

# OBSERVATIONS ON THE FLOWERS OF *ILLICIUM*

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## Introduction

The fruit of *Illicium verum* Hook. f., generally known as star anise fruit, has been used in the Orient for centuries to flavour food. It was first mentioned in the Western literature by Clusius in 1601 (Smith 1947). He described it under the name of "Anisum Philippinarum insularum" as it apparently reached him from the Philippines though the plant is S. China in origin. The valid generic name *Illicium* was proposed by Linnaeus in 1759 in the 10th edition of his *Systema Naturae*. The type species is *I. anisatum* Linn.

Originally, *Illicium*, together with *Drimys* and a few related genera, was classified as a tribe (Tribe Winteraeae, Bentham and Hooker 1862; Tribe Illicieae, Prantl in Engler and Prantl 1891) of the family Magnoliaceae. Van Tieghem (1900), after extensive comparative morphological study, suggested that not only the tribes of the family Magnoliaceae, but also a number of the genera within the tribes should be elevated into separate families. As a result of further studies by Bailey and his associates, a number of smaller, but better-defined families, including the monogeneric family Illiciaceae (cf. Bailey & Nast, 1945, Smith 1947, Hutchinson 1959) were recognized or established.

In a monograph prepared by Smith (1947), forty-two species of *Illicium* are enumerated. They are distributed in two widely separated geographical regions: (1) Southeastern Asia: from Japan, southern China, and northeastern India to Sumatra, northern Borneo, the Malay Peninsula, the Indo-China Peninsula and the northern Philippines; and (2) Southeastern America and the Caribbean Islands: from the southeastern United States, and eastern Mexico, Cuba to Haiti. Two sections are recognized (Smith 1947) based on the characters of the perianth-lobes or tepals. They are as follows.

### Section 1. *Badiana* Spach

Perianth-lobes narrowly oblong, ligulate or lanceolate; the inner ones thin, membranaceous, somewhat lax at anthesis. This section includes *I. philippinense* Merr. (fig. 1) *I. daibuense*\* Yamamoto, etc.

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\* Smith (1947, p. 33) has reduced this species as synonymous with *I. philippinense* Merr.

### Section 2. *Cymbostemon* A. C. Smith

Perianth-lobes usually ovate or suborbicular; the inner ones carnose to papyraceous, not lax.

This section includes *I. arborescens* Hayata (fig. 2), *I. kinabaluense* A. C. Sm., *I. tenuifolium* A. C. Sm., *I. sumatranum* A. C. Sm., etc.

Extensive investigations of the stem and leaf of *Illicium* have been made by Bailey and Nast (1948). Their work may be summarized as follows. Stomata are of a distinct type, as are the structural patterns of the cuticle. The nodes are unilacunar, with a single trace. The primary vascular cylinder of the stem is of a continuous pseudo-siphonostelic type. Vessels are numerous in the secondary xylem, and the multiseriate rays are of a highly modified and much reduced type. Vessel elements are long and slender, with long-overlapping ends, which have many scalariform perforations. Tracheary pitting ranges from scalariform to opposite multiseriate. Sieve-tube members, like the vessel elements, are long, slender, with extensive overlapping ends and numerous sieve areas on the walls. There are no fibres in the secondary phloem.

The present study is mainly based on the collections of pickled flowers of three Formosan species\*, *I. philippinense*, *I. daibuense*, *I. arborescens* but material of three more Malaysian species\*\*, *I. kinabaluense*, *I. tenuifolium* and *I. sumatranum*, was obtained from the herbarium of the Singapore Botanic Gardens for examination.

Microtome sections were made at 10  $\mu$  and stained with a safranin-fast green combination. Clearings were made with 4 per cent NaOH at room temperature.

### Observations

Species of the genus *Illicium* are erect trees (e.g. *I. arborescens*) or shrubs (e.g., *I. daibuense*), generally aromatic. Leaves are simple, evergreen, exstipulate, spirally arranged on the branchlets, and are often crowded toward the apices. The flower buds are either concealed in several bud scales (e.g., *I. philippinense*, fig. 1A) or are naked (e.g. *I. arborescens*, fig. 2A). The flowers are regular, hermaphrodite, generally brone solitary in the leaf-axils, rarely ramiflorous, as has been reported in one Sarawak species (*I. cauliform* Merr.). There is usually a solitary bracteole borne on the upper portion of the thickened pedicel.

