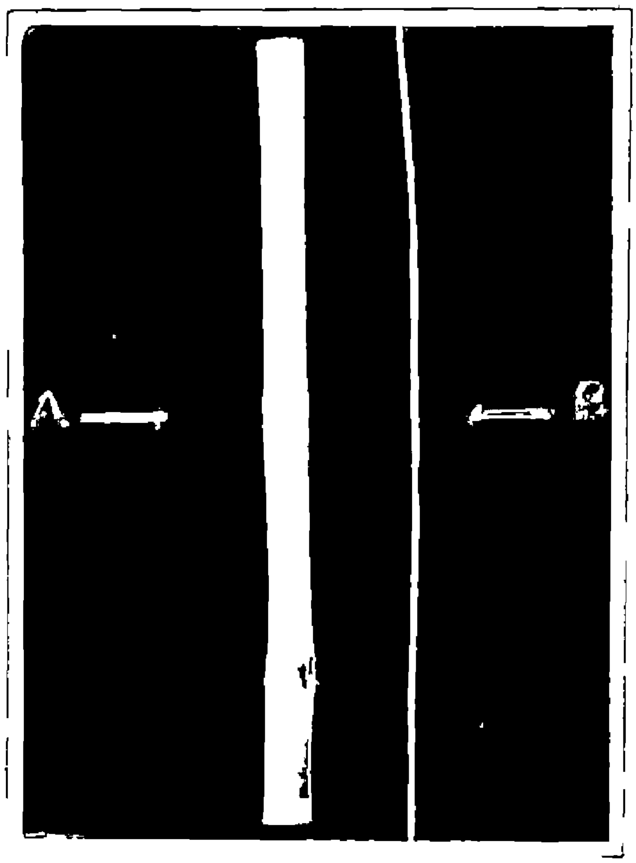


Plate 5

after extraotion the preliminary observations of the selected stems were carried out. They were recorded as follows

C travancoricus

	No of Internodes	Total length
Stem1	34	3.11m
Stem 2	22	2.70 m
Stem 3	32	4 0 m
Stem 4	33	4.37 m
Stem 5	32	3.80 m

C thwaitesii

Stem 1	39	9.80 m
Stem 2	23	4 90 m
Stem 3	44	10 0 m
Stem 4	42	10 0 m
Stem 5	43	10 7 m

Sampling - Transportation of the harvested cane stems as such is a very cumbersome process especially in the case of C thwaitesii Hence smapling was also done as far as possible in the harvest site itself. For uniformity of observations anatomical observations were carried out till the 30th internode The physical properties , internode length and diameter were however studied upto the available nodes

To find the variation, along the stems in both the species, the 1st, 5th, 10th, 20th, and 30th internodes were selected. The internodes were correctly marked out and sawn with a hand saw. The stem number and the internode number were marked on the sampled internodes and properly sealed in polythene bags to prevent from the loss of moisture.

Observations recorded

Physical properties - The various physical parameters such as - internode length, internode diameter, density, volumetric shrinkage and moisture content were studied for both the species.

(1) Internode length - In both the species in each of the 5 stems, the length of each internode was measured from the base to the top and recorded.

(2) Internode diameter - The diameter of each of the internode was measured from the base to the top in each stem and recorded separately. This was also done along with the measurement of internode length soon after harvest. The diameter was measured in millimetres, using a sliding calliper.

(3) Density - The internodes namely 1st, 5th 10th, 20th and 30th from each of the stem in both species were taken to the laboratory for measurement of density Density was determined on an ovendry weight to green volume basis.

Water displacement method was used to measure the green volume of the samples.

(4) Volumetric shrinkage - The sampled internodes were used for measurement of volumetric shrinkage in both the species. It was measured as a percentage of the ratio between the difference of green and ovendry volumes to the green volume. The green volume and the oven dry volume were measured using the water displacement method.

(5) Moisture content - The moisture content present within the stems of both the species of canes was calculated on an ovendry basis by considering the sampled internodes from each stem. The moisture content was calculated as a percentage of the ratio between the difference of green and ovendry weight to the ovendry weight.

Two way analysis of variance (ANOVA) was performed to study the within-stem and between - stem variations of physical characteristics.

Sampling procedure for anatomical studies

Five positions of each stem were selected for the study of anatomical and physical characteristics namely 1st 5th, 10th, 20th and 30th internodes as they gave a fairly true representation of variation trend from base to the top of a stem. These particular internodes were adhered to because, certain distinct trends were found to be related to particular internodes.

Preparation of crosssections

For studying the anatomical characters, approximately .5 to 3 cm thick samples, depending on the length of internodes, were taken from the middle portion of the sampled internodes in each stem to avoid the effect of nodes. Standard microtechnique procedure was followed to prepare sections for observation under microscope. These samples were boiled to soften them and remove the air bubbles within. About 15-20 um thick transverse sections were cut using sliding microtome. At least two sections were selected from each internode. *C. travancoricus* being a small diameter cane, the crosssections of the entire stem were taken. In *C. thwaitesii*, due to the large diameter of the stem, a wedge shaped portion was removed for taking transverse section (Fig. 1).

The transverse sections were stained in 50% alcoholic safranin. For routine anatomical studies, temporary slides were used by mounting the stained transverse sections in glycerine. In order to observe the silica bodies, radial longitudinal sections of 20-25 um thickness were taken. However for the purpose of photography, or when peculiarities were noticed, permenant slides were mounted. For this, the transverse sections were kept in 50% alcoholic

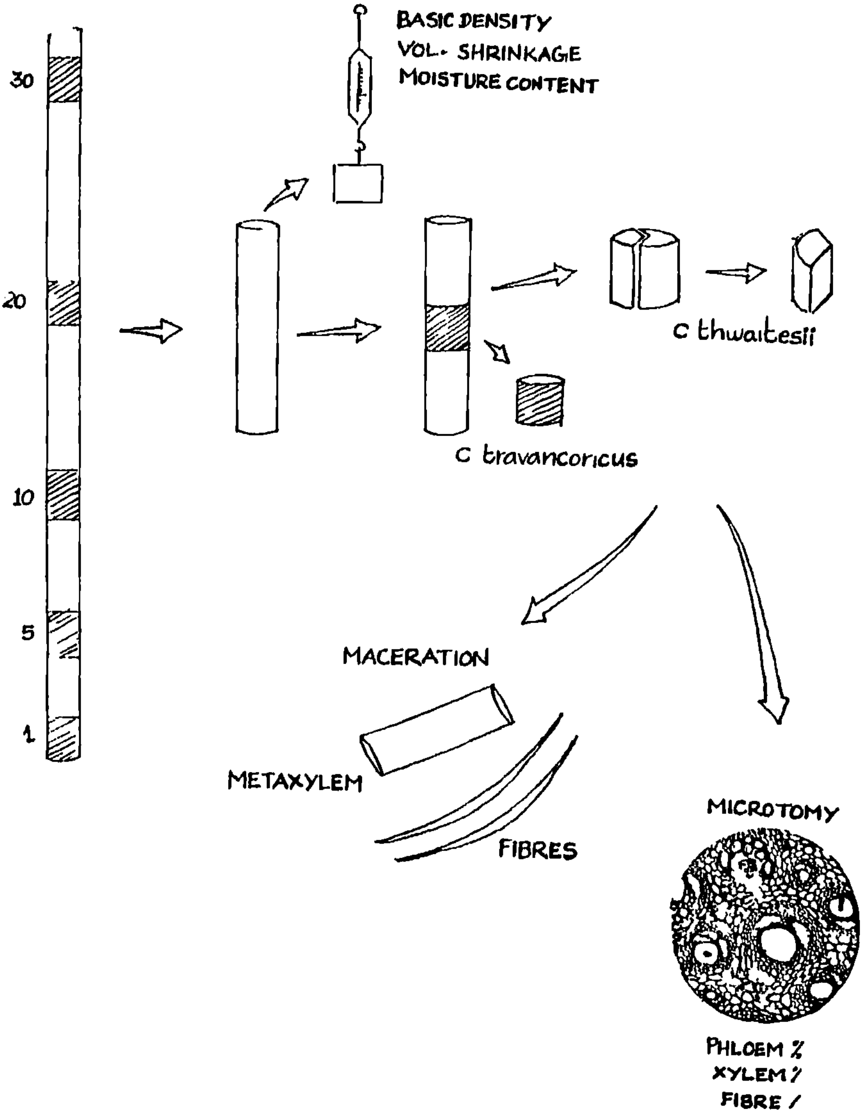


Figure 1 Diagramatic illustration of sampling procedure

safranin for about 5 minutes The section were then passed through an alcohol series - 60%, 70%, 80%, 90% and 95% alcohol, keeping in each for about 3 minutes. They were then passed through one change of acetone and two changes of xylene. After all the moisture were removed, the sections were mounted in DPX mountant.

Anatomical parameters

(1) Vascular Bundle Frequency - The transverse sections of the various internodes were used for finding out the vascular bundle frequency. The number of vascular bundles in a field area of 2 9 mm^2 was measured under microscope. In the case of *C. travancoricus*, the frequency of vascular bundles was measured only for the entire central cylinder. But for *C. thwaitesii*, the vascular bundle frequency for the inner and outer portions of the central cylinder were taken separately.

(2) Vascular bundle diameter - The distance from the fibre sheath to the end of the protoxylem was measured as the vascular bundle diameter under microscope. For *C. travancoricus* the diameter of 10 largest vascular bundles from the central cylinder were measured. For the thicker cane, diameter in the inner and outer portions of the central cylinder was measured.

(3) Fibre percentage - For the estimation of fibre percentage, in *C. travancoricus*, the entire central cylinder

was considered while in <u>C. thwaitesii</u>, two fields - representing the inner and outer region of central cylinder were taken. A special statistically designed 25 point grid was used and the points coming against the fibre portions were counted. By rotating the grid four times each time through an angle of 90°, the percentage of fibres was calculated.

(4) <u>Xylem and Phloem percentage</u> - For both the species these properties were measured only in the central cylinder. Here also the special statistically designed 25 point grid was used to estimate the percentage.

(5) <u>Metaxylem diameter</u> - The transverse section of the stem was examined under microscope to measure the diameter of wide metaxylem using occular micrometer. Ten widest vessels from the central one-third of the diameter of transverse section were measured for both the species.

(6) <u>Cortex percentage</u> - The radial distance from the epidermis to the point where the first real vascular bundle originated was measured as the cortex. Then the ratio between the width of the cortex to the total radius of the transverse section of the internode was worked out and expressed as a percentage.

<u>Maceration of tissues</u>

For the measurement of cell length, small radial segments were removed from the sampled middle portions of the selected internodes and macerated following Franklin's (1946) method.

The material to be macerated was first reduced to slivers of about 5 mm thickness and 1-2 cm length. The slivers were placed in a centrifuging tube and a mixture of equal parts of glacial acetic acid and Hydrogen peroxide were added. The preparation was placed in an oven at 70°C for 48 hours. The chemicals were then decanted and washed with water. A mild agitation was given to separate out the elements. The macerated material was then washed over a filter paper repeatedly using the centrifuge.

Before staining, the material was washed 5-6 times in water to remove all traces of acid that affect staining. Then a mordant 2% Ferric alum was added and kept for 3-6 minutes.

After washing in about 5-6 changes of water, 5% aquous Haematoxylin was added and kept for about 7-16 minutes. Finally basic Fuchsin was added, after washing in 5-6 changes of water and kept for 1 hour

For *C. travancoricus*, the whole piece of stem was macerated as one lot. But for *C. thwaitesii*, the inner and outer portions of the stem were macerated separately (Fig. 1). The stained macerated material was then mounted on slides for observation under a binocular microscope with ocular micrometer. At least two slides were observed from each macerated sample.

Measurement of cell size

By macerating the material, the various cell elements can be separated out facilitating the measurement of their dimensions.

(1) *Metaxylem length* - The length of atleast 10 wide metaxylem elements were measured from each slide. For *C thwaitesii* outer and inner portions of the stem were treated separately The length from on end to the other end of each metaxylem element was measured with the ocular micrometer.

(2) *Fibre length* - Only the intact and complete fibre elements were selected for measurement. The total length between the two tapering ends was measured. The length of atleast 25 fibres was measured from each slide. Care was taken to include both long and short fibres. In *C. thwaitesii*, measurements were taken separately for the outer and inner portions.

(3) *Lumen width* - In a fibre element, the space between the

fibre walls diametrically is called the lumen. This has an important bearing on the physical properties as the double thickness of fibre wall influences various properties. At least 25 fibre elements in each slide were measured for their lumen size. Care was taken to include fibres with both narrow and large lumen

(4) Fibre width - At least 25 fibres in each slide were measured for their width

Statistical analysis

Two way analysis of variance (ANOVA) was carried out to study within-and between-stem variation in both anatomical and physical properties. The variation patterns along the stem were elucidated using quadratic regression models. Further, the quantitative data were compared in two species using student's t-test.

RESULTS

4. RESULTS

Anatomical observations under the microscope revealed the following details.

The transverse section of stem shows a central cylinder surrounded by outer cortex (Plates 6-9). The central cylinder consists of ground parenchyma tissue in which are embedded the vascular bundles. There in no distinct demarcation between outer cortex and inner central cylinder except that the vascular bundles are more densely arranged and congested towards the periphery of the central cylinder. Obiviously, the number of vascular bundles per unit cross sectional area increases towards the periphery from the centre. In cortex only the fibrous bundles or incomplete vascular bundles are distributed which contribute mainly to the mechanical behaviour of the stem. The outer most layer is epidermis. The epidermal cells have more or less triangular lumen in C. travancoricus while it is columnar in C. thwatesii. (Plate 10 & 11).

