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# Petal venation of a few species of *Malvaceae* and its possible utility in tracing relationships

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Abstract

Analysis of vein anastomosis of the petals of 13 species of *Malvaceae* shows that the species differ in respect of frequency and distribution pattern of venation types. Differences are statistically significant. The investigation suggests that the venation anastomosis types may be utilized as additional envidence of taxonomic delimitation.

## INTRODUCTION

In comparison with venation anastomosis in leaves, petal venation shows both greater simplicity and more diversity (Gumppenberg, 1924). For this reason, many scientists are inclined to use petal venation for interpretations of taxonomy and phylogeny (Arnott, Tucker, 1963, 1964; Datta, Saha, 1968; Foster, 1961). Venation and anastomosis patterns in petals of *Phaseoleae (Leguminosae)* appear to be specific in their frequency and distribution (Datta, Saha, 1968). The present analysis of species of another family, attempts to test the potentiality of petal venation as an aid to determining interrelations.

The family *Malvaceae* has been classified into a varying number of tribes, three by Bentham and Hooker (1862-67) and Waalkes (1966) four by Schultze-Motel (1964) and five by Hutchinson (1967). The sequence of arrangement of genera is also different in these systems. Recent cytological investigation of the family (Hazra, 1968) also supplies a few facts, useful in finding relationships within the family. Distribution of venation types in petals is worth interpreting, therefore, in the light of these taxonomical and cytological works.

## MATERIAL AND METHODS

Petals were collected from plants growing in Calcutta and suburbs. Flowers were studied (arranged after Bentham and Hooker). Sample numbers are stated within brackets.

A. Tribe *Malveae*

a) *Althea rosea* Cav. (Chowdhury 1; Calcutta; Chowdhury 2, Calcutta); b) *Sida rhombifolia* Linn. (Chowdhury 3, Calcutta; Datta 5, Chandernagore); c) *Sida cordifolia* Linn. (Chowdhury 4, Calcutta; Datta 6, Chandernagore); d) *Abutilon indicum* Sweet (Chowdhury 7, Calcutta; Datta 8, Chandernagore).

B. Tribe *Ureneae*

a) *Malachra capitata* Linn. (Chowdhury 9, Calcutta; Datta 10, Chandernagore); b) *Urena sinuata* Linn. (Chowdhury 11, Calcutta; Datta 12, Hooghly); c) *Urena lobata* Linn. (Chowdhury 13, Calcutta); d) *Malvaviscus arboreus* Cav. (Chowdhury 14, Calcutta; Chowdhury 22, Behala).

C. Tribe *Hibisceae*

a) *Hibiscus abelmoschus* Linn. (Chowdhury 15, Calcutta; Datta 23, Hooghly — flower); b) *Hibiscus cannabinus* Linn. (Datta 16, Calcutta); c) *Hibiscus surattensis* Linn. (Chowdhury 17, Calcutta); d) *Thespesia populnea* Soland. (Chowdhury 18, Calcutta; Datta 20, Chandernagore); e) *Gossypium herbaceum* Linn. (Datta 21, Chinsura; Chowdhury 19, Barrackpore).

Petals of open flowers were preserved in 70% alcohol, which removed the pigment within a fornight. These clear petals were mounted on glass-plates in 30% aqueous glycerine. Venation pattern were drawn by projection through an enlarger (at magnifications of nine and five, as was convenient). Petals of 20 flowers of each species were studied separately. Each drawing of a petal was divided into three broad sectors, peripheral, central and basal, each of which was again subdivided into left, median and right, peripheral left (PL), peripheral median (PM), peripheral right (PR), central left (CL), central median (CM), central right (CR), basal left (BL), basal median (BM) and basal right (BR). The number of different types of anastomoses for each sector was counted from the drawings, and the data were analysed statistically.

## RESULTS

Venation types in the petals of the species studied fall within the radiate and dictyodromous (reticulate) category of Kerner and Oliver (1895) (Fig. 1). According to Rao (1952), the primary trace of each petal in the *Malvaceae* originates in the receptacle as a conjoint staminode-petal trace which splits into three bundles. The lateral bundles undergo chlorosis. The median staminodal trace remains adnate

to the petal trace and beyond this non-functional. The median part of the petal trace splits into a number of strands which enter the petal. H e e l (1966) observed a fasciculate nature of the traces for petals, stamens and sepals in this family. The fasciculate traces of the petals, as observed here, divide into several equally prominent main bundles: 12-15 in *Thespesia populnea*, 10-12 in *Malvaviscus arboreus*, 8-9 in *Hibiscus surattensis*, 7-9 in *H. abelmoscus*, 6-7 in *H. cannabinus* and *Gossypium herbaceum* and 3-5 in *Urena lobata*. In *Malachra capitata*,