\* Voucher specimens are as follows: *I. philippinense*, Mt. Taiping, alt. 2300 m., Taiwan, C.S. Feung & M.C. Kao s.n., Aril, 1963 (Herb. Acad. Sin., Taiwan Univ., and Univ. of S'pore); *I. daibuense*, Mt. Tahwu, Taiwan, alt. 1000 m., W.C. Hsieh, s.n., 1962. (Herb. Chun-Hsin Univ.); *I. arborescens*, Gangu, Taiwan, H. Keng & M.C. Kao s.n. Feb. 1956 (Herb. Taiwan Univ.).

\*\* *I. kinabaluense*, Mt. Kinabalu, above Tenompok, 5200 ft., C.E. Carr 26926, *I. tenuifolium*, Bukit Payong Kajang, Selangor, Malay Peninsula, C.F. Symington 24243; *I. sumatranum*, Mt. Kemiri, Sumatra, C.G.G.J. van Steenis 9537.

The fruit is a typical follicetum, with the same number or slightly fewer follicles as there were carpels in the flowers. The follicles are radially arranged around, and are persistent on, the central axis (or torus). They are from coriaceous to woody, compressed, dehisce along the ventral suture, and each contains one seed. The seed-coat is bony, shining, with abundant endosperm and a tiny embryo inside.

Observations on the major flower parts: Perianth, Androecium and Gynoecium, follow.

#### 1. *Perianth*

The perianth consists of a number of free perianth-lobes or tepals, which are arranged more or less in 1-3 series without clear differentiation of calyx and corolla. The lobes are generally all of the same colour, but the outer ones tend to be small, the inner ones are gradually larger, and the innermost ones again are reduced in size.

In *I. philippinense* (figs. 1 & 5), the number of perianth-lobes is about 18 (between 17 to 20). They are oblong to lanceolate, thin membranaceous, pale yellow or dirty white in colour, arranged in three successive whorls. The outer ones are comparatively short and broad (average  $12 \times 4$  mm.), and the two inner whorls long and narrow (average  $18 \times 3$  mm.). In *I. arborescens* (figs. 2 & 7), the number of perianth-lobes is about 15 (between 13 and 16). They are ovate to suborbicular, often thickened in the central portion, dark purple in colour and arranged in 3 whorls. The perianth-lobes of the outer whorl are deltoid to orbicular, (average  $6 \times 6$  mm.); those to the middle whorl are the largest, from orbicular to ovate (average  $9 \times 8$  mm.), and those of the innermost whorl are oblong to linear and much small (average  $5 \times 2$  mm.).

A comparison of cleared and stained material revealed that the perianth-lobes of *I. philippinense* (fig. 3) and *I. daibuense* (both belonging to § *Badiana*) possess only a single main trace from which an open dichotomous branching system is formed; and those of *I. arborescens* (fig. 4), *I. kinabaluense*, *I. tenuifolium*, and *I. sumatranum* (all belonging to § *Cymbostemon*), in contrast, contain 5 to many traces at the base, each of which ramifies dichotomously. Anastomosing of these normally "open" dichotomously branching veins is occasionally observed.

Ethereal oil cells which are found throughout the plant body, are often concentrated in the thickened portion of the perianth-lobes in the species of § *Cymbostemon*.

Although the perianth-lobes of the innermost whorl tend to be narrow and small, in the available material studied, no intermediate or transitional forms between stamens and perianth-lobes as reported by Baillon (1871, p. 149) in *I. religiosum* have been observed.

## 2. *Androecium*

The number of stamens in a flower is more or less constant for a species, but variable from one species to the other. In *I. kinabaluense*, there are only 5 to 7 stamens arranged in a single whorl; whereas in *I. philippinense* (figs. 5 & 6) and *I. arborescens* (figs. 7 & 8), there are about 18-23 and 37-41\* stamens respectively, in a flower.

