Internodal vessel elements were investigated in 7 genera and 27 species of the Tiliaceae with special reference to their taxonomic significance. On average, the longest vessel elements are 441 μm, recorded in Grewia asiatica and Triumfetta rhomboidea, and the shortest 78 μm, in Grewia microcos. The average maximum diameter is 79 μm in Corchorus australis, and the minimum 22 μm in Grewia microcos. The vessel elements are either cylindrical, spindle-shaped, column-, drum- or funnel-like, conical, clavate or oval. Perforation plates are simple in all the species studied, except in Grewia asiatica, where ephedroid-like perforation plates were recorded. There are usually two perforation plates in the majority of the members, rarely three or one. Adjacent wall thickening is commonly simple-pitted, but bordered, reticulate or scalariform pits have also been observed. Vessel elements vary in form and structure, number and inclination of perforation plates and side wall thickening. These characters are of taxonomic importance.

Die takonomiese waarde van die internodale vaatelemente van 7 genera en 27 spesies van die Tiliaceae is onder­sok. Die langste elemente (gemiddeld 441 μm) is in Grewia asiatica en Triumfetta rhomboidea aangetref en die kortste (gemiddeld 78 μm) in Grewia microcos. Die gemiddelde maksimumsmaat was 79 μm (Corchorus australis) en die minimum 22 μm (Grewia microcos). Die vaatelemente is silindries, spoelvormig, kolom-, drom- of trekteragtig, keël-, kolf- of ovaalvormig. Met die uitsondering van Grewia asiatica waar die perforasieplate eefdel/edagtig is, is die perforasieplate eenvoudig. Daar is meestal twee perforasieplate teenwoordig, maar soms een of drie. Die aangrensende wandverdikking is meestal eenvoudig gestippel, maar omringde, geretikuleerde en leervormige stippels is ook waargenoom. Vaatelemente varieer in vorm en struktuur, getal en helling van die perforasieplate en sywandverdikking. Hierdie kenmerke is van takonomiese belang.

**Keywords**: Anatomy, systematic position, Tiliaceae, vessel element structure.

**Material and Methods**
Plant material was collected from different parts of India. Mature internodes of fresh material, fixed in FAA, and herbarium material were macerated following the method of Jane (1956). Macerated tissue was washed thoroughly in distilled water, stained in Delafield's haematoxylin and mounted in glycerin jelly. All observations are supported by diagrams, drawn by using camera lucida at constant magnification (Figures 1–70).

The size of the vessel elements represents mean values of 30 readings. The list of species investigated, size of vessel elements, disposition and number of perforation plates and type of adjacent wall pitting are compiled in Table 1, arranged in alphabetical order.

**Results**

**Size**
Internodal vessel elements show great variation length and are therefore, for the sake of convenience, grouped into long (> 345 μm), medium (205-344 μm) and short (< 205 μm) (see Table 1).

(a) **Long**
Average length of long vessel elements ranges from 441 μm in Grewia asiatica and Triumfetta rhomboidea to 367 μm in Triumfetta pentandra, and diameter varies from 35 μm in Grewia asiatica and Grewia microcos to 71 μm in Triumfetta rhomboidea.

(b) **Medium**
Average length of medium vessel elements ranges from 312 μm in Corchorus fascicularis to 207 μm in Triumfetta pilosa, with diameter varying from 95 μm in Triumfetta rhomboidea to 22 μm in Grewia microcos.

(c) **Short**
Average length of short vessel elements ranges from 153 μm in Grewia tenax to 78 μm in Grewia microcos, and the diameter from 59 μm in Grewia villosa to 24 μm in Tricuspidaria dependens.

**Shape**
The vessel elements may be cylindrical (Figures 1–3, 6, 9, 11–13, 15, 25, 27, 28, 30–32, 37, 39, 42, 44, 49, 52–55, 59), spindle-like (Figures 4, 20, 22–24, 29, 38, 43, 48, 50, 51, 62, 64, 66, 67), column-like (Figures 17, 35), drum-like (Figures 5, 7, 8, 40, 46, 56, 58, 61, 69), conical (Figures 10, 14, 18, 36, 45, 47, 57, 65, 68, 70), clavate (Figures 16, 21, 33, 34), funnel-like (Figures 19, 26, 41, 60) or oval (Figure 63).