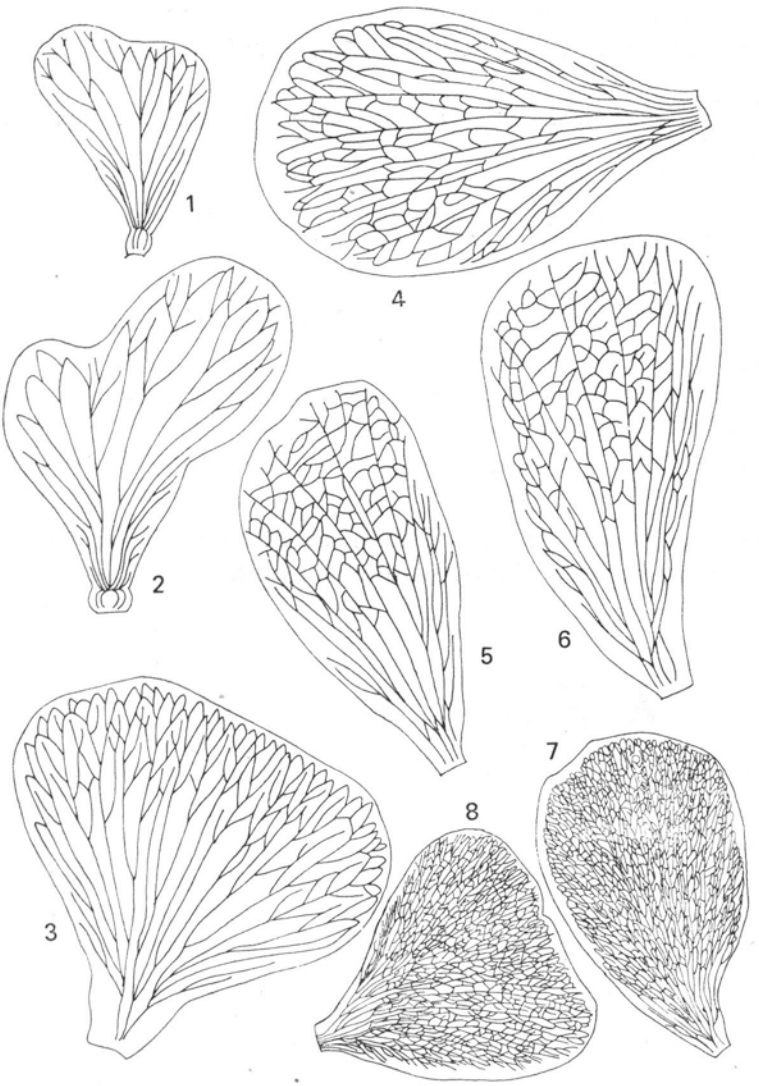


Fig. 1. Petal venation in (1) *Sida rhombifolia*, (2) *Sida cordifolia*, (3) *Abutilon indicum*, (4) *Malachra capitata*, (5) *Urena sinuata*, (6) *Urena lobata*, (7) *Hibiscus abelmoschus* and (8) *Gossypium herbaceum*

*Althaea rosea, Abutilon indicum* and *Sida* species, there are usually 3-4 main basal bundles, each dividing into a number of equally strong bundles. These latter major veins generally show a strong similarity to a monopodial condition above, more rarely to a dichotomy at the base. Distinction between mid-vein and lateral ones is impossible, and these major veins form a closed reticulate type of anastomosis in the median and peripheral sectors.

The petals examined represent nine anastomosis types (Fig. 2):

A — a single strand splitting and then fusing into a single vein;

B — a single strand, dichotomising, reuniting and then dividing again;

C — two branches derived from two different strands fusing into a single vein;

$C_1$ — two successive branches of a single vein anastomosing;

$C_2$ — two successive branches of a single vein uniting and dividing again;

$C_3$ — two branches from two different strands fusing in an arcuate pattern (F o s t e r, 1950), without forming a prolongation or having any evidence of a fusion point;

$C_4$ — two branches two different strands fusing into a single strand and then dividing;

D — one short and oblique from one strand fusing with an adjacent strand;

E — a long and straight vascular connection or laid down perpendicularly between two almost parallel strands.