From observations on the transverse sections of the flower buds, those species with a very large number of stamens have them arranged in a rather definite pattern. For example, in *I. philippinense* (fig. 5, plate 1, a), in which the commonest number of carpels is 8, the first two whorls of the androecium have 8 stamens each, arranged so that they alternate in the two rings, with the remaining stamens, varying from 2 to 7, are distributed in the third or outermost ring. Stamens of the third ring tend to be longer and broader, yet bear normal pollen-sacs. The situation is very much the same in *I. arborescens* (fig. 7, plate 1, c). The commonest number of carpels in this species is 13. The first two whorls have each of their 13 stamens alternating, with the remaining varying from 11 to 15, distributed in the third or even fourth rings. Thus it appears that the small variability in stamen number found within each species of *Illicium* is mainly due to the variations in number amongst those of the outermost whorl. This represents perhaps one of the transitional stages between acyclic & indefinite and cyclic & definite androecia.

The filaments of stamens are generally cylindrical or slightly flattened, or they may be angular owing to mutual compression. Each filament bears two pairs of protuberant pollen-sacs on the upper portion (Fig. 9 and plate 1, f). The anthers are introse or slightly lateral-introre. The connectives are truncate or slightly protrusive or depressed at the top, sometimes more or less constricted immediately below the anthers. In *I. kinabaluense*, the filaments are very flattened and thin, and narrowed abruptly at the lower portion. The stamens are of single, dorsal-veined type. The simple, median veins are rather broad, sometimes appearing to be composed of 2 separate bundles especially when studied in cleared and stained material (plate 1, f), and occasionally bifurcate at the top, e. g. in *I. tenuifolium* (fig. 9D).

A transverse section of a filament is generally orbicular or elliptic, the epidermis is slightly cutinized, and the ground tissue is composed of 4 to 5 layers of parenchyma cells; in the central portion, there is a broad vascular bundle often seeming, as earlier noted, to be a fusion of two separate bundles; sometimes, it becomes very distinct (plate 1, h).

The anther is 2-lobed and 4-loculate. Before dehiscence the partition between

\* According to Smith (1947), this is the highest number discovered in the species of § *Cymbostemon*.

the two locules of the same anther-lobe breaks down so that the two locules form a single chamber which is bordered on the outside by the epidermis and endothecium. The epidermis of the anther consists of a layer of large cells coated with thick cuticle. In a mature anther, the endothecium is composed of a layer of cells with prominent strips of secondary thickening, within which, there is one persistent layer of parietal cells lining the pollen-sac cavity (plate 1, g).

A longitudinal line of dehiscence develops in the central portion of the anther-lobe where the epidermis is composed of very tiny cells, and the pollen grains are released upon the rupture of these cells. The pollen grains are of a basic tricolpate type. The present observation agrees with the previous reports (Wodehouse 1935, Erdtman 1952).

The anthers are introrse and dehisce early, the pollen grains being fully matured long before anthesis. In *I. arborescens* and most species belonging to the § Cymbostemon, the perianth-lobes only unfold slightly and never fully expand during anthesis.