Each vascular bundle consists of xylem, phloem, axial parenchyma and thick walled sclerenchyma fibres (Plate 12) The latter contributes to the axial strength of the stem. Occasionally fibres are septate and show constrictions in cell wall (Plate 13). The phloem is divided into two strands lateral to a single wide metaxylem vessel. Ground

Plate 6 T S of _C_ _thwaitesii_ stem (basal most internode)

Plate 7 T S of _C_ _travancoricus_ stem (basal most internode)

Plate 8 T S of _C._ _thwaitesii_ stem (internode No 20 from bottom)

Plate 9 T S of _C_ _travancoricus_ stem (internode No 20 from bottom)

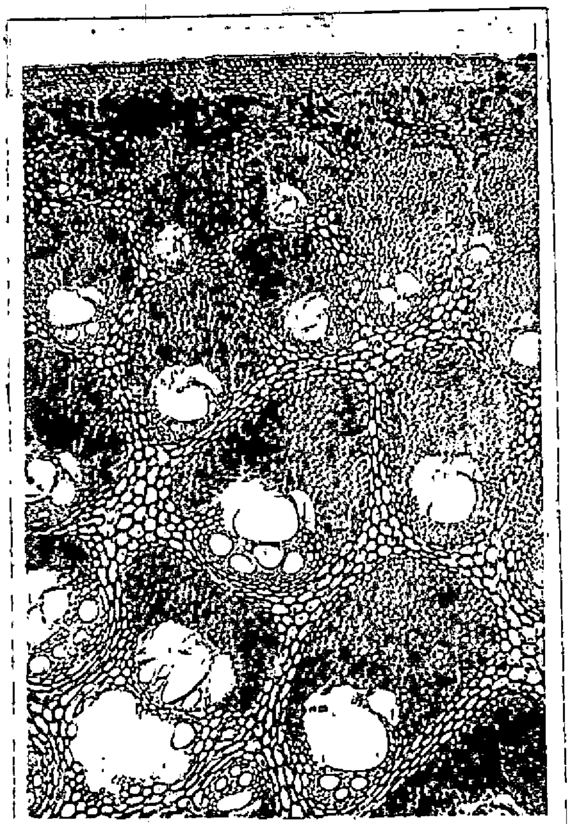


Plate - 6

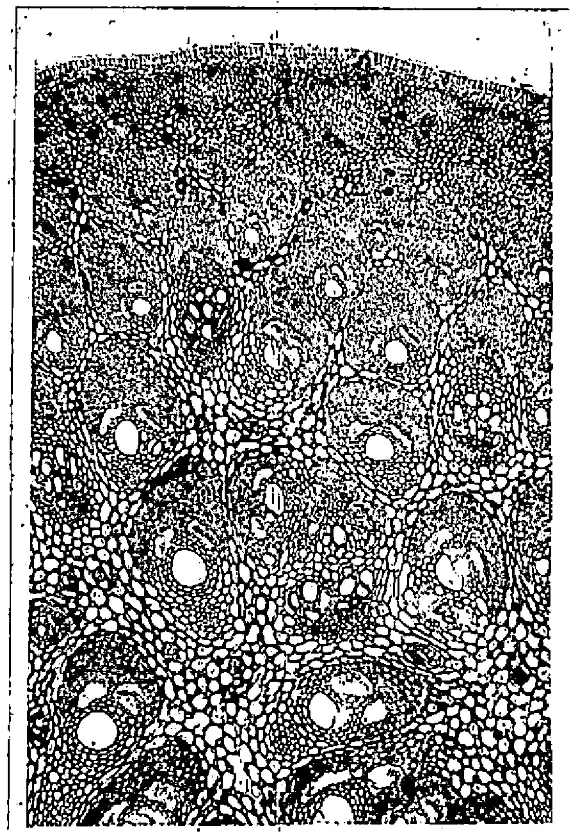


Plate - 7

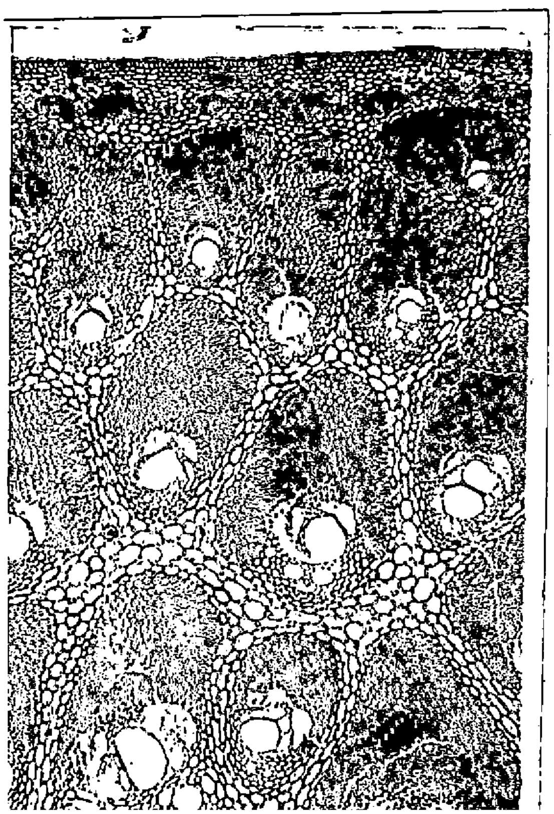


Plate - 8

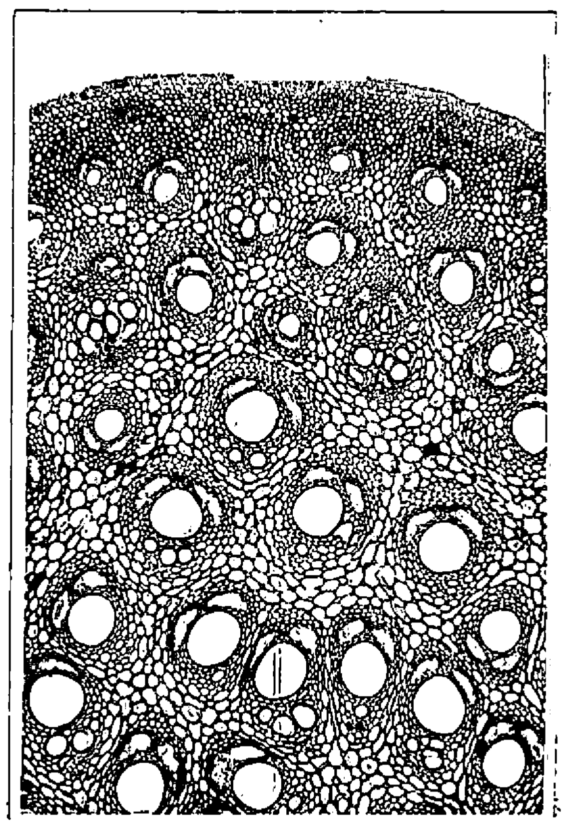


Plate - 9

Plate 10. Epidermal cells of *C* *travancoricus* showing oval or triangular lumen

Plate 11 Epidermal cells of *C* *thwaitesii* showing rectangular lumen

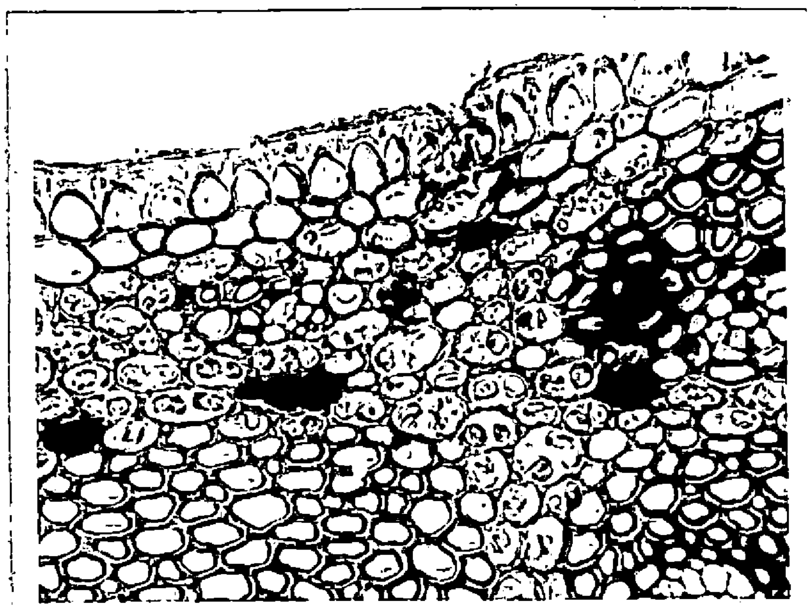


Plate - 10

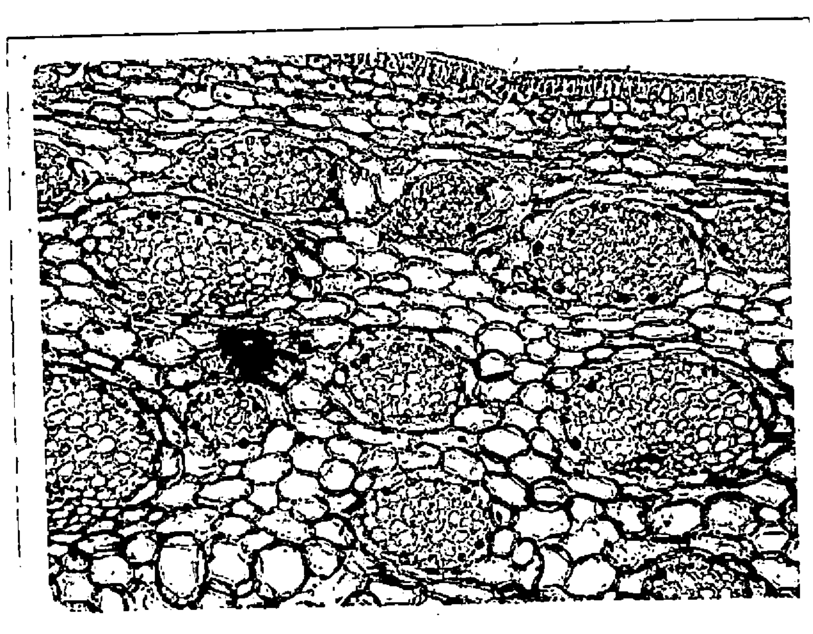


Plate - 11

Plate 12 Single vascular bundle in TS of _C travancoricus_ stem (F - Fibrous sheath mx - metaxylem px - protoxylem ph - phloem)

Plate 13 L.S of _C thwaitesii_ stem showing stegmata

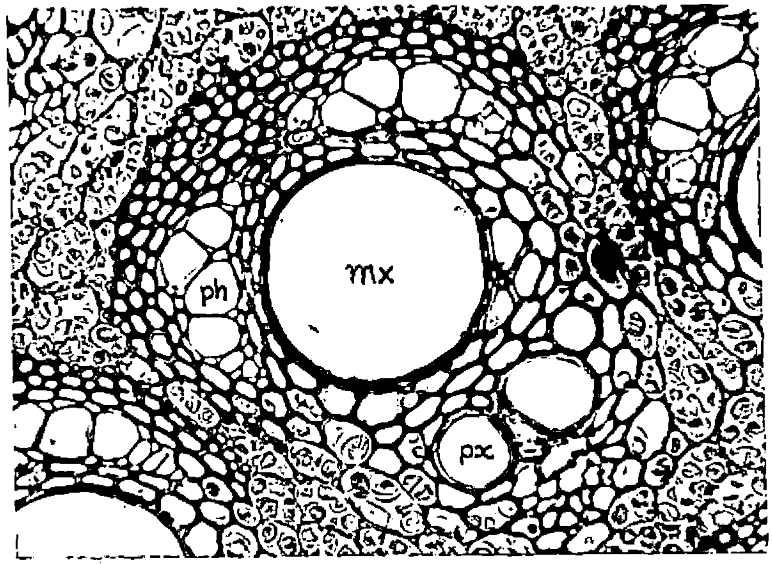


Plate - 12

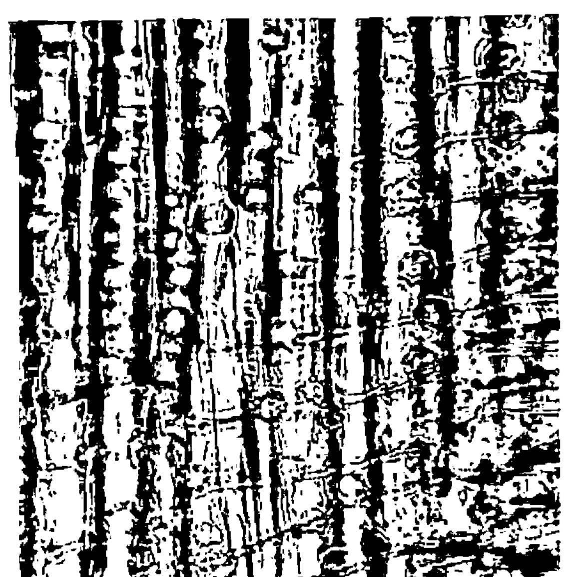


Plate - 13

parenchyma cells and often cortical cells are interspersed with intercellular spaces and mucilage canals. Starch grains are more abundant in young stems. Silica grains are present in special cells (viz. stegmata) associating with fibres of both vascular and non vascular bundles (Plate 13).

Tracheary elements have both perforate and imperforate ends. End walls are either oblique to very oblique with scalariform perforation plates or transverse with simple perforation plates (Plates 14-17). The protoxylem elements are usually long imperforate tracheids or often with scalariform perforations (Plate 18) while the metaxylem vessel elements have specialised simple perforation plates. Often branched protoxylem elements occur as seen in <u>C. thwaitesii</u> (Plate 19) Sieve tubes have generally simple sieve plates (Plate 20). Quantitative data of important anatomical features are presented in Table 2.