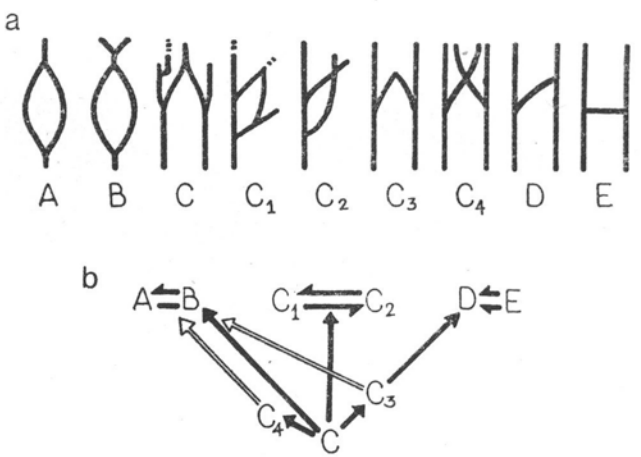


Fig. 2a. Types of anastomoses in *Malvaceae*
Fig. 2b. Possible affinities of venation anastomosis types of *Malvaceae*

Fig. 1 drawn to scale, gives a comparative idea of the length and breadth of the petals of the 13 species. Lengths of a hundred petals of each species, plotted against the number of their anastomoses (Fig. 3), shows no clear correlation between these two variables. The figure also represents the range of the numbers of anastomoses per petal for each species. The range clearly differs among the species. A comparison of mean length and petal area with the number of anastomoses in different species (Fig. 4) reveals no relationship.

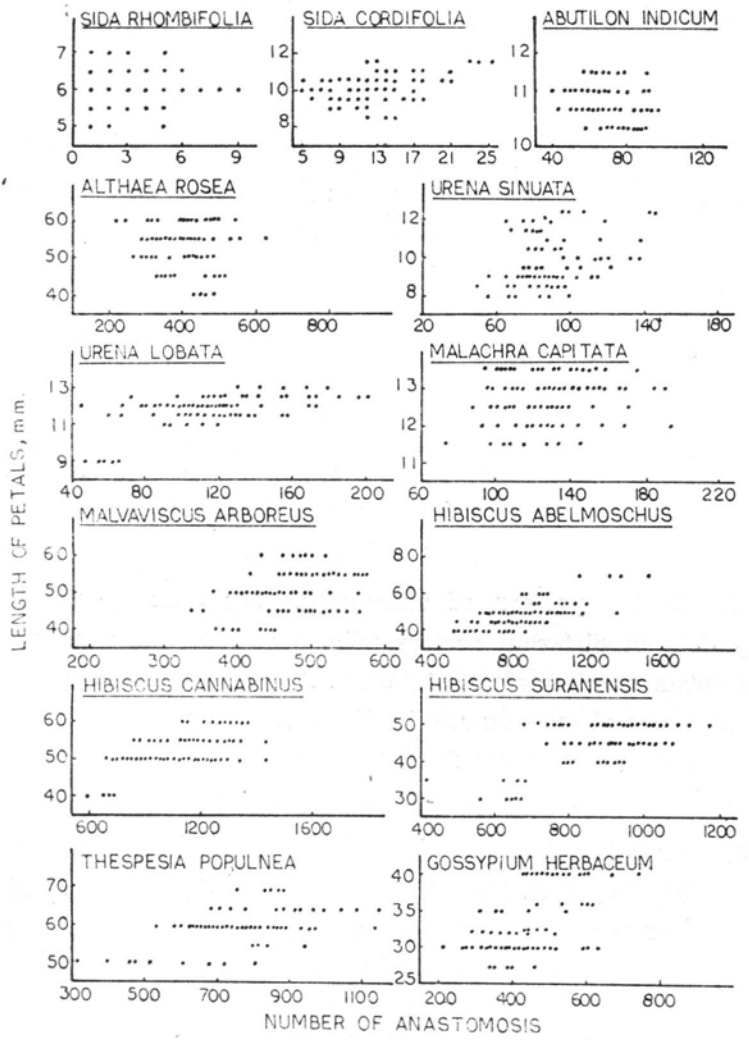


Fig. 3. Number of anastomoses in 100 petals of each species plotted against the length of respective petals