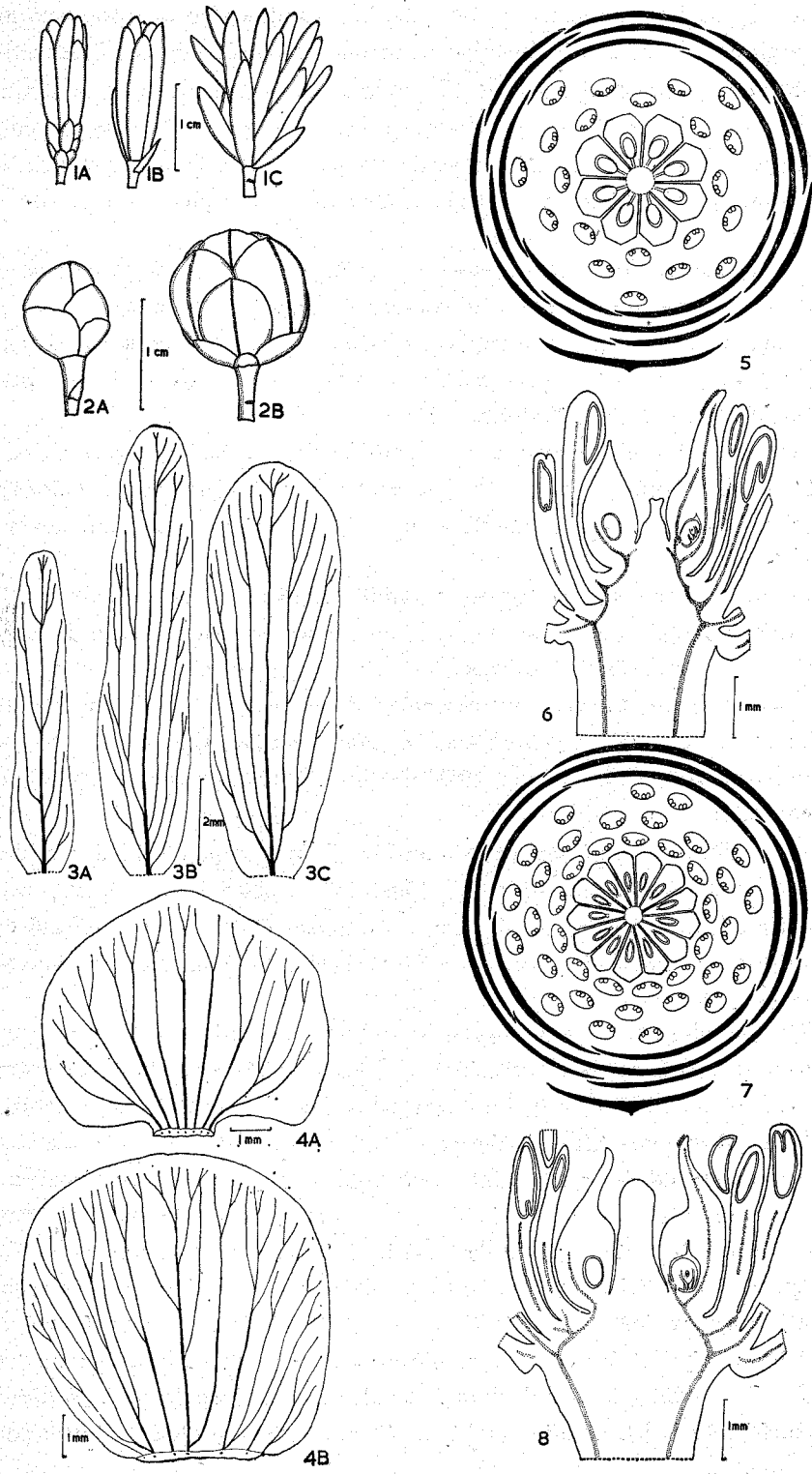
Another interesting feature of the androecium of *Illicium* species studied is that although the number of stamens per flower for each species is not quite constant, and very variable between species, yet nearly all of them, whether in one, two or three whorls, are normally developed. This is in contrast to a number of other ranalian genera such as *Austrobaileya*, *Calycanthus*, *Eupomatia*, *Himantandra*, *Kingdonia* (Foster 1961) etc. in which staminodes commonly occur.

### 3. Gynoecium

The gynoecium consists of a number of free carpels which are laterally attached to a conical-shaped torus (figs. 6 & 8, plate 1, d). Each carpel is differentiated into an enlarged ovary, a narrow style and a long and curved stigmatic crest which is covered with receptive trichomes or papillae on the ventral side (fig. 10).

The vasculature of the carpel, in comparison with that found in most of the ranalian members, is rather simple. The vascular strands of the receptacle enter the ovary and divide into two parts, one dorsal and one ventral. The dorsal strand extends through the style and terminates in the stigmatic crest; the ventral strand bifurcates into two branches in its upward course. The vascular supply to the ovule is derived from one of the ventral branches. These ventral branches generally end in the upper part of the ovary (e. g. *I. arborescens*, *I. kinabaluense*, figs. 10 C, & 10 E), but sometimes nearly reach the stigmatic crest region (e. g. *I. philippinense*, *I. tenuifolium*, figs. 10 A and 10 D).

Each carpel contains only a single ovule. The ovule is either anatropous (e. g. *I. arborescens*, fig. 8, and plate 1, d, e), or nearly so (e. g. *I. philippinense*, fig. 6, and plate 1, b). Baillon (1871, p. 148, footnote) reported the latter position



in *I. parviflorum* and described it as “incompletely anatropous”. It is of interest that *I. parviflorum*, like *I. philippinense*, belongs to the § Badiana. The ovules of all these three species, and perhaps throughout the genus are bitegmic and attached to the ventral side of the ovary locule by a thickened, obliquely orientated raphe and a very brief funiculus.

