Mitsuko SUGIYAMA*: A vascular system of "node to leaf" in *Magolia virginiana* L.

杉山明子*: ヒメタイサンボクの葉の維管束系

Introduction The nodal anatomy of primitive dicotyledonous genera has been studied extensively by Sinnott, Bailey and their co-workers, and received much attention phylogenetically. Ozenda (1948), in his voluminous contribution, described a multilacunar node in the Magnoliaceae and allied families, and gave us an interesting nodal analysis of the taxon. On the other hand, Canright (1955) described nodal anatomy of several species in different genera in the Magnoliaceae emphasizing its phylogenetic significance. Most of these investigations on nodal vasculature, however, were restricted to the level of the node, or in some cases included the petiole but were not extended into the leaf lamina.

Vasculature of "node to leaf" was first investigated by Swamy and Bailey (1950) for *Sarcandra*, the vesselless genus of the Chloranthaceae; this was followed by Nakazawa's (1953) study of *Chloranthus serrata*, and Yamazaki's (1965) of *Liliodendron tulipifera*, *Kadzura japonica*, and others. Nevertheless, it might be still expected that a comprehensive study dealing with the course of vascular tissues from "node to leaf" is needed for further understanding of the phylogenetic significance of nodal vasculature among primitive dicotyledons.

Material and Methods *Magnolia virginiana* L. is a North American tree which is cultivated at the Botanical Garden, Faculty of Science, University of Tokyo, where it is deciduous. In early spring, a large stipular sheath, adnate to the adaxial side of the petiole for half of its length, encloses the shoot apex. It soon drops off when the folded leaf has opened.

The present investigation is concerned with the pattern of vasculature from node to leaf lamina in the young shoot collected in Spring 1971.