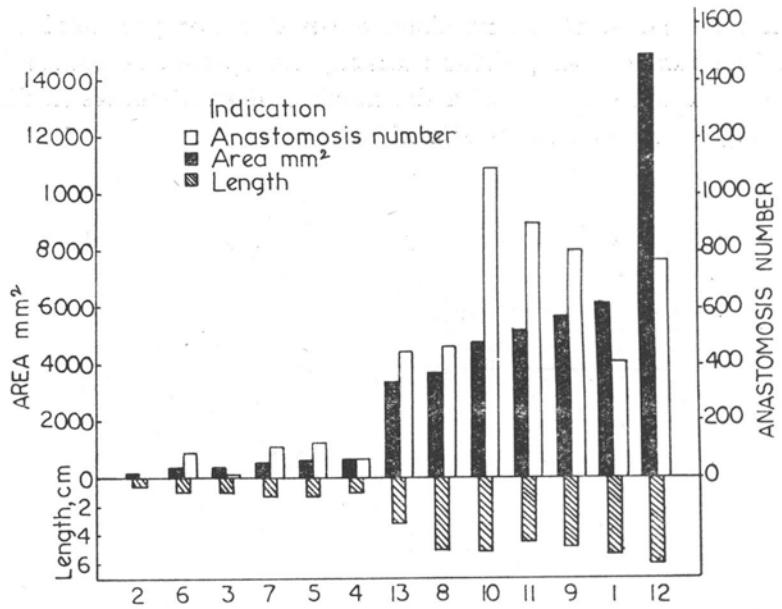


Fig. 4. Histogram comparing the mean length of petals (columns hanging downwards), area of petals and number of anastomoses per petal in each species. Species numbers are as in Figs. 5 and 6

The distribution pattern of anastomosis for each species is represented by dots in different sectors (Fig. 5 and 6), the number of dots indicating mean number of anastomoses. A comparison of the frequency of different types of anastomosis in different species (Fig. 7) shows that A, C, $C_4$ and E are the most frequent types.

Statistical analysis of variance of total number of anastomoses per flower and per petal (Table 1) shows that the calculated value of F is highly significant at both 1% and 5% levels of significance. This shows that the number of anastomoses for one species per petal and per flower, differs significantly from that of the others. Similarly, the number of each type: A, B, C, D and E per petal (Table 1) differs significantly (at both 5% and 1% levels) for each species. Species to species variation of the number of anastomoses per sector (Tables 2 and 3) is also significant.

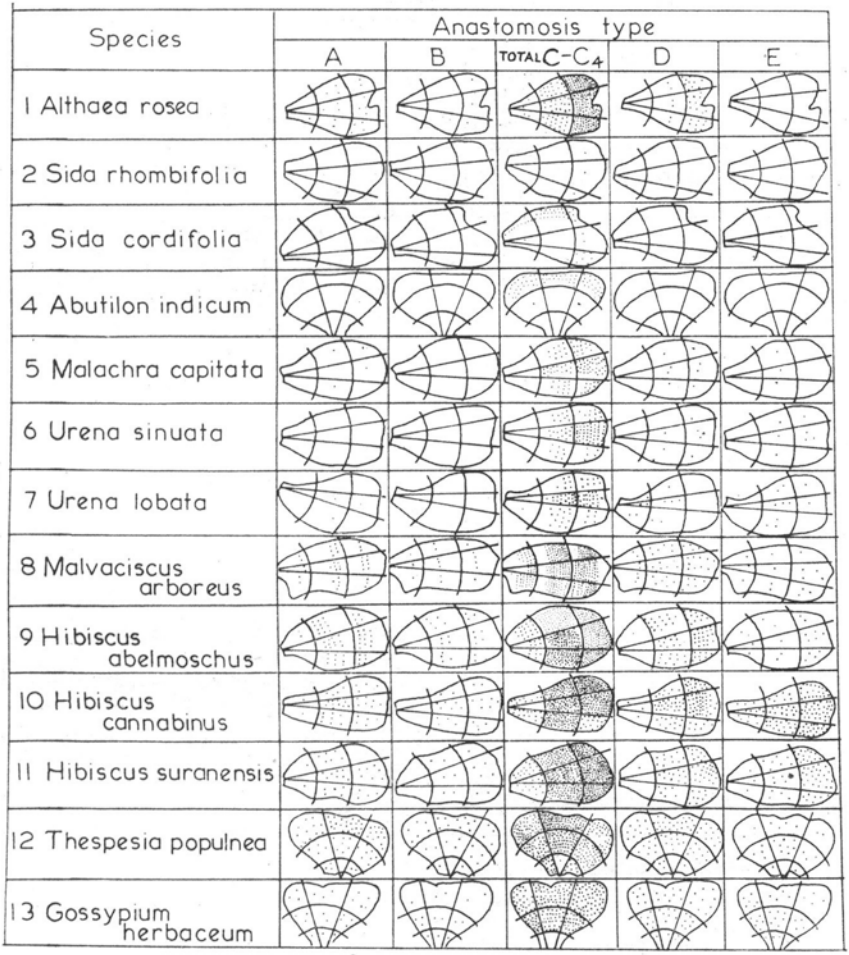


Fig. 5. Pattern of distribution of main anastomosis types (A, B, total, C, D, E) in petals of each species.
Mean numbers of anastomoses (by converting fractions to near wholes) are indicated by number of dots on respective sectors.