Short traces, other than the one which supplies the ovule, deriving from the ventral branches or from the dorsal strand, are occasionally found (figs. 10 A to 10 E, plate 1, i). Their presence perhaps suggests that the uni-ovulate is evolved from an ancestral many-ovulate condition.

A study of serial sections of carpels revealed that in the stigmatic and stylar regions, the ventral sides of the margins of a carpel are only “connivent” or paired, and are far from being fused (plate 1, a, c, j & k). Only at the ovary level they are completely sealed up (plate 1, l). No ontogenetic study has been made, but it seems plausible that the carpel primordium of *Illicium* is perhaps like those of *Degeneria vitiensis* (Swamy 1949) or *Drimys winteri* (Tucker 1959), in the form of a shallow cup; owing the uneven growth of the rim, it finally transforms the carpel into a conduplicate structure.

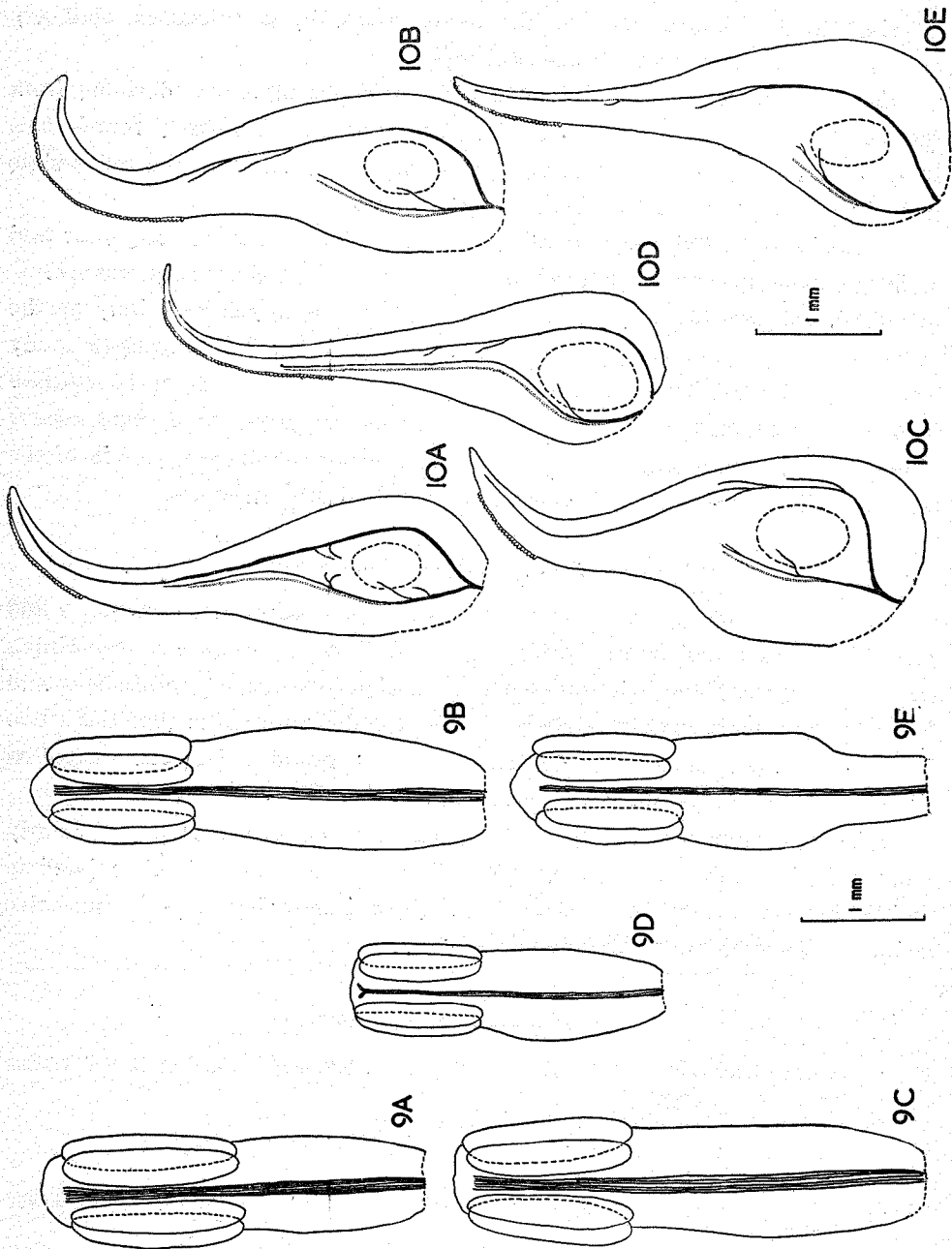
#### Conclusion—A taxonomic consideration.