4.1 <u>Physical properties</u>

4.1.1 <u>Internode length</u>

The mean values are given in Table 1.

The mean values show that <u>C. thwatesii</u> had longer internode than <u>C travancoricus</u>. The range of values was quite high but, the amount of variation was similar for both the species (Table 1). No definite trend in the

Plate 14. Metaxylem vessel element of _C. thwaitesii_ showing simple perforation plate

Plate 15. Metaxylem vessel element of _C. travanoorious_ showing simple perforation plate

Plate 16 Metaxylem vessel element of _C. thwaitesii_ showing scalariform perforation plate

Plate 17. Metaxylem vessel element of _C travancorious_ showing soalariform perforation plate

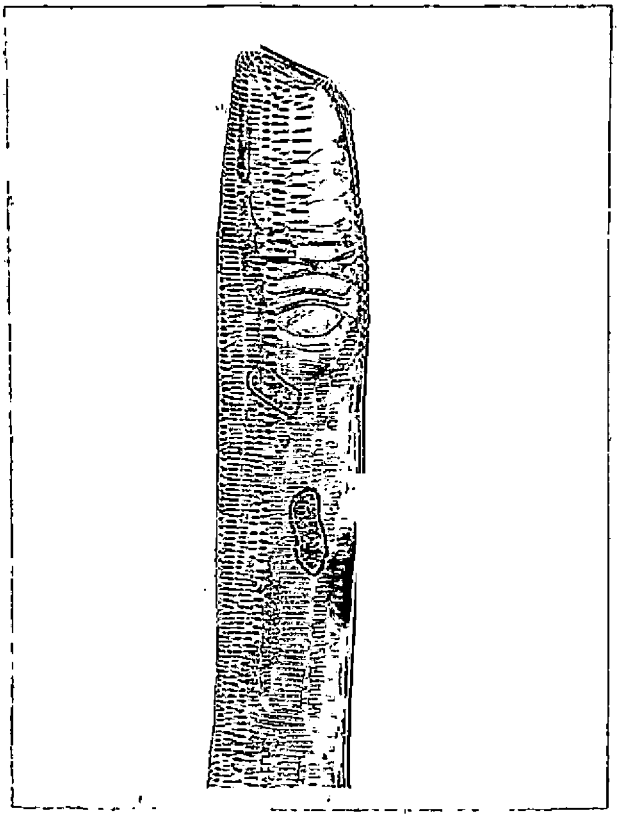


Plate - 16

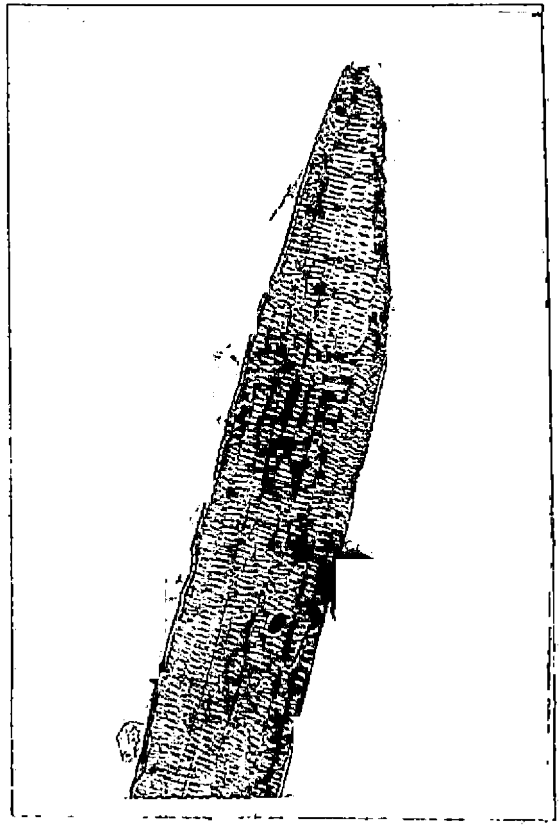


Plate - 17

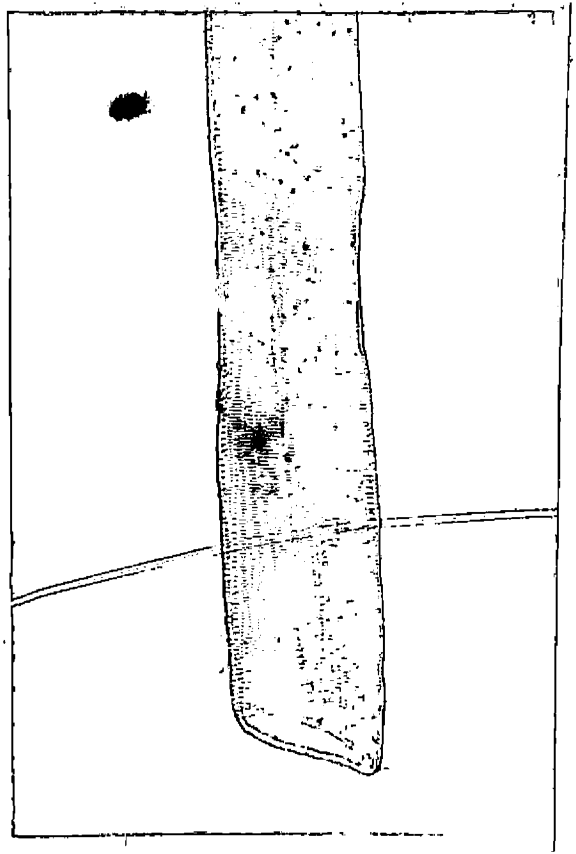


Plate - 14

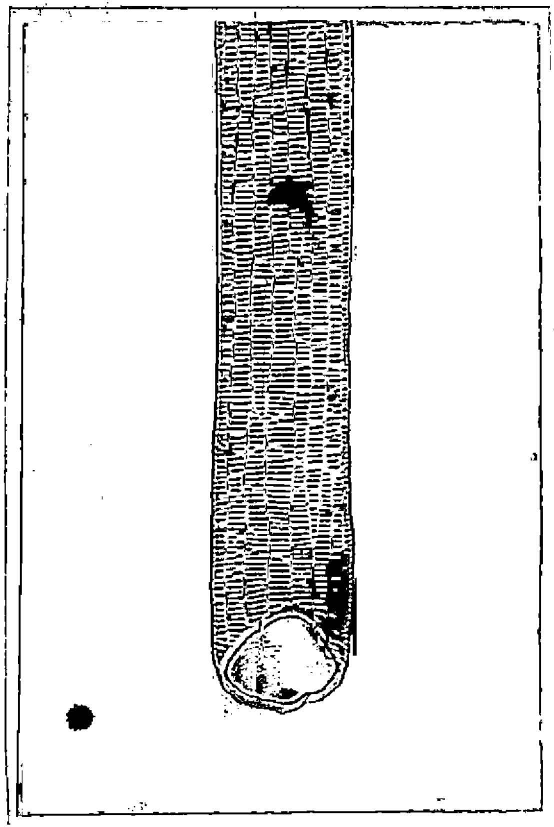


Plate - 15

Plate 18. Protoxylem vessel element with scalariform perforation plate

Plate 19 Branched protoxylem vessel element in _C thwaitesii_

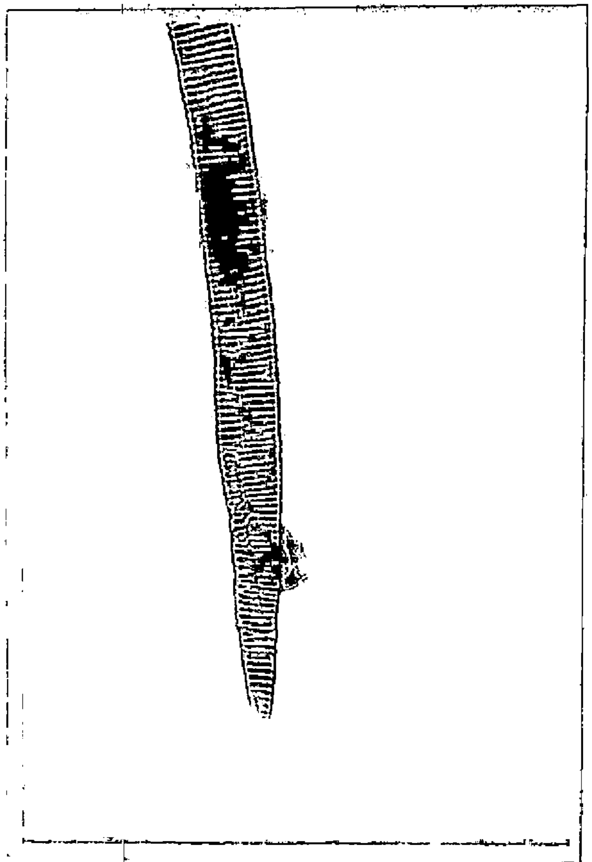


Plate - 18

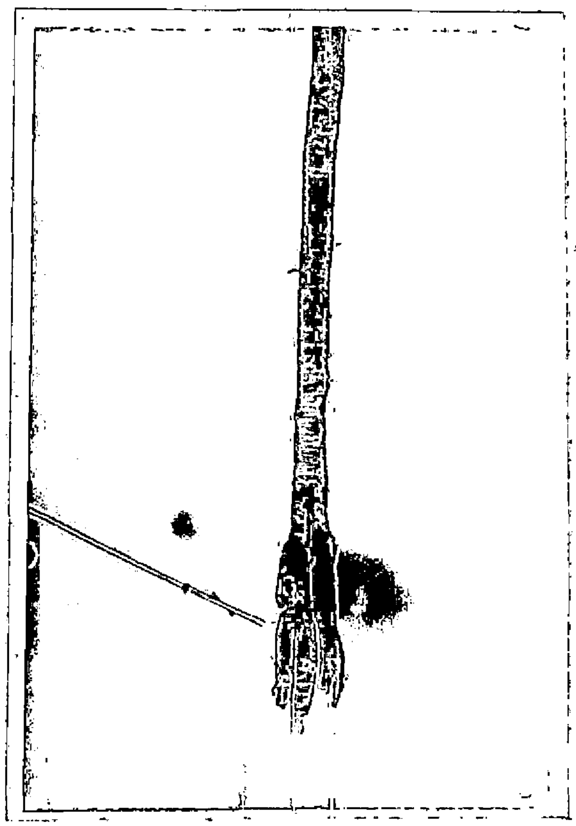


Plate - 19

Table 1

Comparison of quantitative data for physical properties in *C. travancoricus* and *C. thwaitesii*.

Physical properties

	C. travancoricus			*C. thwaitesii*			
Parameter	Mean	Range	C V	Mean	Range	C V	t-value
1. Internode length % (cm)	11.5	2.8-20 5	36 21	21 17	6 3-34	37 2	-15.53^{**}
2 Internode Diameter (mm)	3 8	2.7- 4 9	11.7	28 2	21.4-37 7	13 6	$-66\ 74^{*}$
3. Density (g/c.c)	.486	.276-.766	26 4	410	260- 617	24 2	$2\ 05^{*}$
4 Volumetric shrinkage (%)	29.9	6.98-58.6	42.4	30 9	18.2-58.4	35.4	$.056^{ns}$
5. Moisture content (%)	129.1	60-242.9	39.7	171.3	78 2-287 9	37.9	-2.38^{*}

Plate 20 Sieve tube element in C. thwaitesii

Plate 21 Septate Fibre with constriction in the fibre wall in C thwaitesii

Plate 22 Metaxylem vessel element in the outer portion of central cylinder of the stem of C thwaitesii showing relatively large number of bars

Plate 20

Plate - 21

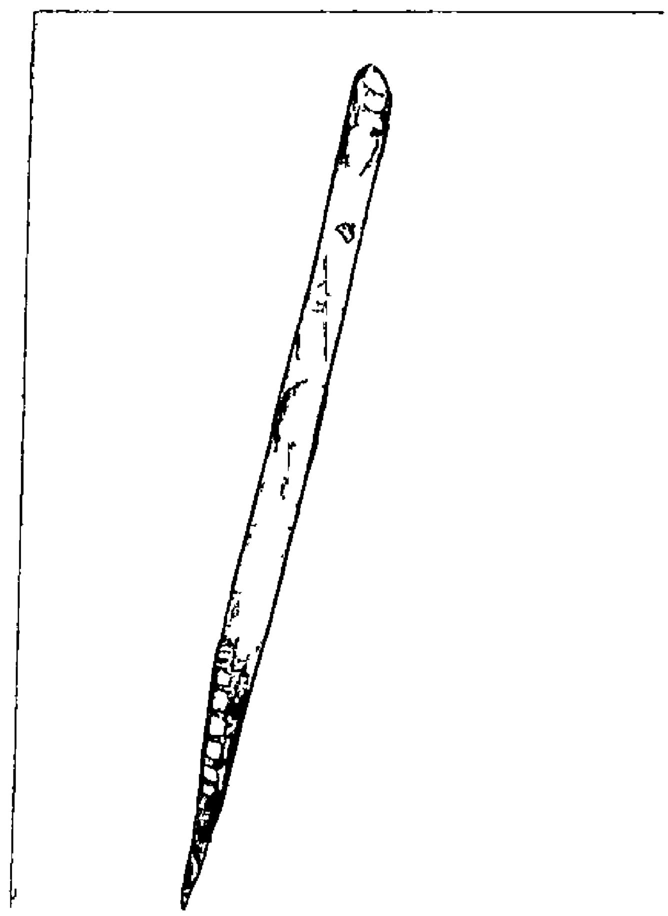


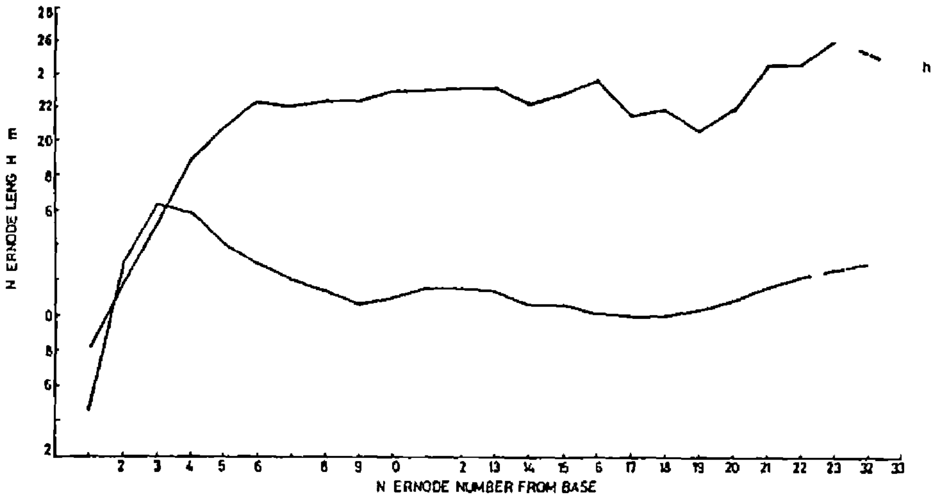
Plate - 22

variation along the stem could be observed, although, the first 3-4 internodes are relatively short from the base (Fig. 2). But the variation between the species was found to be statistically significant. (Table 1).