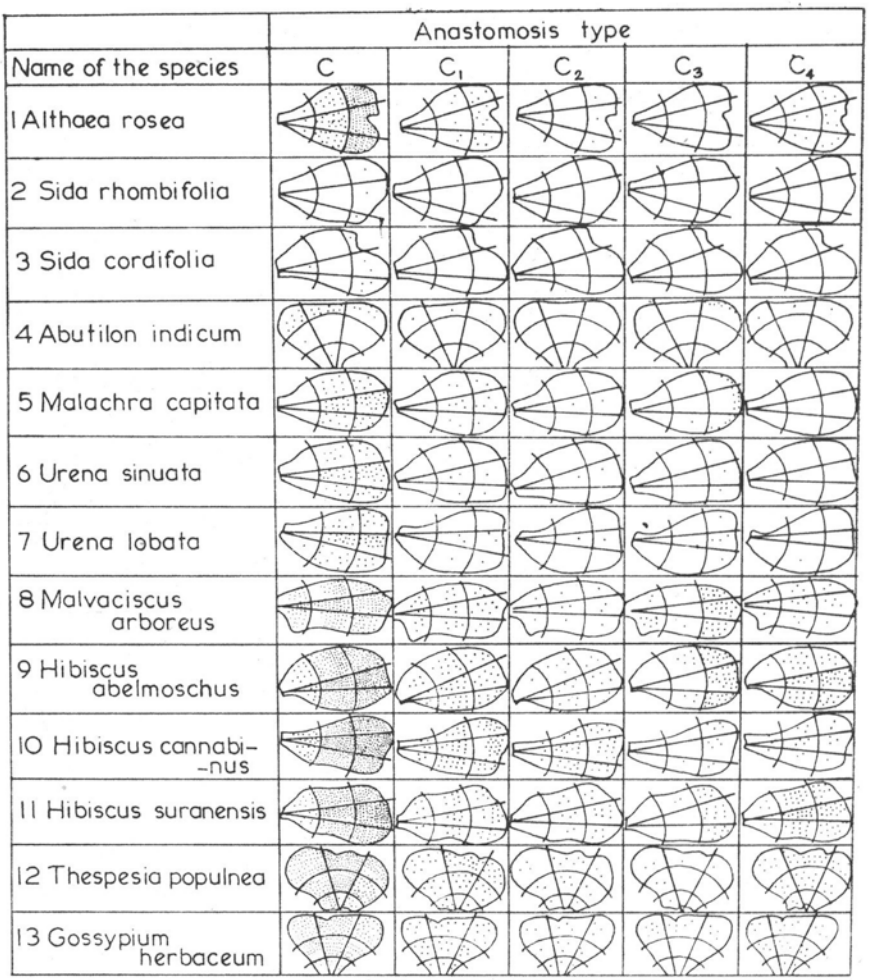


Fig. 6. Pattern of distribution of different C types (C, $C_1$, $C_2$, $C_3$, $C_4$) in petals of each species.
Dots indicates mean number as in Fig. 5