On the basis of the pollen grain morphology and other features, Bailey and Nast (1945, 1948), and Smith (1947) suggested that the Illiciaceae (containing the genus *Illicium*) and Schisandraceae (containing two genera, *Schisandra* and *Kadsura*) are most closely related. Smith intended to propose that these two families (with the three afore-mentioned genera) should perhaps be treated as a suborder among the order Ranales (*sensu lato*).

This suggestion was challenged by Hutchinson (1959, p. 125) who obviously supported the traditional view that the Illiciaceae are more closely related to the Winteraceae (including *Drimys* and allied genera, and at one time also including *Illicium*), than other families.

#### Explanation of figures

- Fig. 1. Flower buds and flower of *I. philippinense*. (A. bud with budscales; B. bud with a bracteole; C. opening flower)  
Fig. 2. Flower bud and flower of *I. ardorens*.  
Fig. 3. Drawings of the cleared and stained perianth-lobes of *I. philippinense*.  
Fig. 4. The same, of *I. arborescens*.  
Fig. 5. Floral diagram of *I. philippinense*. (based on several transverse sections of flower buds)  
Fig. 6. Longitudinal section of the flower of *I. philippinense*.  
Fig. 7. Floral diagram of *I. arborescens* (based on several transverse sections of flower buds).  
Fig. 8. Longitudinal section of the flower of *I. arborescens*.





The morphological data accumulated in the present observations are far from sufficient to make an overall re-assessment of the phylogenetic position of this genus or the family and besides, they lend little support to either concept. However, there are at least two interesting points which are perhaps worthwhile to be mentioned.

Firstly, the doubleness of the median strands, often exhibiting various degrees of fusion, as seen in the filaments of some *Illicium* species, has also been reported in *Austrobaileya* (Austrobaileyaceae) Bailey and Swamy, (1949) and *Sarcandra* (Chloranthaceae) (Swamy and Bailey, 1950).

Secondary, the vasculature of the carpels of *Illicium* species is much simpler than that of nearly all the members of Magnoliaceae (*sensu stricto*) (Canright 1960), Winteraceae (Bailey and Nast 1943), *Schisandra* (Schisandraceae) (Ozenda 1949, p. 81) and many other families under Magnoliales (*sensu* Hutchinson). It is, however, more comparable to that found in Monimiaceae (Money, Bailey and Swamy 1950), Lauraceae (Kasapliligil 1951), Austrobaileyaceae (Bailey and Swamy 1949), and perhaps Chloranthaceae (Swamy and Bailey 1950).

Furthermore, such features as the presence of ethereal oil cells, the unilacunar nodes, and the uni-ovulate ovary found in *Illicium* also indicate a close resemblance to many of the taxa classified under Hutchinson's (1959) "Laurales" or to those listed in Money, Bailey and Swamy's (1950) "Category A". Both "Laurales" and "Category A" include Monimiaceae, Lauraceae, Austrobaileyaceae, etc. The "Category A" also includes Chloranthaceae.

If these resemblances are proved to be phylogenetic, then the Illiciaceae represent perhaps a specialized group of the Magnoliales (*sensu* Hutchinson) showing a greater tendency to reductions which bring about an approach to the Laurales (*sensu* Hutchinson).

### Summary

Observations on the flowers of six *Illicium* species reveal several interesting morphological characters. Perianth-lobes possess either a single main trace or 5 to many traces at the base. The broad, median vein of filaments appears to be a fusion of two separate strands. The vasculature of carpels, mainly con-