**Perforation plates**
These are simple in all the members studied, except for Grewia asiatica, where ephedroid-like perforation plates have been...
Figures 1-70 Internodal vessels showing variation in size, shape, position, number of perforation plates and wall thickening. 1-3. *Berrya ammonilla*. 6-7. *Corchorus aestuans*. 8-18. *C. antichorus*. 19-21. *C. depressus*. 22-32. *C. capsularis*. 33-44. *C. trident*. 45. *C. olitorius*. 46-52. *C. trilocularis*. 53. *Elaeocarpus serratus*. 54-56. *Grewia asiatica*. 57, 58. *G. disperma*. 59, 60. *G. emarginata*. 61. *G. obtusa*. 62. *G. salvifolia*. 63, 64. *Muntingia calabura*. 65, 66. *Triumfetta pentandra*. 67, 68. *T. rhomboidea*. 69, 70. *T. rotundifolia*. (Magnification of the figures: ×220.)
Table 1  Size of vessel elements, type, number and position of perforation plates and adjacent wall thickening in Tiliaceae

| No. | Taxon                           | Size of vessel (μm) | Perforation plates  |
|-----|--------------------------------|---------------------|---------------------|
|     |                                | Long l D/B          | Medium l D/B        | Short l D/B        | Ave. l D/B | Type 1 2   | 1 2 3 M O La | Sp Bp Rp Slp |
|-----|--------------------------------|---------------------|---------------------|-------------------|------------|------------|--------------|--------------|
| 1   | *Berrys ammonilla* Roxb.       | —                   | —                   | —                 | —          | —          | —            | —            |
| 2   | *Corchorus aescuus* Ham.       | 381 50              | 248 79              | 90 52             | 239 60     | —          | —            | —            |
| 3   | *C. antichorus* Rauchsch.      | —                   | —                   | —                 | —          | —          | —            | —            |
| 4   | *C. capsularis* L.             | —                   | —                   | —                 | —          | —          | —            | —            |
| 5   | *C. depressus* (L.) Stocks     | —                   | —                   | —                 | —          | —          | —            | —            |
| 6   | *C. fascicularis* Lam.         | —                   | —                   | —                 | —          | —          | —            | —            |
| 7   | *C. olitorius* L.              | 410 49              | 274 72              | 105 57            | 263 59     | —          | —            | —            |
| 8   | *C. tridentes* L.              | —                   | —                   | —                 | —          | —          | —            | —            |
| 9   | *C. trilocularis* L.           | 410 45              | 259 45              | 114 35            | 261 41     | —          | —            | —            |
| 10  | *Elaeocarpus serratus* L.      | 378 43              | 255 35              | 148 31            | 260 36     | —          | —            | —            |
| 11  | *Grewia abutilifolia* Jass.    | —                   | —                   | —                 | —          | —          | —            | —            |
| 12  | *G. asiatica* L.              | 441 35              | 240 33              | 79 36             | 253 34     | SEP c r    | r o c c c r   |
| 13  | *G. dispersa* Roth.            | —                   | —                   | —                 | —          | —          | —            | —            |
| 14  | *G. emarginata* W. & A.        | —                   | —                   | —                 | —          | —          | —            | —            |
| 15  | *G. microcos* L.               | 378 35              | 271 22              | 78 29             | 342 29     | —          | —            | —            |
| 16  | *G. obtusa* Wall.              | —                   | —                   | —                 | —          | —          | —            | —            |
| 17  | *G. pilosa* Lam.               | —                   | —                   | —                 | —          | —          | —            | —            |
| 18  | *G. salvi/folia* Heyne         | —                   | —                   | —                 | —          | —          | —            | —            |
| 19  | *G. tenax* (Forssk.) Flori     | 378 36              | 274 50              | 153 45            | 268 44     | SP c r c  | —            | —            |
| 20  | *G. villosa* Willd.            | —                   | —                   | —                 | —          | —          | —            | —            |
| 21  | *Muntingia calabura* L.        | —                   | —                   | —                 | —          | —          | —            | —            |
| 22  | *Triumfetta annuus* L.         | 405 43              | —                   | —                 | 405 43     | SP c r c  | —            | —            |
| 23  | *T. penindra* Guill. Le Perr.  | 367 52              | 264 33              | 103 36            | 244 40     | SP c r c  | —            | —            |
| 24  | *T. pilosa* Lam.               | 400 36              | 107 26              | —                 | 254 31     | SP c r c  | —            | —            |
| 25  | *T. rhomboidea* Jacq.          | 441 71              | 236 95              | 124 55            | 267 74     | SP c r c  | —            | —            |
| 26  | *T. rotundifolia* Lam.         | 224 43              | 145 37              | 123 40            | 267 74     | SP c r c  | —            | —            |
| 27  | *Trichaspatiaria dependens* Ruiz & Pav. | 249 24 136 24 178 24 24 | —                   | —                   | —                   | —                   | —                   | —                   |

a  L, length; D/B, diameter/width.
a  b  SP, simple perforation plate; SEP, simple and/or ephedroid perforation plate.
a  c  common; o, occasional; r, rare; —, not observed.
a  d  M, median; O, oblique; La, lateral.
a  e  SP, simple pitted; BP, bordered pitted; RP, reticulate; SLP, scalariform.