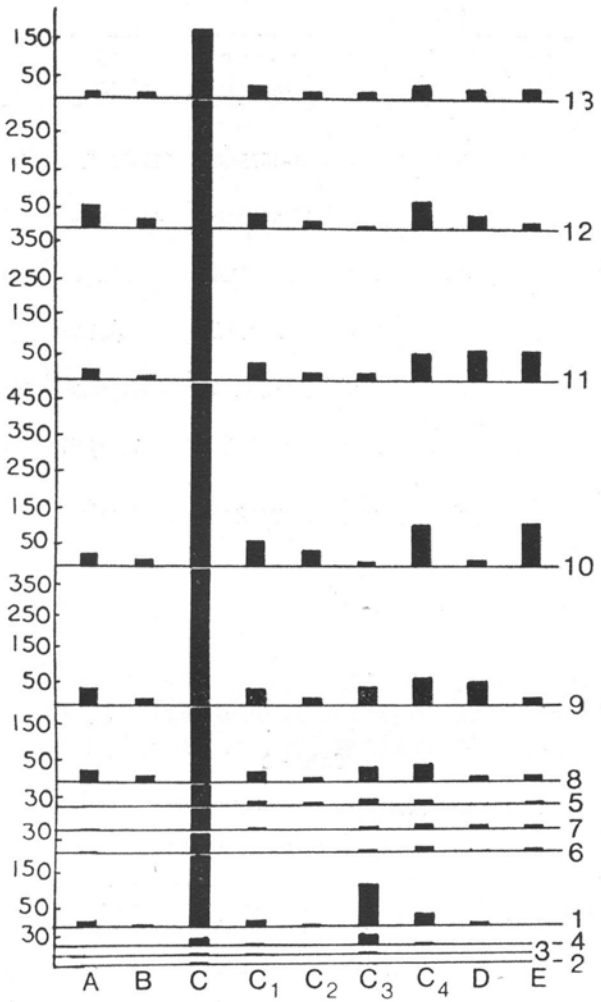


Fig. 7. Histogram comprising the numbers of different types of anastomosis per petal for each species.
Species numbers are as in Figs. 5 and 6

Table 1

Number of anastomoses per flower and per petal—Analysis of variance

| Analysis of variance | d.f. | | | S.S. | | | F |
|---|---|---|---|---|---|---|---|
| | Between species | Within species | Total | Between species | Within species | Total | |
| Total anastomoses per flower | 12 | 247 | 259 | 890446758.8 | 64343257.3 | 954790016.1 | 284.80 |
| Total anastomoses per petal | 12 | 247 | 259 | 35565190.0 | 4480188.8 | 38045378.8 | 162.58 |
| Type A anastomoses per petal | 12 | 247 | 259 | 134371.65 | 5527.0 | 139898.65 | 502.76 |
| Type B anastomoses per petal | 12 | 247 | 259 | 27969.26 | 4403.78 | 32373.04 | 120.35 |
| Type C anastomoses per petal | 12 | 247 | 259 | 16532163.3 | 4064486.9 | 20596650.2 | 84.38 |
| Type D anastomoses per petal | 12 | 247 | 259 | 446265.31 | 16594.95 | 462860.26 | 556.56 |
| Type E anastomoses per petal | 12 | 247 | 259 | 425742.8 | 46361.4 | 472104.2 | 188.28 |

Table 2

Total anastomoses per sector—Analysis of variance

| Analysis of variance | d.f. | | | S.S. | | | F |
|---|---|---|---|---|---|---|---|
| | Between species | Within species | Total | Between species | Within species | Total | |
| Sector BL | 12 | 247 | 259 | 43245.15 | 12282.75 | 53527.89 | 78.62 |
| Sector BM | 12 | 247 | 259 | 16270.07 | 4000.34 | 20270.41 | 84.83 |
| Sector BR | 12 | 247 | 259 | 29352.70 | 20783.71 | 50136.41 | 26.90 |
| Sector CL | 12 | 247 | 259 | 678663.39 | 80616.64 | 759280.03 | 173.99 |
| Sector CM | 12 | 247 | 259 | 957716.13 | 61589.63 | 1019305.76 | 320.69 |
| Sector CR | 12 | 247 | 259 | 398155.02 | 28020.26 | 426175.28 | 291.33 |
| Sector PL | 12 | 247 | 259 | 614050.08 | 93613.28 | 707663.36 | 134.49 |
| Sector PM | 12 | 247 | 259 | 2875672.10 | 177104.10 | 3052776.20 | 335.18 |
| Sector PR | 12 | 247 | 259 | 787495.10 | 101732.15 | 889227.25 | 159.31 |

Table 3

Total types C (total nos. of C, $C_1$, $C_2$, $C_3$, $C_4$) per sector —Analysis of variance

| Analysis of variance | d.f. | | | S.S. | | | F |
|---|---|---|---|---|---|---|---|
| | Between species | Within species | Total | Between species | Within species | Total | |
| Sector BL | 12 | 247 | 259 | 24919.65 | 6266.14 | 31185.79 | 80.26 |
| Sector BM | 12 | 247 | 259 | 6150.00 | 1838.03 | 7988.03 | 67.91 |
| Sector BR | 12 | 247 | 259 | 18011.55 | 1982.48 | 19994.03 | 187.28 |
| Sector CL | 12 | 247 | 259 | 396707.60 | 44496.70 | 441204.30 | 183.16 |
| Sector CM | 12 | 247 | 259 | 504235.80 | 18445.60 | 522681.40 | 561.83 |
| Sector CR | 12 | 247 | 259 | 210061.38 | 35593.36 | 245654.74 | 121.42 |
| Sector PL | 12 | 247 | 259 | 347936.70 | 54881.70 | 392818.40 | 189.65 |
| Sector PM | 12 | 247 | 259 | 1523769.40 | 158192.50 | 1681961.90 | 197.57 |
| Sector PR | 12 | 247 | 259 | 451122.80 | 66527.20 | 517650.00 | 137.89 |