The F values indicate that both the between-stem and within-stem variations in internode length were significant in both species (Table 3)

4.1.2 Internode diameter

The mean values are given in Table 1. *C. thwatesii* recorded a higher mean value compared to *C. travancoricus*. The coefficients of variation show that the amount of variation was quite small and almost similar in both species. Within a stem, internode diameter decreased initially in the first few internodes from the base and then gradually showed an increasing trend in *C. thwatesii*, the 32nd internode being thickest while the variation was relatively small in the internode diameter of *C. travancoricus* with the thickest internode being in the base (Fig. 3). However, within-and between-stem variations in both species were statistically significant (Table 3). The t-value indicates that the difference between the species was significant (Table 1).



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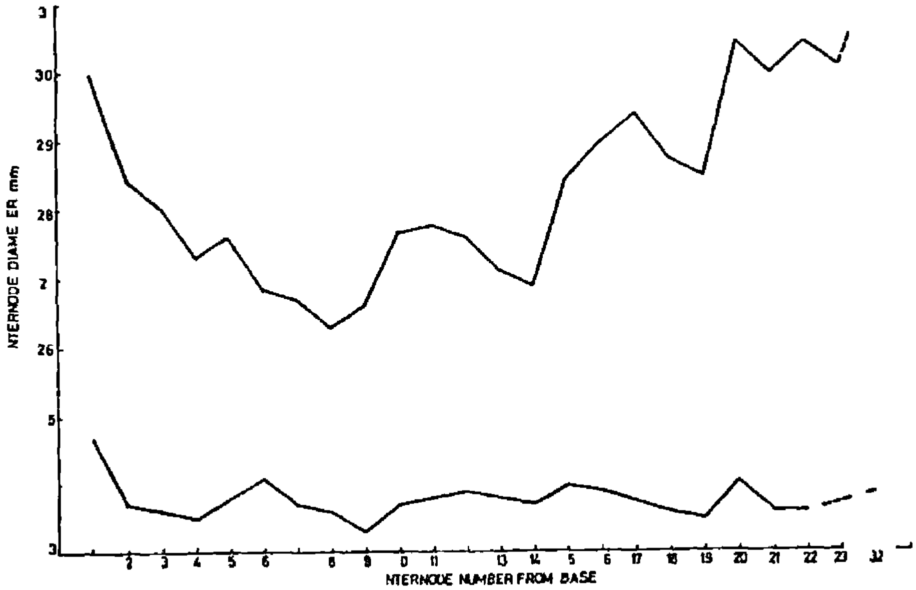


Iigure 3 Rel tion hip between internode diameter and
distance from the tem ba e (number of internodes)
C th - C thwaite ii
C tr - C travancoricus

4.1.3 Density

The mean values are given in Table 1 and the individual observations are tabulated in Appendix - I.

The thick cane, C. thwaitesii had lower density compared to the slender cane. The range of values was more or less similar and the coefficients of variation indicated that the extent of variation within the species was similar for both the canes. Between the species, the difference was significant only at 5% level of probability (Table 1).

The F values reveal that the within- and between-stem variations in both canes are statistically significant (Table 3). Within the stem, in both species, the density decreased from the bottom to the top in a curvilinear manner (Fig. 4).

4.1.4 Volumetric shrinkage

The mean values of the observations are given in Table 1 and the individual sample values are tabulated in Appendix II.

Although C. thwaitesii had a higher value for volumetric shrinkage, the variation between the species in this property was not statistically significant (Table 1) The range of the values was more for C. travancoricus, and hence the variation in values was also high as indicated by

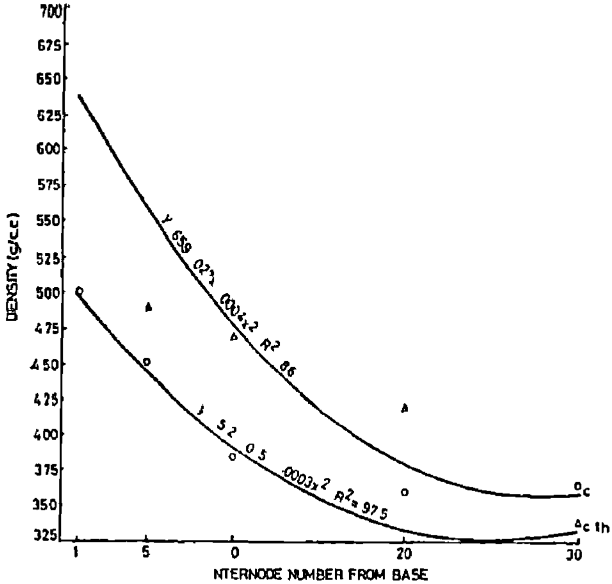


Figure 4 Density variation as a function of distance from the stem bottom (number of internodes)

C.th - C. thwaitesii
C.tr - C. travancoricus

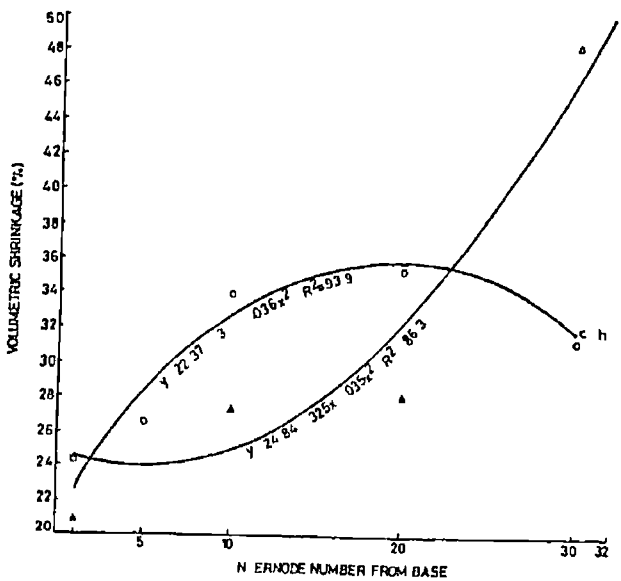


Figure 5 Volumetric shrinkage variation as a function of distance from the stem bottom (number of internodes)

C.th - C. thwaitesii
C tr - C. travancoricus

the coefficient of variation (Table 1). Along the stem volumetric shrinkage increased from the bottom to the top in a curvilinear fashion although there was a small decreasing trend in the top portion in <u>C. thwaitesii</u>. In contrast, volumetric shrinkage increased steadily after an initial decrease in the bottom portion in <u>C. travancoricus</u> (Fig. 5).

The analysis of variance revealed that both the within- and between-stem variations were significant in <u>C. travancoricus</u> whereas only the between-stem variation was significant in <u>C. thwaitesii</u> (Table 3).

<u>4.1.5 Moisture content</u>

The mean values of the observations are given in Table 1 and the individual values are tabulated in Apendix III.

The results showed that at 5% probability level, the variation in moisture content between the two species was statistically significant (Table 1) <u>C. thwaitesii</u> recorded a higher moisture content. As in the case of density, the range in values was high but, the coefficients of variation indicated that the variation in both species was similar (Table 1)

The F Table shows that the between-and within-stem variations were significant in both species (Table 3). Within the stem, both species showed an increase in moisture content towards the top as a reverse trend compared to density (Fig. 6).

4.2 Anatomical Characteristics

4 2.1 Vascular bundle frequency

The mean values of the observations are given in Table 2 and the individual observations are tabulated in Appendix IV.

The variation in values for this property between the species was found to be highly significant. The slender cane, *C. travancoricus*, recorded a higher mean value of 19 5 compared to 3.3 of *C. thwaitesii*. The range in values was also different for both species. The coefficients of variation indicated that the variation in *C. thwaitesii* was higher compared to the other species.

The F Table shows that the between- and within- stem variations along the stem were not significant in *C. thwaitesii* whereas, only the within-stem variation was significant at 5% probability level in *C. travancoricus* (Table 4). Within the stem, the vascular bundle frequency increased from the bottom upto a certain height level and then decreased slowly towards the top in *C travancoricus* whereas the value decreased from bottom to the middle in *C thwaitesii* and then increased slightly towards the top

Table 2

Comparison of quantitative data for anatomical properties in *C. travancoricus* and *C. thwaitesii*.

Physical properties

Parameter	*C. travancoricus* Mean	Range	C.V	*C. thwaitesii* Mean	Range	C V	t-value
1. V.B Frequency/mm^2	19.5	17-23	9 7	3.3	2-9	31.5	36 49**
2. V.B Diameter (mm)	.313	.22-.46	8 1	.76	.56-.1.1	10 8	- 26.2**
3. Fibre %	26.4	13.5-40.5	28 4	27.6	16-47	22.5	-.605^{ns}
4. Phloem %	10.1	5-13 5	24.3	8.9	5-12	21.7	1.89**
5. Metaxylem Diameter (mm)	.140	.08-.18	14.7	.352	.146-.448	25	-11.6**
6. Xylem %	33	17-43	21.7	27.8	15-38	24 9	2.52**
7. Cortex %	14.7	8 2-14.7	35.6	2.5	1.2-5.6	45	10 8**
8. Metaxylem length (mm)	1.8	.370-4.9	32.2	1.7	.5-3.3	24.9	1.28^{ns}
9. Fibre length (mm)	1.4	.5-2.8	13.7	1.7	.5-4	12.2	-6.15**
10. Lumen width (mm)	.007	.002-.02	28.4	.008	.002-.02	28	-2.07*
11. Fibre width (mm)	.017	.012-0 28	8.8	.019	.008-.034	4.2	-7.5**

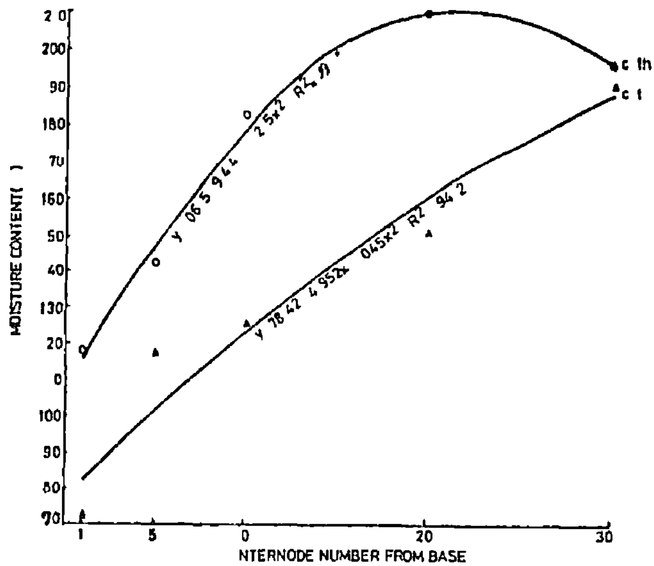


Figure 6 Moisture content variation as a function of distance from the stem base (number of internodes)

C th - C. thwaitesii
C.tr - C. travancoricus

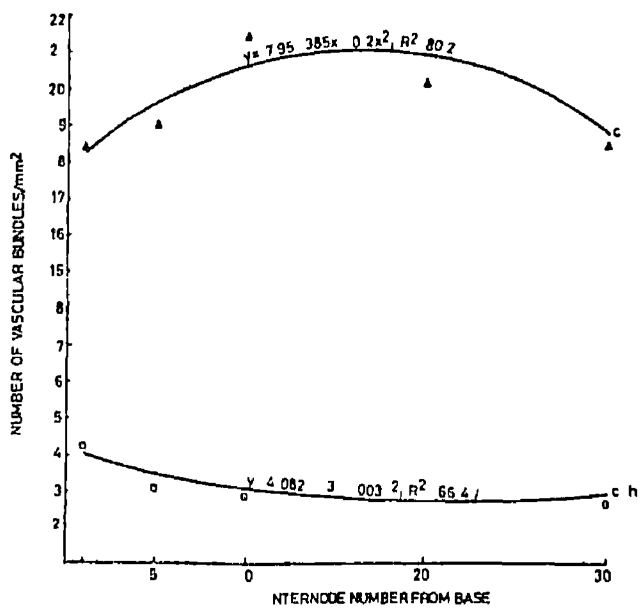


Figure 7 Variation of vascular bundle frequency as a function of distance from the stem bottom (number of internodes)

C.th - C thwaitesii
C,tr - C trav ncoricus

(Fig. 7). In C. thwaitesii, the vascular bundle frequency increased from the centre to the periphery (Appendix IV) Similar variation was observed in the thinner cane also.