noticed (Figure 55). The disposition of perforation plates may be median and transverse (Figures 1, 6, 8, 9, 18, 19, 31, 69), oblique (Figures 7, 15, 21, 37, 40–48, 67, 70) or lateral (Figures 2, 3, 5, 6, 16, 22–25, 28–30, 34, 38, 50–53, 55, 56, 59, 60, 62). Oblique and lateral dispositions of perforation plates are common, while median and transverse are rare. There are mostly two perforation plates in the majority of the taxa, rarely three or one (Figures 10, 14, 16, 23, 24, 26, 33, 36, 45, 46, 52, 59, 67, 70). The shape of the perforation plates is usually circular or oval, and rarely rectangular (Figures 17, 35), lenticular or triangular (Figures 53, 61). In *Grewia salvi/folia* the napiform type of perforation plate has been observed (Figure 62). The perforation plates may be as wide as or narrower than the diameter of the vessel (Figures 1–70).

Adjacent wall thickening
The side wall thickening may be simple-pitted, bordered-pitted, reticulate or scalariform. Simple pits are circular or oval (Figures...
1–38, 40–53, 55–70), and their arrangement may be opposite, alternate or random. The bordered pits vary in shape and arrangement (Figures 39, 54). They may be transversely elongated in a ladder-like fashion (scalariform) or arranged in diagonal rows or lines (alternate) (Figures 39, 54). Simple-pitted side wall thickening is, however, commonly observed in Tiliaceae. Details of the vessels of the various specimens are given in Table 1.

End wall

Vessels of the investigated taxa may be with or without tails. The apex of the tails or the end wall varies from acute, obtuse, mucronate, rounded or truncate (Figures 2–6, 10–12, 14, 16, 18–30, 32–36, 38, 39, 41–46, 48–53, 55–57, 59, 60, 62–67, 69, 70).

Discussion

The Tiliaceae comprises 50 genera and about 450 species widely distributed in tropical and temperate regions, but chiefly in South East Asia and Brazil (Willis 1973). According to Metcalfe and Chalk (1950), vessel elements in Tiliaceae are small to medium-sized, with simple perforation plates and intervessel pitting minute to moderately large. The longest vessel elements recorded during the present study are 441 μm in Grewia asiatica, and the shortest 78 μm in Grewia microcos.

Radford et al. (1974) classified the vessel elements taking length as a criterion. In our investigation the vessel elements fell in the categories extremely short (< 175 μm) to medium-sized (350–850 μm). The maximum and minimum diameters ranged from 95 to 22 μm in Triumfetta rhomboidea and Grewia microcos, respectively. The diameters of the vessel elements also fell under the categories of extremely small (< 25 μm) to moderately small (50–100 μm) of Radford et al. (1974). Inamdar et al. (1983) and Bhat and Chalk (1992) made similar observations in the members of Malvaceae and Sterculiaceae, respectively. These investigations, therefore, conform with those of Metcalfe and Chalk (1950). The shapes of the vessels were cylindrical, fusiform, column-like, conical, fish-like, cup-like, clavate, ovate, funnel-like or erratic. The majority of the vessels were, however, cylindrical. Perforation plates were exclusively simple in all the species investigated. The disposition of the perforation plates was mostly oblique or lateral and occasionally median and transverse. The number of perforation plates was mostly two, but there were vessel elements with one or three perforation plates among the species studied. Side wall thickening in most species was simple-pitted with opposite, alternate or random arrangement, but bordered, reticulate, mixed bordered with simple-pitted or scalariform types were also observed. The vessel members of the family were mostly without tails. Vessel elements closely resembling tracheids are considered most primitive and those least resembling them most specialized (Chadle & Kosakai 1980). Short vessels with an end wall transversely placed and having a single, simple perforation plate are also considered to be the most specialized state (Chadle & Kosakai 1982).

Since most of the features regarding vessel characters are common among the tribes of the family, it can be concluded that the family Tiliaceae comprises a natural group of tribes. Vessels in the Tiliaceae are highly specialized in the internodes, and the present investigation revealed many advanced features, such as the short vessels, with simple perforation plates at the transverse end and simple pits with alternate arrangement.

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