## DISCUSSION

Pioneer workers on petal vention (Arnott, 1959a; 1959b; Arnott, Tucker, 1963; 1964) have suggested the need to study anastomosis types and the distribution patterns for the assessment of their significance in evolution and phylogeny. An investigation in *Phaseoleae* (Datta, Saha, 1968) has revealed the specificity of distribution pattern of anastomosis types, as suggested by Arnott and Tucker. The present work shows more clearly that the distribution pattern of anastomosis type is significantly constant and distinct for particular species. The total number of anastomoses per mature petal for a particular species varies insignificantly with the variation in petal size.

Apart from a few modifications, the types of anastomoses observed here are very similar to those described by Arnott and Tucker (1963). The C is the most frequent type in all species. Anastomoses are most common in the peripheral regions. In spite of these common characters, suggesting a homogeneity of the group, differences between tribes are marked. For example, E type is absent from the species studied in the tribe *Malveae*. Apart from C, the next most frequent type differs according to the tribe: $C_3$ in *Malveae*, $C_3$ and $C_4$ in *Ureneae* and $C_4$, D and E in *Hibisceae*.

The species differ also in the distribution of anastomosis types. Type C occurs most frequently in the left and right peripheral sectors of *Sida* species, in the left and right peripheral sector of *Abutilon indicum* and in the peripheral median sector in all other species. $C_1$ is most common in the peripheral right sector in *Sida* species, peripheral left sector in *Abutilon indicum*, peripheral median sector in *Althaea rosea, Urena lobata, Malvaviscus arboreus, Hibiscus cannabinus, Hibiscus surattensis,*

*Thespesia populnea* and *Gossypium herbaceum* and the central right sector in *Urena sinuata* and *Hibiscus abelmoschus*. Similarly, all the other anastomosis types also differ in respect of the sector of highest frequency. The distribution of C type anastomoses shows a gradation of frequency per sector of PL, PM, PR, CR, CM, CL, BM, BR, BL for *Sida rhombifolia;* and PM, PL, PR, CR, CL, CM, BR, BL, BM for *Althaea rosea*. Similarly, each species has a specific gradation in frequency in the distribution of a particular anastomosis type. So, it is clear from this study that in *Malvaceae*, both pattern and frequency of distribution of anastomosis type is characteristic and have a very narrow range of variation within a species.

Tracing evolution or phylogeny within the *Malvaceae* on the basis of petal-vein anastomosis is no doubt impossible, particularly when only 13 species have been examined. But the possible relations of the venation patterns are worth discussing. The classification of Schultze-Motel (1964) represents *Abutilon* as the most primitive genus in the tribe *Malveae*, next being *Althaea* and *Sida*, while according to Bentham and Hooker (1862-67), *Althaea* is more primitive than both *Sida* and *Abutilon*. In the classification of Waalkes (1966), the sequence is *Althaea-Abutilon-Sida*. Hutchinson (1967) gives the same sequence, but *Abutilon* and *Sida* are in a separate tribe, *Abutileae*. The species of *Ureneae* follow the sequence *Malachra-Urena-Malvaviscus* in Bentham and Hooker (1862-67) and in Schultze-Motel (1964), *Malvaviscus-Urena-Malachra* in Waalkes (1966) and *Malvaviscus-Malachra-Urena* in Hutchinson (1967). The species of *Hibisceae* show the order *Hibiscus-Thespesia-Gossypium* in Bentham and Hooker, in Schumann and in Waalkes, but *Hibiscus-Gossypium-Thespesia* in Hutchinson. A cytological study by Hazra (1968) represents *Thespesia* and *Hibiscus* as the most primitive and the most advanced genera, respectively, with *Malachra, Abutilon, Urena*, etc. forming a secondary set in the family. Saad (1960) and Fryxell (1965) have divided *Hibisceae* into *Hibiscineae* and *Gossypineae*. Fryxell (1968) suggests a separation of *Gossypieae* from *Malvaceae* on the basis of anatomical, morphological and cytological characters. The sequences of the tribes also vary in different systems: *Malvaea-Ureneae-Hibisceae* (Schultze-Motel and Bentham and Hooker), *Hibisceae-Ureneae-Malveae* (Waalkes), and *Hibisceae-Malveae-Abutiloneae-Ureneae* (Hutchinson).