4.2.2 Vascular bundle diameter

The mean values of the observations are given in Table 2 and the individual values are tabulated in Appendix V.

Between the two species, t-value shows that the difference in this property was highly significant (Table 2) The thicker cane had a larger vascular bundle with a higher range of values. However, the coefficients of variation showed that the variation was more or less similar for both canes (Table 2).

The F- value showed that in C. thwaitesii, the within-stem and between-stem variations in vascular bundle diameter were statistically significant, whereas in C. travancoricus, only the within-stem variation was significant (Table 4). Within the stem of thicker cane, the vascular bundle diameter showed an increasing trend from the bottom to the top, whereas in the slender cane, the vascular bundle size slightly decreased initially and then gradually increased towards the top (Fig. 8).

4.2.3 Fibre percentage

The mean values of observations are given in Table 2

Table 3

Analysis of variance of physical properties in the two rattan species.

Physical properties

Parameter	*C. travancoricus* Source of Variation	Degree of Freedom	Mean Square	F	*C. thwaitesii* Source of Variation	Degree of Freedom	Mean Square	F
1. Internode length	Between	4	59.98	24.22**	Between	4	80.1	5.1**
	Within	21	20.2	10.58**	Within	22	84.2	5.36**
	Error	84	2.48		Error	88	15.7	
2. Internode Diameter	Between	4	2.76	26.87**	Between	4	305.3	95.2**
	Within	21	0.4	3.93**	Within	22	8 17	2.55**
	Error	84	0.1		Error	88	3.2	
3. Density	Between	4	0.017	15.28**	Between	4	0.036	21.2**
	Within	4	0 086	77.24**	Within	4	0.020	11.7**
	Error	16	0.001		Error	16	0.017	
4. Volumetric Shrinkage	Between	4	273.69	4.78**	Between	4	408.76	7.79**
	Within	4	541.33	9.46**	Within	4	110.03	2.096^{ns}
	Error	16	57.25		Error	16	52.49	
5. Moisture Content	Between	4	3454.2	8.6**	Between	4	14822.2	17.99**
	Within	4	10360.6	25.8**	Within	4	8079.72	9.8**

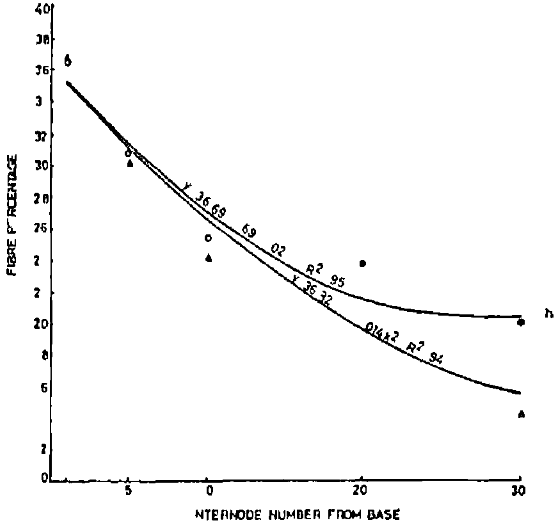


Figure 9 Variation of Fibre percentage as a function of distance from the stem bottom (nu ber of internodes)

C th - C thwaitesii
C tr - C.travancoricus

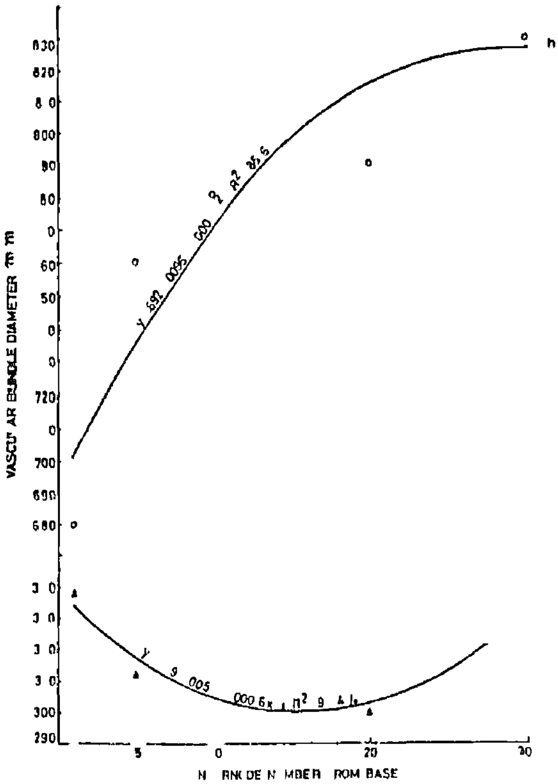


Figure 8 Vascul r bundle diameter v ri tion as a function of di tance from the tem a e (nu ber of internodes)

C th - C thw it sii
C tr - trav ncoricu

and the individual values are tabulated in Appendix VI. *C. thwaitesii* had a greater mean fibre percentage than *C. travancoricus*. The coefficients of variation showed that the range and hence the variation in values were greater for the latter (Table 2). The difference between the two species was not found to be statistically significant. The inner and outer regions of *C. thwaitesii* showed that the percentage of fibres decreased from the periphery to the centre. (Appendix VI) In *C. travancoricus* also, similar pattern was observed.

The F values showed that in the slender cane, both the between-stem and within-stem variations were significant, whereas in the thicker cane, only the variations within a stem were significant (Table 4). Similar patterns of variation within the stem were exhibited by both the species - the bottom recording the maximum value and a gradual decrease towards the top (Fig. 9).

4.2.4 Phloem percentage

The mean values of the observations are recorded in Table 2 and the individual values are given in Appendix VII.

A higher mean value for phloem percentage was shown by the slender cane, *C. travancoricus*. The range of values was higher for the latter and hence the variation was also greater for this species as indicated by the coefficients of

Table 4

Analysis of variance of anatomical properties in the two rattan species

Anatomical parameters

	C Tra ancoricus				C thwaitesii			
	Sou ce of Variation	Degree of Freedom	Mean Square	F	Source of Variation	Dcg ee of F eedom	Mean Square	F
1 Vascular Bundle Frequency	Between	4	4 94	2 18^{ns}	Between	4	1 98	2 9^{ns}
	Within	4	9 04	3 99^{ns}	Between	4	66	2 42^{ns}
	Error	16	2 27		Error	16	0 69	
2 V B Diameter	Between	4	0 00067	2 73^{ns}	Between	4	0 2	9 4**
	Within	4	0 001	5 1**	Within	4	0 13	6 46**
	Error	16	0 0002		Error	16	0 21	
3 F bro po oontnge	B wo n		72 1	10 07**	Bo ween	4	16 06	2 6 ^{ns}
	Within	4	285 8	39 89**	Within	4	207 51	33 82 *
	Error	16	7 71		Error	16	6 14	
4 Phloem %	Between	4	8 64	2 06^{ns}	Between	4	0 66	0 25^{ns}
	Within	4	11 74	2 8^{ns}	W thin	4	11 26	4 27*
	Error	16	4 19		Error	16	2 64	
5 Metaxylem Diameter	Between	4	0 00005	0 93^{ns}	Between	4	0 006	8 06**
	Within	4	0 002	47 78**	Within	4	0 039	53 8**
	Error	16	0 00005		Error	16	0 0007	
6 Xylem %	Between	4	49 5	3 87*	Between	4	7 74	94^{ns}
	Within	4	221 3	17 29**	Within	4	251 12	30 57**
	Error	16	12 8		Er or	16	8 22	
7 Cortex %	Between	4	25 87	7 2**	Between	4	0 89	5 84**
	Within	4	138 37	38 59**	Within	4	5 9	38 78**
	Error	16	3 59		Eror	16	0 15	
8 Metaxylem Length	Between	4	0 27	2 15^{ns}	Between	4	0 11	1 6^{ns}
	Within	4	0 3	2 4^{ns}	Between	4	0 66	9 62**
	Error	16	0 12		Error	16	0 069	
9 Fibre Length	Between	4	0 06	3 98*	Betwe n	4	0 08	2 43^{ns}
	Within	4	0 08	5 34**	Within	4	0 06	1 72^{ns}
	Error	16	0 02		Error	16	0 03	
10 Lumen Width	Between	4	0 000008	8 19**	Between	4	0 00001	18 82**
	Within	4	0 00001	11 8**	Between	4	0 00002	22 004**
	Error	16	0 000001		Error	16	0 0000008	
11 Fibre Width	Between	4	0 000005	2 94^{ns}	Between	4	0 000002	5 6**
	Within	4	0 000002	1 33^{ns}	Within	4	0 0000003	0 71^{ns}
	Er or	16	0 000002		Error	16	0 0000004	

variation. The variation between the species was significant only at 5% probability level (Table 2).

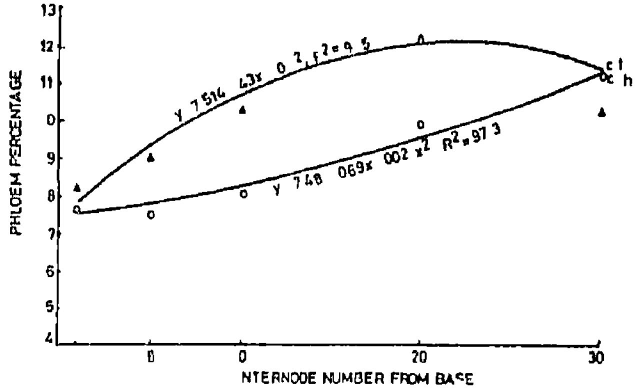
The F value showed that the between-stem variations were not statistically significant for both the species, whereas in C. thwaitesii the variations within-stem were significant at 5% probability level (Table 4). Within the stem, the variation patterns were not similar but an increasing trend was observed from the bottom to the top (Fig. 10).

4.2.5 Metaxylem diameter

The mean values are shown in Table 2 and the individual observations are tabulated in Appendix VIII.

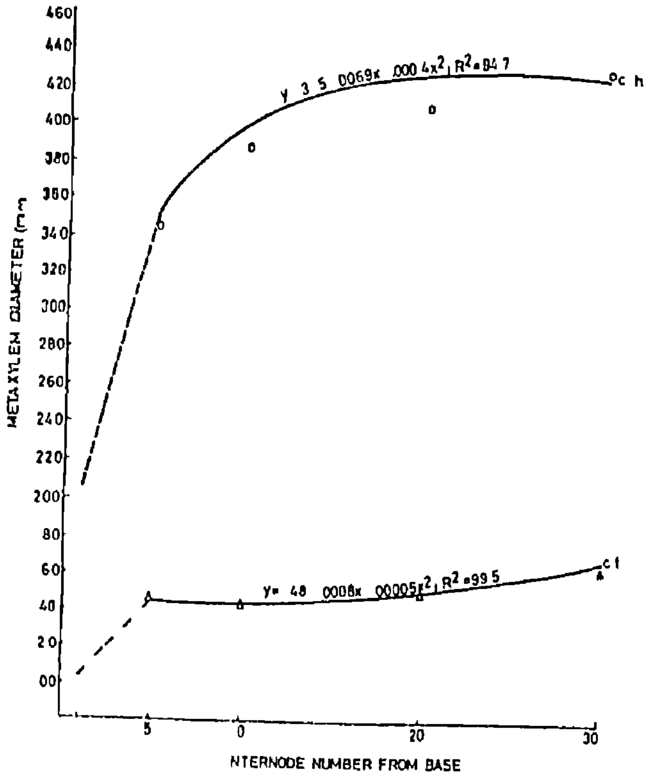
The results showed that C. thwaitesii had a wider metaxylem vessel than C. travancoricus. The range of values was also higher in the former and hence had a higher variation as indicated by the coefficients of variation The difference in the metaxylem diameter between the two species was statistically significant (Table 2).

The F value revealed that in C. thwaitesii, both the within-stem and between-stem variations were significant, whereas in C. travancoricus, only the within-stem variation was significant (Table 4). The variations along the stem showed similar patterns in both species, the values



Iigure 10 Phloem percentaje v riation as a function of di.stance from the .stem bottor (number of internode.)

C.th - C thwaitesii
C.tr - C.travancoricus



Iijure 11 Variation of the Metaxylem diameter as a function of di tance from the .stem base (number of internodes)

C th - C thwaitesii
C tr - C travancoric s

gradually increasing from base to top, although a marked increase from internode number 1 to 5 was noticed (Fig 11)

4.2.6 Xylem percentage

The mean values of the observations are shown in Table 2 and the individual values are tabulated in Appendix IX

C. travancoricus had a higher xylem percentage than the other cane. The variation in values was similar in both species but range in values was slightly more for the thicker cane, as indicated by its coefficient of variation The t- value revealed that the difference between the species was statistically significant (Table 2)

The F value showed that the within-stem variations were significant for both canes while the between-stem variation was significant at 5% level of probability for *C travancoricus* alone (table 4). The variation along the stem in both canes showed a similar pattern, increasing from the base to the top (Fig. 12).

4 2.7 Cortex percentage

The mean values of the observations are recorded in Table 2 and the individual values are tabulated in Appendix X.

The slender cane, C. travancoricus had a higher mean cortex percentage of 14.7 compared to 2.5% of the thicker cane. The range in the values was high and the variation in the species was large as indicated by their coefficients of variation. Between the species, the t- value shows that the variation in this property was significant (Table 2).