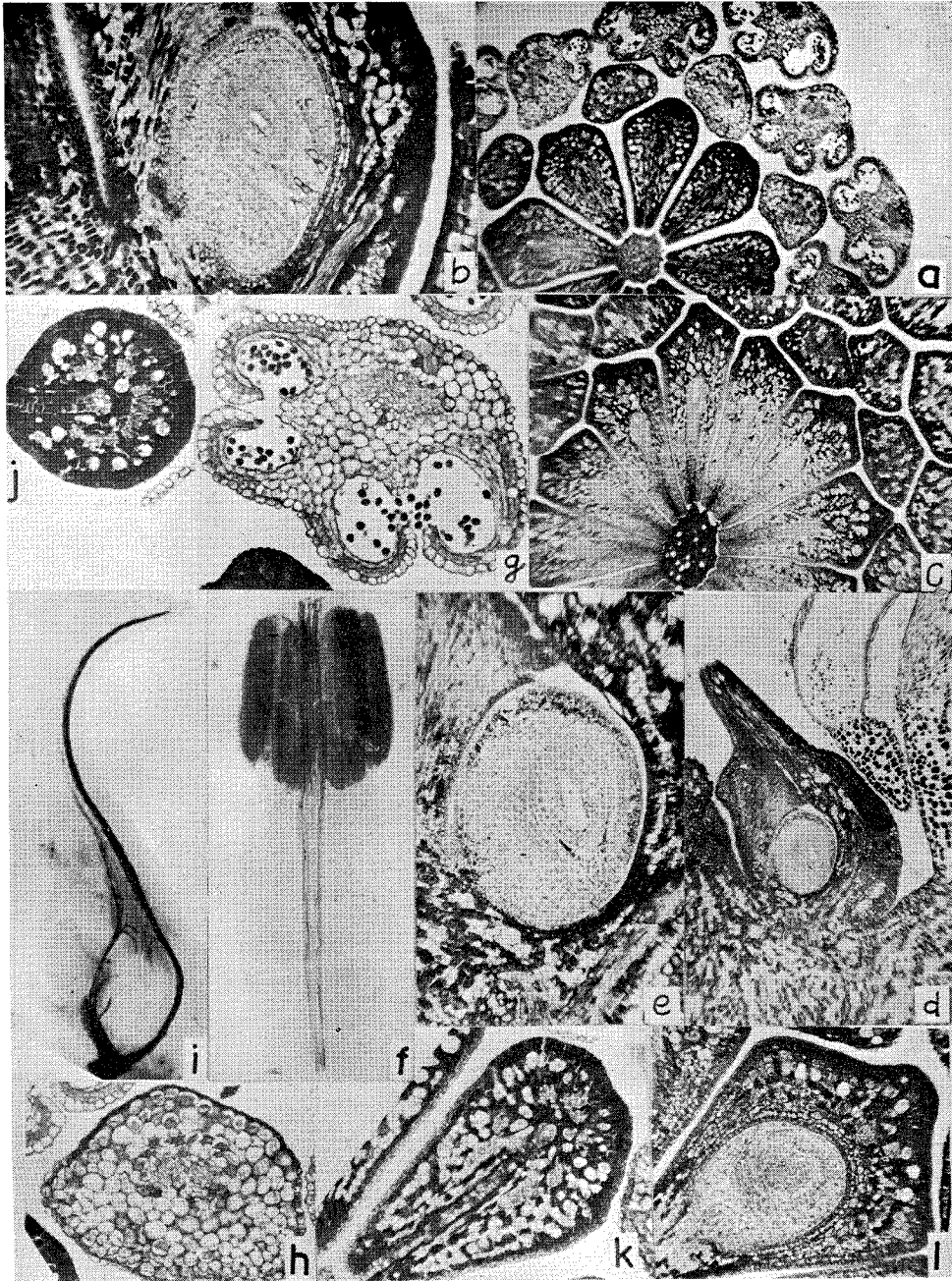
### Explanation of figures

Fig. 9. Drawings of the cleared and stained stamens of:

A. *I. philippinense*, B. *I. daibuense*, C. *I. arborescens*, D. *I. tenuifolium*, and E. *I. kinabaluense*.

Fig. 10. Drawings of the cleared and stained carpels of:

A. *I. philippinense*, B. *I. daibuense*, C. *I. arborescens*, D. *I. tenuifolium*, and E. *I. kinabaluense*.



sisting of a dorsal and a ventral strands, is much simpler than that of the other members of the Magnoliales. *Illicium* represents perhaps a specialized group of the Magnoliales showing a greater tendency to reductions which bring about an approach to the Laurales.