In the *Malveae*, the total number of anastomoses per area (Fig. 4) is highest in *Althaea*, next in *Sida* and then *Abutilon*. In the tribe *Ureneae*, *Urena* shows the highest frequency per area, *Malachra* next and then *Malvaviscus*. This sequence does not tally with any of the systems. Of course, increase in vascularization "should be expected as often as reduction although virtually no papers, at present, claim the former"

(Carlquist, 1969). If, instead of reduction, gradual elaboration is regarded as the trend this sequence tallies with that of Hutchinson. In the *Hibisceae*, the order of reduction of number of anastomosis is *Hibiscus-Gossypium-Thespesia*. This sequence corresponds only to the classification of Hutchinson. According to Carlquist (1969), the extent of branching of petal-veins may be related to the width of the petal expanse. But in the species investigated here, the number of anastomoses per area shows no relation to the width.

Can we find any evolutionary trend in anastomosis type? Type C is most frequent in the family. Therefore C appears to be probably basic pattern. From a glance at the different anastomosis types (Fig. 2a), one can derive types $C_4$ and $C_3$ from C (Fig. 2b). Marked modification is noticed in A and B, one of which may be derived from the other, either by increase or by reduction of the apical extensions. These types may arise from C, $C_4$ or $C_3$ by fusion of the basal parts of the two strands. Another marked modification in a different line, is noticed in types $C_1$ and $C_2$, derived probably by the fusion of basal parts. These two types may also arise from each other. D and E are also very similar structures, and are probably derived from $C_3$. On this basis, decrease in frequency of type C and increase of derived types (A, B, $C_1$, $C_2$, D and E) should indicate advancement. But the opposite trend (i.e., gradual increase in frequency of C and decrease of non-C types) is also possible.

*Althaea* and *Abutilon* have a more or less similar frequency of type C per petal area, *Sida* has a distinctly lower frequency. This new sequence based on frequency of anastomoses of type C per area tallies with Waalkes and Hutchinson. The frequency of such anastomoses per area in the *Ureneae* shows a sequence of *Urena-Malachra--Malvaviscus*. Hutchinson's classification shows an opposite series (*Malvaviscus, Malachra, Urena*) which corresponds to a gradual increase in number of C anastomoses, instead of a decrease. The sequence of gradual decrease in number of type C per area in the *Hibisceae* is *Hibiscus-Gossypium-Thespesia*, which tallies with Hutchinsons classification. Cytologically, advanced characters of *Hibiscus* and primitive characters of *Thespesia* (Hazra, 1968), contrasts with the sequence mentioned above but fits well into Fryxell's new classification, which separates *Gossypieae* (including *Gossypium* and *Thespesia*) from the rest of the family. This idea is not contradictory to the present observations.

Modern classifications (Hutchinson, 1967; Waalkes, 1966) match with the present analysis, if one assumes two trends, one of reduction (in *Malveae*, including *Abutileae* of Hutchinson, and in *Hibisceae*) and the other of gradual increase (in *Ureneae*). In the line of reduction, the *Hibisceae* possesses definitely higher numbers of type C anastomoses per area than the *Malveae* (including *Abutileae* of Hu-

tchinson). The classification of Waalkes (1966) and Hutchinson (1967) corroborate this sequence.

Although, it is impossible to obtain a conclusive result from the study of such a small number of species from a family, a comprehensive analysis of this nature, along with other aspects of investigation will be useful in taxonomic interpretation. For testing the reliability of venation anastomosis patterns in taxonomic interpretations, a comparison is required with modern literature on the subject, along with the studies of embryology, anatomy, cytology, morphology, etc. From the present investigation, at least, it has become clear that the analysis of the frequency of anastomosis types can supply very useful and potential informations for using as additional data, along with other micro- and macromorphological informations.

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## *Możliwość wykorzystania unerwienia płatków kwiatowych kilku gatunków Malvaceae do badań taksonomicznych*

Streszczenie

Analiza anastomozy unerwienia płatków 13 gatunków *Malvaceae* wykazała, że gatunki te różnią się pod względem zagęszczenia i sposobu rozkładu typów unerwienia. Różnice te są statystycznie istotne. Badania wskazują, że typy anastomozy unerwienia płatków kwiatowych mogą być wykorzystane jako dodatkowa cecha taksonomiczna.