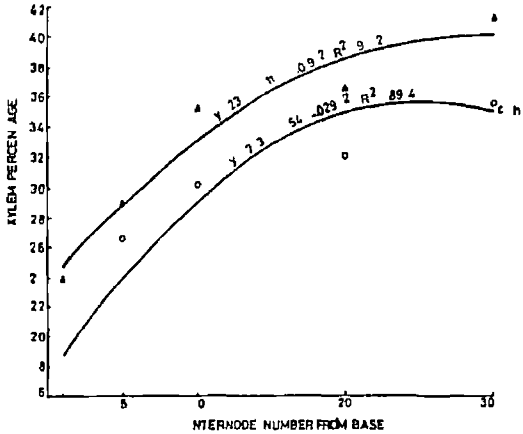
The variations both between the stems and within the stems were statistically significant (Table 4). Within the stem, the variation patterns were similar the basal internode recording the highest value and decreasing towards the top (Fig. 13).

4.2.8 Metaxylem element length

The mean values of the observations are recorded in Table 2 and the individual values are tabulated in Appendix XI.

The thinner cane had a slightly higher mean value than the other cane. The coefficients of variation showed that the variation in both the species was more or less similar The variation in values for this property was not statistically significant between the species (Table 2).

The analysis of variance showed that in C. travancoricus, the the between- and within-stem variations were not significant whereas in C. thwaitesii, the within-



Iigure 12 Xylem percentage varıation as a function of distance from the stem bottom (number of ınternodes)

C.th <u>C thwaitesıı</u>
C.tr - <u>C travancoricus</u>

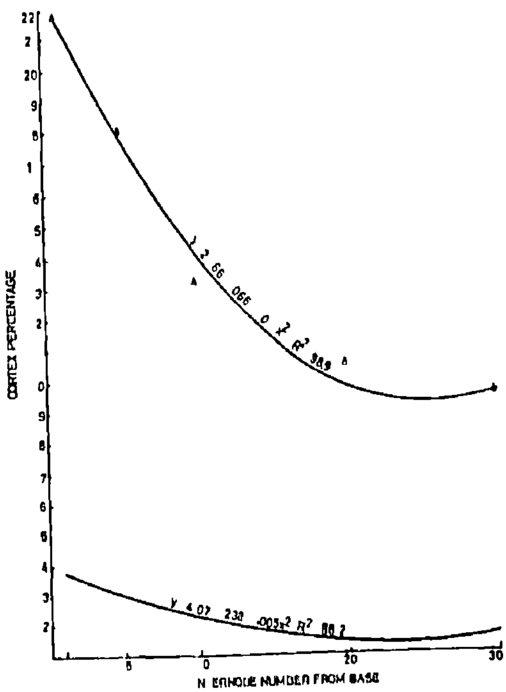


Figure 13 Cortex percentage varıatıon as a function of dıstance from the stem bottom (number of internodes)

C.th - <u>C.thwaitesıi</u>
C.tr - <u>C.travancoricus</u>

stem variation alone was significant (Table 4). No definite trend could be observed in the variations from the centre to the periphery for the thicker cane (Appendix XIII). Along the stem, both species recorded increasing values from the base to the top (Fig. 14).

4.2.9 Fibre length

The mean values of the observations are recorded in Table 2 and the individual values are tabulated in Appendix XII.

The reusits showed that C. thwaitesii had a mean fibre length of 1.7 mm, almost same as that of its mean metaxylem length whereas, C. travancoricus had a lower mean value of 1.4 mm. The coefficients of variation showed that the total variation was the same in both cases. However, the t - value indicates that the between-species variation was significant (Table 2).

The F-value showed that in C. travancorious, the between stem and within-stem variations were significant while, they were not significant in the other species (Table 4). An increasing trend could be observed in the fibre length from the centre to the periphery (Appendix XII) for C. thwaitesii Along the stem fibre length showed an increasing trend from the base to the top in C. thwaitesii while in C. travancoricus it initially decreased and then showed a gradual increase to attain the initial fibre length value (Fig. 15).

4.2.10 Fibre width

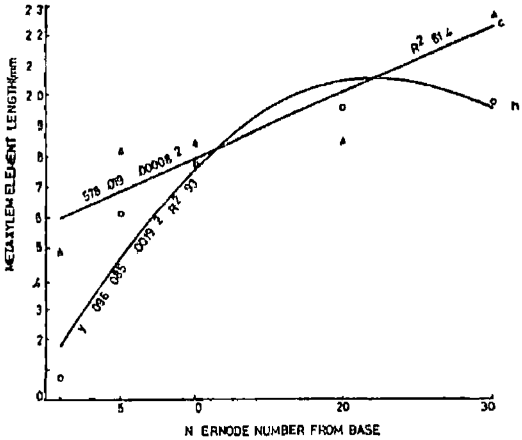
The mean values of the observations are given in Table 2 and the individual values are tabulated in Appendix XIII

The thicker cane had a higher mean fibre width. However, the coefficients of variation indicated a greater variation in values in C. travancoricus The t - value revealed that the variation between the species was statistically significant (Table 2).

The F Table showed that the between-stem and within-stem variations in C. travancoricus were not significant while, only the between-stem variation was significant in the thicker cane (Table 4). The results showed a decresing trend in fibre width from centre to the periphery in C. thwaitesii.

4.2.11 Lumen width

The mean values of the observations are recorded in Table 2 and the individual values are tabulated in Appendix XIV.



Ligure 14 Variation of metaxylem element length as a function of distance from the stem bottom (number of internodes)

C.th - <u>C.thwaitesii</u>
C.tr - <u>C.travancoricus</u>

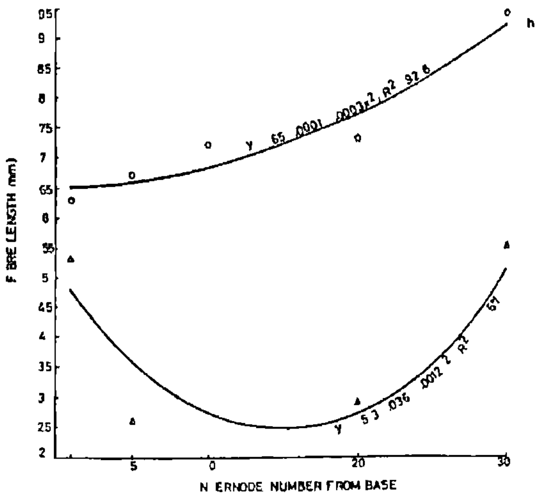


Figure 15 Libre length variation as a function of distance from the stem bottom (number of internode

C th - <u>C.thwaitesii</u>
C tr - <u>C travancoricus</u>

As in fibre width, the thicker cane recorded wider lumen and the variations in both species were similar as shown by their coefficients of variation. The between-species variation in values was significant only at 5% probability level (Table 2).

The variations both between-stem and within-stem were significant in both the species (Table 4). In *C. thwaitesii*, the variation in lumen width showed the opposite trend to that in fibre width, gradually decreasing from centre to periphery (Appendix XIV). Along the stem, however, the same trend of the fibre length was observed, increasing gradually from the bottom to the top (Fig. 17)

Correlation among physical and anatomical properties

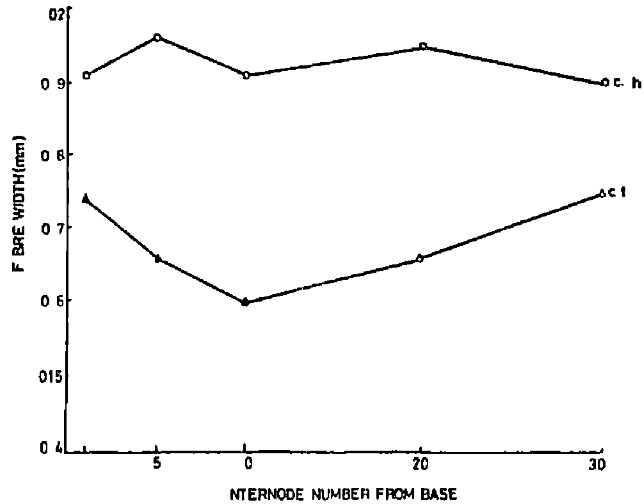
In order to assess the interrelationships among various properties, correlation coefficients are presented in Table 5. The more meaningful relationships, to explain the performance and behaviour of cane, are given below.

The length and diameter of internodes did not show consistent relationships with other variables although some of the correlation coefficients were significant. Wood density showed highly significant negative correlation with moisture content and volumetric shrinkage. The correlation coefficients also revealed that density was positively correlated with fibre percentage and that xylem percentage

Table 5

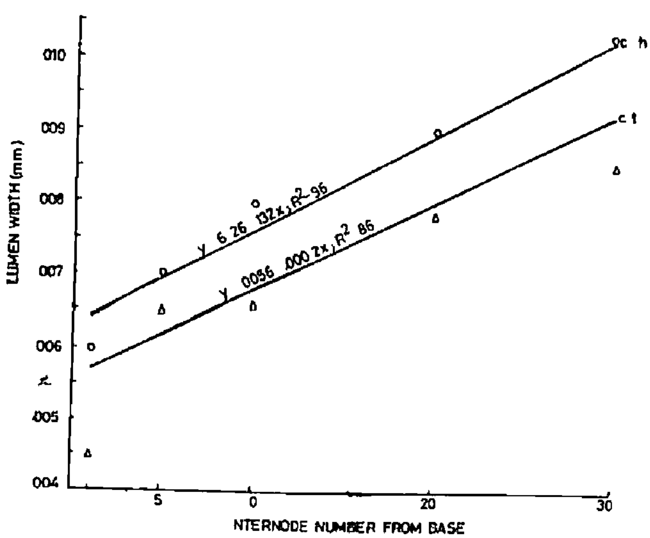
Correlation coefficients for the relationships between certain physical and anatomical variables

Parameters		Int. Length	Int. Dia.	Den-sity	Vol Shrink	M.C %	V.B Freq	V B Dia.	Fib. %	Phl	Met.Xy Dia.	Xyl %	Cor %	Met.xyl Length	Fib. Length	Lumen Length	F b w dth
Internode Length	(t)		326^{ns}	819**	554**	74**	03^{ns}	4*	65*	35^{ns}	81**	52**	-.59**	.60**	17^{ns}	69**	01^{ns}
	(T)		11^{ns}	44*	32^{ns}	41*	41*	44*	68**	39^{ns}	73**	79**	81**	85**	50*	48*	01^{ns}
In ernode Diameter	(t			16^{ns}	19^{ns}	03^{ns}	72*	30^{ns}	09^{ns}	14^{ns}	374^{ns}	16^{ns}	175^{ns}	225^{ns}	369^{ns}	048^{ns}	.299^{ns}
	(T)			522**	376^{ns}	377^{ns}	512**	64**	09^{ns}	022^{ns}	203^{ns}	09^{ns}	122^{ns}	223^{ns}	153^{ns}	47*	46*
Density	t)				714**	942**	038^{ns}	501*	898**	501*	894**	768**	825**	576**	065^{ns}	877**	097^{ns}
	(T)				83**	956**	588**	797**	422*	22^{ns}	786**	464*	374^{ns}	.279^{ns}	187^{ns}	86**	343^{ns}
Vol Sh inkage	( )					.823**	369^{ns}	177^{ns}	661**	254^{ns}	613**	47*	45*	437*	.231^{ns}	774**	406*
	(T)					893**	327^{ns}	531**	188^{ns}	159^{ns}	60**	285^{ns}	302^{ns}	11^{ns}	075^{ns}	681**	.282^{ns}
M.C %	(t)						163^{ns}	426*	871**	506*	788**	688**	776**	478*	046^{ns}	91**	191^{ns}
	(T)						409*	644**	417*	241^{ns}	734**	443*	375^{ns}	.266^{ns}	155^{ns}	.857**	.258^{ns}
V B Frequency	t)							-.517**	038^{ns}	242^{ns}	012^{ns}	033^{ns}	037^{ns}	.08 ^{ns}	143^{ns}	158^{ns}	364^{ns}
	T							768**	393^{ns}	067^{ns}	633**	334^{ns}	437*	.26^{ns}	306^{ns}	513 *	445*
V B Diameter	(t)								482*	503*	313^{ns}	354^{ns}	468*	432*	007^{ns}	442*	185^{ns}
	(T								397^{ns}	305^{ns}	777**	473*	423*	.225^{ns}	222^{ns}	691**	324^{ns}
Fibre %	(t)									562**	81**	883**	865**	513**	107^{ns}	797**	116^{ns}
	(T)									479*	771**	86**	803**	773**	348^{ns}	545**	139^{ns}
Phloem %	(t)										432*	558**	588**	415*	21^{ns}	395^{ns}	079^{ns}
	(T)										445*	442*	497*	392^{ns}	155^{ns}	369^{ns}	07^{ns}
Met. Xylem Dia.	(t)											760**	788**	.586**	177^{ns}	709**	026^{ns}
	T)											828**	766**	642**	253^{ns}	779**	143^{ns}
Xylem %	t)												829	448	183	584	006
	T)												848	833	375	528	104
Cortex %	(t)													534**	1 9^{ns}	603**	194^{ns}
	(T)													837**	-579*	478*	06^{ns}
Met. Xyl Length	(t)														309^{ns}	464*	049^{ns}
	(T)														573**	402*	03^{ns}
Fibre Length	t)															06^{ns}	065^{ns}
	(T)															.263^{ns}	056^{ns}
Lumen Width	(t)																395^{ns}
	T																447*



Iigure 16 Relatıonshıp between fıbre width and distance from the stem base (numbeı of ınternodes)

C.th - <u>C thwaitesii</u>
C.tr - <u>C.travancorıcus</u>



Iıgure 17 Lumen width variatıon as a functıon of dıstance from the stem base (number of ınternodes)

C th - <u>C thwaitesıı</u>
C.tr - <u>C ıravancorıcus</u>

and diameter of metaxylem vessels were inversely related to density. The diameter and number of vasoular bundles per unit area showed different relationships in thick and thin canes. What is evident from the table is that the most important contributing factors to stem density were the percentage of fibres, fibre lumen (or in turn fibre wall thickness), often cortex percentage, diameter of metaxylem vessel and percentage of xylem. Volumetric shrinkage was positively correlated with initial moisture content. Volumetric shrinkage was more related to the diameter of metaxylem vessel, lumen width and hence the wall thickness of fibres than to the number of vascular bundles per mm^2 and their diameter. It had inverse relationship with fibre% in _C. travancoricus_ in contrast to non significant correlation in _C. thwaitesii_.