#### Acknowledgements

I should like to express my sincere thanks to Professor A. S. Foster, Professor H. B. Gilliland, and Dr. J. M. Pallot for reading the manuscript of this paper and for their suggestions. My thanks are also due to the Director and Curator of Singapore Botanic Gardens, and to Messrs. M. C. Kao, C. S. Feung and W. C. Hsieh for supplying the herbarium and pickled materials for this study, and to Mr. D. Teow for taking the photomicrographs.

## 茴香屬植物花之研究

耿 煊

本文為依據六種茴香屬植物花之各部份切片及透明研究後所得之結果如下：

#### Explanation of Plate

##### Plate I.

- a. Transverse section of the flower bud of *I. philippinense* showing the arrangement of carpels and stamens. (cf. fig. 5).  $\times 10$
- b. Longi-section of the ovary of *I. philippinense* showing the "incompletely anatropous" ovule. (cf. fig. 6).  $\times 25$
- c. Transverse section of the flower bud of *I. arborescens* showing the arrangement of carpels and stamens. (cf. fig. 7).  $\times 10$
- d. Longi-section of the carpel of *I. arborescens* showing the solitary, anatropous ovule. (cf. fig. 8).  $\times 10$
- e. Detail of d.  $\times 25$
- f. Cleared and stained stamen of *I. philippinense* showing the broadened filament with indistinctly double traces. (cf. fig. 9 A).  $\times 10$
- g. Transverse section of the anther *I. philippinense*.  $\times 25$
- h. Transverse section of the filament *I. philippinense* showing the doubleness of the vascular strand.  $\times 25$
- i. Cleared and stained carpel of *I. philippinense* showing the general vasculature. (cf. fig. 10 A).  $\times 15$
- j. Transverse section of the stigmatic crest showing the "connivent" ventral margins.  $\times 25$
- k. Transverse section of the style showing the "connivent" ventral margins.  $\times 25$
- l. Transverse section of the ovary showing the solitary ovary and the completely sealed up ventral margins.  $\times 25$

1. 花被部份——花被裂片數目不定，分爲數輪排列；內外各輪形狀大小略有差異，唯色澤及質地近似，無花萼與花冠之顯著區別。

屬中兩亞屬之花被裂片之外形與內部維管束構造頗有差別：*Badiana* 亞屬花被裂片狹仄，基部僅具維管束一條；*Cymbostemon* 亞屬花被裂片寬潤，近於圓形，基部維管束亦有5條或7條之多。

此六種植物中，花被裂片與小蕊之間界限明顯，未有中間型構造（退化蕊或著生花藥之花被裂片）存在。

2. 小蕊部份——小蕊數目依種類而異，少者僅5~7枚，多者則在30或40枚以上，分輪排列，頗有規則。最內輪之數目大體與心皮數目相等而互生；如在三輪以上，則最外輪數目有時不一定，此或係爲由螺旋狀排列遞嬗爲輪狀排列之最後階程之遺跡。

小蕊之花絲寬潤扁平，花藥四室，藥室內向。花絲中僅維管束一條，唯自其基部之切面中，似顯示其爲由兩條維管束併合而成者。

3. 大蕊部份——大蕊中之心皮排列爲一輪，每一心皮上之花柱與柱頭無顯著區分——花柱之腹面即爲柱頭面。

心皮中之維管束構造極爲簡單，僅背、腹維管束各一。背維管束自基部直達花柱頂端，腹維管束初爲一條，稍上分岐爲二枝，自其中之一枝上有細小之分枝達於胚珠上。除此以外，腹、背各維管束常有此項細小之分枝數條存在，似顯示茴香屬之祖先子房中之胚珠似或係不祇一粒者。

胚珠具胚珠被兩層，有短柄。兩亞屬之胚珠著生位置似略有差別，*Badiana* 亞屬之胚珠爲“不完全”倒生者；*Cymbostemon* 亞屬之胚珠則係真正倒生者。

以上各項均須待屬中更多種類研究以後方能成爲結論。

關於茴香屬之親緣位置有兩項相似之說法：Bailey, Smith 諸氏以爲與北五味子科最爲接近；Hutchinson 氏維護傳統之說法，以爲與 Winteraceae 最爲相近。本文作者認爲茴香科（僅茴香屬一屬）雖應留存在 Hutchinson 氏之木蘭目（Magnoliales）中，但有若干性質（如大小蕊中維管束構造等）似極與樟目（Laurales）相近。

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