Initial moisture content was positively correlated with both the diameter of metaxylem vessel and the percentage of xylem.

Vasoular bundle diameter was negatively correlated with the number of vascular bundles per unit area in both species.

In both the species the percentage of fibres had negative association with phloem and xylem percentages while, it was positively correlated with cortex percentage.

DISCUSSION

5. DISCUSSION

5.1 Variability of physical properties

Along the stem, internodes become longer upto atleast 3 to 5 internodes from the base and then either remain more or less constant or slightly increase in length towards the terminal end. Thus, no definite pattern of variation in internode length could be established. The diameter, as measured in the middle part of internode, also does not elucidate a clear trend although there is an initial drop from the first internode from the base and there is an increasing trend towards the top in *C. thwaitesii*. This observation supports the results of earlier studies in different species of *Calamus* (Fisher, 1978, Bhat and Renuka, 1986).

The other physical properties such as density, initial moisture content and volumetric shrinkage show difinite patterns of longitudinal variation. Such variation could best be explained using quadratic regression models as the R^2 values are in the range of 86-98%. (Fig. 4-6).

Density decreases in the stem from the base to the top, although the slope of the curve is more steep only upto about 20 internodes from the base. Density decline from the base to the top is also reported in other erect palms like *Cocos nucifera* although it is a linear decrease (Richolson and Swarup, 1977 Sudo, 1980 Killmann, 1983). Undisputedly, density value is higher in the periphery than in stem centre, in a given height level as reported in coconut stem (Richolson and Swarup, 1977 Meylan, 1978). The longitudinal variation in moisture content is almost in a reverse pattern compared to density in both species of rattans in contrast to a linear increase in coconut stem (Killmann, 1983).

Although volumetric shrinkage increases considerably from the base to the top in both species of rattans, the patterns of variation are different. In C. travancoricus, it increases even up to the internode number 30 from the base while in C. thwaitesii, it starts decreasing after internode number 20 with an initial increase from the the base. This difference is probably attributable to variation in the texture of the stem between the two species.

5.2 Anatomical variability

5.2.1 Cortex percentage

Despite the presence of relatively wide cortex in C. thwaitesii (Renuka et al, 1987) the mean percentage of cortex in the cross sectional area of the stem is higher in C. travancoricus. This indicates that in large diameter canes like C. thwaitesii the proportion of central cylinder in the stem is greater than that in the stem of C.

travancoricus. This is also often due to the diffuse secondary growth resulting in over all cell division and cell enlargement in the parenchymatous ground tissue. It may be noted that in C. travancoricus cortex percentage declines more rapidly upwards in the stem than in C thwaitesii. However both the variation patterns obey the regression curves of the second degree polynomial (Fig 12).

5.2.2 Frequency and diameter of vascular bundles

Longitudinal pattern of variation in number of vasuclar bundles per mm^2 area differs between the two species, although, the extent of variation within the stem of each species is relatively small. The pattern of an initial increase up to a certain stem length from the base and then a gradual decrease towards the top, exhibited by C travancoricus is almost similar to that reported in arborescent palm viz., Phoenix sylvestris (Swamy and Govindarajulu, 1961). On the other hand, an opposite trend is shown by C. thwaitesii, although the variation is insignificant. Tomlinson (1961) made an observation that the number of vascular bundles per unit area of the stem is approximately the same at all heights in palms. However, a linear increase in number of vascular bundles per cm^2 was observed with increasing stem height in coconut trunk (Richolson and Swarup, 1977 Killmann, 1983). The pattern displayed by coconut stem is in agreement with that noted in

Chrysalidocarpus eutescens by Zimmermann and Tomlinson (1974) Thus it is evident that the longitudinal variation in frequency of vascular bundles per unit area differs in both lianoid and non-lianoid palms. One feature which is in general agreement in the reported studies, is that the diameter of vascular bundles shows a reverse trend in variation to that of vascular bundle frequency from the bottom to the top (Zimmermann and Tomlinson, 1974 Killmann, 1983).

5.2.3 Percentage of fibres and vascular tissues

In spite of the differences in size and frequency of vascular bundles and their variation patterns between the thick and thin canes, the percentage of fibres and the trend in their curvilinear decrease from the bottom to the top are similar in both species. On the other hand, the percentage of xylem and that of phloem differ between the species. In general they increase with increasing stem height although the patterns showed by phloem percentage are different between the two species.. This inverse relationship of fibres with vascular tissues in their longitudinal variation can cause the decline in fibrovascular ratio from the bottom to the top as observed in non-lianoid palms like *Phoenix sylvestris* (Swamy and Govindarajulu, 1961)

5.2.4 Cell dimensions

Length of vessel elements (wide metaxylem) is almost similar in both the species. However, its increase from the bottom upwards in the stem is in a linear fashion in slender cane (*C. travancoricus*) in contrast to curvilinear manner in *C. thwaitesii*. The pattern of initial increase upto certain internode number from the base before the gradual decrease towards the terminal portion, displayed by *C. thwaitesii* is in agreement with the lainoid palm *Sabal palmetto* (Tomlinson and Zimmermann, 1967). As in the length of metaxylem elements, fibre length increases considerably from the bottom to the top in *C. thwaitesii* while it does not differ much between the bottom and top internodes in *C. travancoricus* However, fibre length varies considerably within the stem, by exhibiting an initial drop and then a gradual increase so as to attain more or less similar length in the top as in bottom portions of the stem. In spite of these differences between the species, the longitudinal variation in cell diamension could be elucidated using curvilinear regression models as the R^2 values are quite high. This longitudinal variation in cell length contradicts the trend observed in other non-lianoid palms like *Phoenix sylvestris* and *Washingtonia* where vessel elements are significantly longer at the base than at the top (Zimmermann and Tomlinson, 1974, Swamy and

Govindarajulu, 1961). Whether the cell length variation is related to the habit of palms is yet to be understood. For example, the climbing palms like rattans grow to enormous heights under favourable conditions and no information is available on the cell formation and length variation in subsequent stages of growth.

Diameter of metaxylem vessel increases significantly from the first internode at the base towards the top and from the periphery to the centre (Plate 22) while fibre width does not change considerably. However, fibre wall thickness decreases and hence the lumen width increases with increasing stem height and distance from the periphery towards the stem centre.

5.3 Identification based on anatomy

The quantitative data presented in Table 1 shows that internodes are shorter and more slender in *C. travancoricus* than in *C.thwaitesii* This obeys the classification of Kerala rattans proposed by Bhat and Renuka (1986). They include *C. travancoricus* under small diameter rattans (where mean diameter is < 10 mm) and *C. thwaitesii* under large diameter cane (mean diameter is > 19 mm). Although diameter and length of internodes are useful features in distinguishing between the species, they cannot be used as the only criteria due to the fact that there are many other species which come under small diameter and large diameter cane groups This warrants the examination of anatomical features. Except in the percentage of total fibres there are differences between the two species in anatomical characteristics such as cortex percentage, frequency and diameter of vascular bundles, percentage of xylem and phloem as well as length and diameter of metaxylem vessel elements and fibres. However, with distinctly different values between the two species, anatomical features that offer diagnostic clues are the vascular bundle diameter, number of vascular bundles per unit area (1 mm^2) and the diameter of wide metaxylem vessels. Furthermore, the little variation encountered in size and frequency of vascular bundles along the stem (between the internodes) favour these features as diagnostic criteria. Similarly Liese and Weiner (1987), in their preliminary study, made an observation that a comparison of the middle part of the internodes at different height levels reveals no differences in relation to size and distribution of vascular bundles The diameter of wide metaxylem vessels however increases considerably from the bottom-most internode to the top portion. The careful observation indicates that the diameter increase in metaxylem is rapid between internode number 1 and 5 from the bottom and thereafter it is rather slow. Since, the patterns of longitudinal variation are more or less similar in both species, the comparison of samples from the same position of stem may offer enough clue to separate the species based on the diameter of metaxylem vessels.

In addition to these quantitative anatomical differences, some of the qualitative characteristics may also be employed in identification of species. Particularly important are the shape of epidermal cell and its lumen and the width of cortex (Siripatanadilok, 1983). For instance, the cell lumen of epidermal cells is triangular or oval in C. travancoricus in contrast to oblong or rectangular in C thwaitesii. Furthermore, with features like relatively wide cortex and relatively large cells of the latter, an anatomist could distinguish it from C. travancoricus. Liese and Weiner (1987), in attempting intergeneric differentiation of rattans, made the observation that the composition of vascular bundles, their arragement in the peripheral zone, the peripheral paranchyma arrangement and the morphological variation of ground tissues could be used as diagnostic features. However such differences within the genus appear to be too small to act as separation criteria. More research is needed to bring out such minute differences in identification. The occurrence of perforation plates of tracheary elements with simple reticulate and scalariform types even within the species seem to have little diagnostic value in separating the two species.

5.4 Influence of anatomy on behaviour and performance of canes in utilisation

As in conventional timber species, many end-use characteristics of palm stem such as strength, rigidity and hardness are reflected through wood density (Sudo, 1980) The results of the correlation analysis show that the number of vascular bundles per unit area has positive relationship with density of *C. thwaitesii*, while in slender cane, *C. travancoricus*, the relationship is not evident. On the other hand the diameter of vascular bundle has a positive bearing on the density of *C. travancoricus* in contrast to the negative relationship in *C. thwaitesii*. The negative correlation of vascular bundle diameter with density probably indicates that the contribution of vascular tissue to the size of vascular bundles is more than fibres in the central cylinder which constitutes greater proportion of stem tissues in large-diameter cane. The percentage of fibres in the stem has positive contribution to the density in both species, although the relationship is weak in *C thwaitesii*. The proportion of vascular tissues viz., the percentages of xylem and phloem are negatively correlated with density. The diameter of metaxylem shows highly significant negative correlation with density. This relationship supports the observation that the fibre percentage does not differ much in rattan palms and that diameter of metaxylem vessel is one of the most important determining factors of 'wood' density (Tomlinson, 1961). For instance, C. thwaitesii, with wider vessels, has lighter wood than C. travancoricus although both the species have the same percentage of fibres in the stem. Yudodibroto, (1985), however, showed that the tensile strength improved with the increase in fibre percentage among the three species of Calamus grown in Indonesia Another most important contributing factor to the density is fibre wall thickness. The correlation analysis shows that in both species, fibre diameter is not related to density while lumen diameter is negatively correlated and hence fibre wall thickness has positive contribution to 'wood' density. Similarly in coconut palm, wood density was shown to be closely related to fibre wall thickness and the sclerosis of fibres (Meylan, 1978, Sudo, 1980). Since the walls of fibres continue to thicken almost throughout the life in palms, density of older stem is higher than that of younger stem. Similarly, as observed in the present study, older basal parts of the stem have more thick walled fibres and denser 'wood' than young terminal parts. These features explain not only why the basal part of the stem is more rigid and hard than top portion but also why it is denser and harder in the stem periphery than in the stem centre.

Initial moisture content (on over dry basis) of the stem shows a highly significant negative correlation with basic density. This indicates that cell lumen especially that of vessels accommodates more volume of water in the wood as it is a general condition in dicotyledons. Therefore, the diameter of the wide metaxylem vessels and xylem percentage show positive correlation with initial moisture content. Cortex percentage shows negative relationship with moisture content as vascular bundles per unit area and the vascular bundle size, however, it does not show consistent relationship with inital moisture content as observed in coconut palm (Killmann, 1983), although some of the correlation coefficients are significant

As seen from the correlation coefficients, the anatomical features that influence the volumetric shrinkage (from green to oven dry condition) are the width of metaxylem vessels lumen width and hence the fibre wall thickness. The negative association of fibre wall thickness with volumetric shrinkage suggests that the latter in higher in young lower density stems. The condition is somewhat vice-versa in dicotyledonous woods where density is positively correlated with shrinkage (Bhat, 1980) although Trenard and Gueneau (1977) reported that mean density has little influence on shrinkage.

SUMMARY

6. SUMMARY

The present comparative study of anatomy and physical properties of two rattan species, representing thickest and slendermost canes growing in Kerala, draws the following conclusions

1. Except in volumetric shrinkage, the physical properties such as internode length and diameter, density of 'wood' and initial moisture content differ between the two species.

2. The quantitative anatomical properties such as cortex percentage, number of vascular bundles per unit area and their diameter, percentages of xylem and phloem, length of late metaxylem vessels as well as fibre dimensions show distinct difference although the percentages of fibres are similar in two species

3. With the exceptions of internode length and diameter as well as fibre width, all the physical and anatomical properties exhibit a difinite pattern of longitudinal variation. Except in fibre lumen width the longitudinal variations occur in curvilinear fashion obeying the quadratic regression models. The distinctly different variations between the two species are those which were exhibited by volumetric shrinkage, number of vascular bundles per mm^2, the diameter of vascular bundles, phloem

percentage, metaxylem vessel element length and fibre length.

4. In addition to stem diameter and internode length, the most promising anatomical features of diagnostic value in distinguishing between the two species are epidermal cell and its lumen shape, size and frequency of vascular bundles as well as the diameter of wide metaxylem vessels

5. Of the different anatomical variables studied, fibre percentage, xylem percentage, fibre lumen width or the fibre wall thickness and the diameter of the metaxylem vessels are the more important determining factors of 'wood density than the amount or size of vascular bundles per unit area. Denser the 'wood' lower the volumetric shrinkage and initial moisture content in the stem. Basal portion of the stem is harder and heavier than top portion because of more thick walled fibres and smaller wide metaxylem vessels.

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APPENDICCS

APPENDIX I

Parameter Density (g/c.c)

C. thwaitesii

Stem					
Internode	I	II	III	IV	V
1	.617	.392	.462	.566	.460
5	498	.299	.429	.600	.440
10	.470	.260	.319	.525	.344
20	.410	.366	.322	.463	.272
30	.399	.322	.337	.449	.275

C. travancoricus

Internode	I	II	III	IV	V
1	.732	.617	.766	676	.639
5	.573	.490	.503	.445	.440
10	587	.389	.480	.469	.434
20	.516	.308	.484	.419	.374
30	.393	290	335	.354	.276

APPENDIX II

Parameter Volumetric shrinkage (%)

C. thwaitesii

Stem					
Internode	I	II	III	IV	V
1	19.46	35.79	22.16	20.68	24.20
5	21.56	46.85	21.71	18.21	25.08
10	22.54	51.32	30.82	22.13	43.03
20	27.40	38.39	31.54	21.36	58.40
30	26.63	31.47	27.69	25.51	46.06

C. travancoricus

Internode	I	II	III	IV	V
1	12.19	20.56	25.0	16.67	29.51
5	22.67	21.02	31.15	30.81	36.60
10	17.46	38.34	23.53	20.86	36.36
20	21.88	48.10	23.66	6.98	39.65
30	35.96	48.36	49.43	49.44	58 62

APPENDIX III

Parameter Moisture content (%)

C. thwaitesii

Stem

Internode	I	II	III	IV	V
1	81.55	165.79	127.88	94.91	119.66
5	113.81	253.71	131.44	78.21	136 39
10	126.60	287.87	211.80	98.01	192.59
20	163.08	254.88	219.24	127.48	274.16
30	168.38	255.0	207.80	135.23	272.32

C. travancoricus

Internode	I	II	III	IV	V
1	60.0	81.82	69.39	72.46	79.49
5	83.72	116.88	108.70	136.17	140.91
10	83.78	172.0	110.20	121.67	134.88
20	106.06	217.54	108.89	142.59	178.46
30	162.86	220.10	181.36	174.60	242.86

APPENDIX IV

Parameter Vascular bundle frequency/mm^2

C. thwaitesii

Internode	I			II			III			IV			V		
	Stem														
	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean
1	9	6	7.5	3	3	3	3	4	3.5	5	4	4 5	3	3	3
5	3	3	3	4	4	4	2	3	2.5	3	4	3.5	2	3	2.5
10	3	3	3	2	4	3	2	3	2.5	3	4	3.5	2	3	2 5
20	3	4	3.5	3	4	3.5	2	3	2.5	3	4	3.5	2	3	2.5
30	3	4	3.5	3	4	3.5	2	3	2.5	2	4	3	2	3	2.5

C. travancoricus

Internode	I	II	III	IV	V
	Stem				
1	18	18	20	17	19
5	20	19	18	17	21
10	23	18	23	21	22
20	21	17	21	23	19
30	18	17	19	18	19

APPENDIX V

Parameter Vascular bundle diameter (mm)

C. thwaitesii

	Stem														
Internode	I			II			III			IV			V		
	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean
1	.440	.710	.580	.860	.680	.770	.680	.760	.720	.430	.730	.580	.640	.830	.740
5	750	.792	.770	.80	.740	.770	.758	.870	.810	.570	.680	.630	.770	.850	.810
10	.70	.760	.730	.770	.770	.770	.772	.826	80	.70	.734	.720	.840	.870	.860
20	.780	.769	.770	.740	.690	.715	.890	.856	.870	.750	.740	.750	.850	.860	.860
30	.80	.768	.780	.760	.710	.750	.966	.850	.910	770	.70	.740	.890	.860	.880

C. travancoricus

	Stem				
Internode	I	II	III	IV	V
1	.366	.330	.342	.338	.314
5	.318	.30	.328	.332	.282
10	.312	.330	.294	.298	.268
20	.312	.298	.294	.280	.312
30	.338	.318	.316	.310	.308

APPENDIX VI

Parameter Vascular bundle Fibre (%)

<u>C. thwaitesii</u>

	Stem														
Internode	I			II			III			IV			V		
	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean
1	33	47	40	33	34	33.5	33	42	37.5	30	42	36	34	37	35 5
5	24	39	31.5	27	34	30.5	31	35	33	23	29	26	32	35	33.5
10	22	26	24	21	23	22	24	29	26.5	21	28	24.5	27	33	30
20	19	20	19.5	20	23	21.5	23	26	24.5	19	28	23.5	26	33	29.5
30	17	18	17.5	19	21	20	20	21	20 5	16	27	21.5	18	24	21

<u>C. travancoricus</u>

	Stem				
Internode	I	II	III	IV	V
1	37	30	40.5	35	40.5
5	35 5	24	30	32	30
10	27	19	28	27.5	20
20	25.5	14	26.5	25	19.5
30	22	14	18	18	13.5

APPENDIX VII

Parameter Phloem (%)

C. thwaitesii

Stem					
Internode	I	II	III	IV	V
1	10	11	5	7	6
5	6	7	8	9	8
10	8	6	9	10	11
20	9	10	10	10	11
30	10	10	11	12	12

C. travancoricus

Internode	I	II	III	IV	V
1	6	13	10	5	7.5
5	9	12	9	8 5	7
10	7	10	10.5	10.5	13.5
20	12	13	11.5	13	12
30	9	11	11	8	13.5

APPENDIX VIII

Parameter Metaxylem Diameter (mm)

<u>C. thwaitesii</u>

Stem

Internode	I	II	III	IV	V
1	.146	.310	.198	170	.208
5	.342	.40	.370	.278	.334
10	.355	.430	.388	.342	.422
20	.380	.430	.420	.376	.438
30	.434	.430	.436	.388	448

<u>C. travancoricus</u>

Internode	I	II	III	IV	V
1	.106	.116	.102	.10	.098
5	.142	.142	.151	.153	.138
10	137	.144	.146	.144	.146
20	.145	.162	.146	.137	.160
30	.164	.164	.173	.160	.158

APPENDIX IX

Parameter Xylem (%)

C thwaitesii

Stem					
Internode	I	II	III	IV	V
1	17	15	15	18	17
5	27	34	25	26	21
10	29	30	31	30	31
20	33	30	31	36	30
30	38	31	35	37	32

C travancoricus

Internode	I	II	III	IV	V
1	29	33	20 5	20	17
5	25 5	38	30	23 5	28
10	31	41	34 5	36	33
20	33	40	39 5	34	35 5
30	41	41	40	40	43

APPENDIX X

Parameter Cortex (%)

C thwaitesii

Stem					
Internode	I	II	III	IV	V
1	4 70	4 29	5 57	2 82	3 71
5	2 75	2 50	2 95	2 07	2 26
10	2 13	2 40	2 45	1 78	1 65
20	1 54	1 90	2 10	1 80	1 38
30	1 30	1 70	1 87	1 29	1 18

C travancoricus

Internode	I	II	III	IV	V
1	27	16 29	24	18 80	23
5	21	14	15 80	16 17	23
10	15	11 39	14 14	11 11	15
20	13	8 16	9 94	10 40	11
30	10 30	8 0	9 30	9 50	9

APPENDIX XI

Parameter Metaxylem element length (mm)

C. thwaitesii

	Stem														
Internode	I			II			III			IV			V		
	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean
1	.937	.860	.899	1.090	.820	.960	.856	.958	910	1.470	1.410	1.440	1.380	1.040	1.210
5	.949	1.086	1.018	1.834	2.330	2.080	1.530	1.620	1.580	1.650	1.780	1.720	1.580	1.750	1.670
10	1.818	2.320	2.070	1.60	1.440	1.520	1.720	1.637	1.680	1.650	2.120	1.890	1.770	1.570	1.670
20	1.965	2.240	2.10	2.160	1.880	2.020	1.698	1.430	1.560	2.350	2.270	2.310	1.760	1.790	1.780
30	2.350	2.190	2.270	2.10	1.950	2.0	1.623	1.750	1.690	2.250	1.960	2.110	1.850	1.790	1.820

C. travancoricus

	Stem				
Internode	I	II	III	IV	V
1	1.10	2.080	1.425	1.313	1.472
5	1.610	1.845	2.029	1.885	1.664
10	1.427	1.490	1.910	1.940	2.450
20	1.410	1.520	1.962	2.080	2.30
30	1.766	1.80	2.680	2.826	1.769

APPENDIX XII

Parameter Fibre length (mm)

C. thwaitesii

Stem															
Internode	I			II			III			IV			V		
	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean
1	1.120	1.550	1.340	1.130	1.510	1.320	1.323	1.580	1.450	1.896	2.0	1.950	1.990	2.190	2.090
5	1.350	1.549	1.450	1.727	2.020	1.870	1.510	1.650	1.580	1.449	1.710	1.580	1.730	2.030	1.880
10	1.825	2.020	1.920	1.435	1.670	1.550	1.530	1.620	1.580	1.590	2.050	1.820	1.740	1.750	1.750
20	1.730	1.619	1.670	1.60	1.832	1.720	1.770	1.720	1.750	1.690	1.810	1.750	1.710	1.840	1.780
30	1.884	1.90	1.890	1.750	1.90	1.80	1.80	1.80	1.80	1.820	2.10	1.960	2.010	2.170	2.090

C travancoricus

Stem					
Internode	I	II	III	IV	V
1	1 50	1 220	1.715	1.539	1 680
5	1 165	1.237	1 308	1 285	1 280
10	1 205	1 160	1.310	1.520	1 530
20	1.030	1.280	1 213	1 498	1 420
30	1 480	1.40	1 660	1.660	1 380

APPENDIX XIII

Parameter Lumen width (mm)

C. thwaitesii

	Stem														
Internode	I			II			III			IV			V		
	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean
1	.004	003	.004	.008	006	.007	.008	.0058	.007	.005	003	.004	.009	004	.007
5	006	0056	006	010	.007	0085	009	006	008	007	004	0055	010	.005	.008
10	005	004	005	013	008	010	010	007	0085	006	004	005	010	008	009
20	009	007	008	.014	.010	.012	010	008	009	0086	.007	008	.016	009	010
30	012	0076	0098	.014	010	012	009	008	009	009	.0056	008	018	0098	013

C travancoricus

	Stem				
Internode	I	II	III	IV	V
1	004	005	.0038	005	005
5	.005	0057	006	007	009
10	005	008	006	006	008
20	005	.010	006	007	011
30	.008	009	.008	008	010

APPENDIX XIV

Parameter Fibre width (mm)

C. thwaitesii

Internode	Stem														
	I			II			III			IV			V		
	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean	Inner	Outer	Mean
1	.018	.017	.0175	.0198	.0198	.0198	.020	.019	.0195	.019	.0178	.018	.020	.022	021
5	.019	.019	.019	.0196	.0198	.0197	.022	.0198	.020	.020	.019	.0195	.024	.021	.020
10	.018	.017	.0175	.021	.017	.019	.020	.020	.020	.020	.018	.019	.024	.020	.020
20	.019	.018	.0185	.021	.018	.0195	.020	.019	.0195	.020	.0196	.0198	.024	.021	.020
30	.020	.018	.019	.021	.018	.0195	.018	.0186	.018	.020	.018	.019	.026	.020	.020

C. travancoricus

Internode	Stem				
	I	II	III	IV	V
1	.019	.019	.016	.016	.017
5	.016	.014	.017	.017	.019
10	.017	.016	.015	.015	.017
20	.016	.018	.015	.015	.019
30	.018	.018	.017	.016	.019

ANATOMY AND UTILIZATION OF TWO CANE SPECIES OF KERALA (*Calamus travancoricus* and *C. thwaitesii*)

By

MOHAN VARGHESE

ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirement for the degree

Master of Science in Forestry

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ABSTRACT

Variation in certain anatomical and physical properties has been investigated and compared in two rattan species, viz. Calamus thwaitesii and C. tranvancoricus, the former representing the larger diameter and the latter possessing small-diameter canes of Kerala. Five stems possessing more or less similar number of internodes have been sampled in each of two species.

There were significant differences between the two species in certain physical properties such as length and diameter of internode, stem 'wood' density and initial moisture content although volumetric shrinkage did not differ appreciably Similarly, quantitative data for anatomical properties such as cortex percentage, number of vascular bundles per unit area, vascular bundle diameter, xylem and phloem percentage, metaxylem vessel element and fibre dimensions were markedly different between the two species while the fibre percentage had almost similar values.

With the exceptions of internode size and fibre width, the mean physical and anatomical properties in each species showed definite patterns of longitudinal variation, which could be best explained using quadratic regression models.

However, patterns of longitudinal variation were different between the species in volumetric shrinkage, number of vascular bundles per mm^2, vascular bundle diameter, phloem percentage, metaxylem vessel element and fibre length.

The most important useful features in distinguishing between the two species are internode length, stem diameter, epidermal cell and its lumen shape, diameter and frequency of vascular bundles as well as the diameter of wide metaxylem vessels.

The most important determining factors of 'wood' density are fibre percentage, fibre wall thickness and lumen width as well as the diameter of metaxylem vessels although features like the size and number of vascular bundles per unit area also influence this property. Volumetric shrinkage and moisture content are inversely related to the density of 'wood'. With higher density owing to more thick walled fibres and narrower wide metaxylem vessels, basal portion of the stem is harder and heavier than top portion