The material was fixed and preserved in FAA. Usual procedures of

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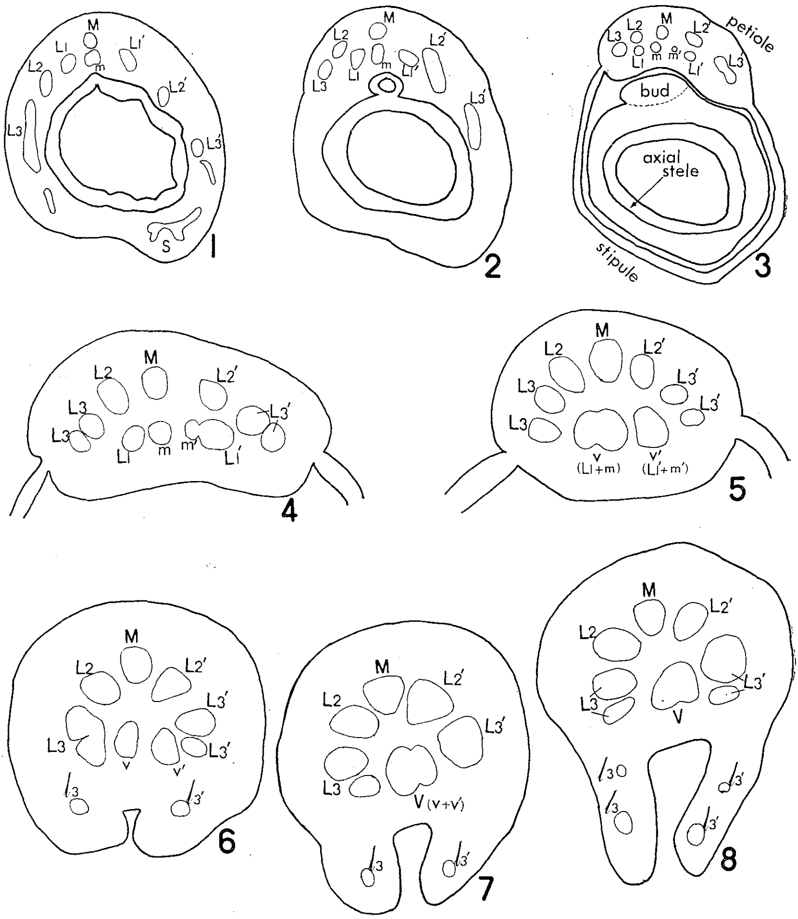
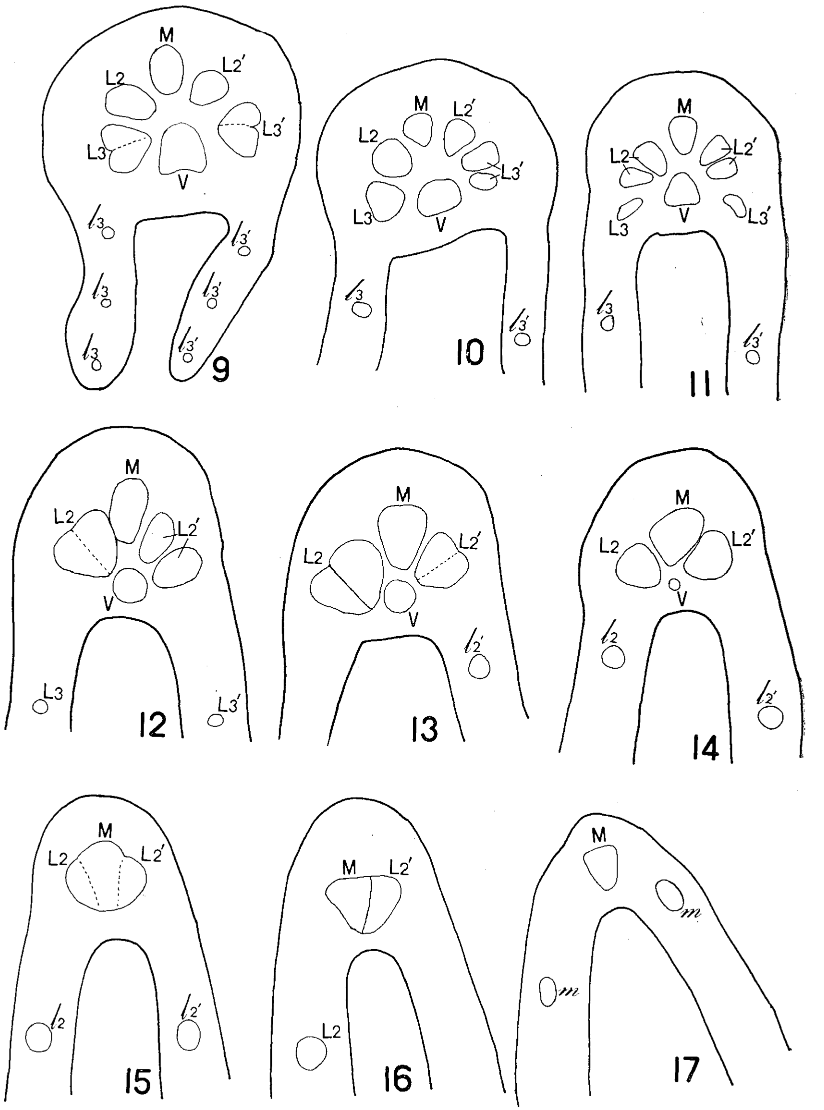


Figs. 1–17. Serial cross view of "node to leaf" vascularization in *Magnolia virginiana* L. Fig. 1: Just above node of vegetative shoot, ×16. Fig. 2: Internode just above node, ×16. Fig. 3: Base of petiole. Stipule encloses main vegetative shoot, ×20. Fig. 4: At a low level of petiole where stipule is still attached, ×40. Fig. 5: Mid petiole level, ×40. Fig. 6: Very base of leaf lamina, ×70. Figs. 7–10: Lower part of leaf lamina, ×70. Figs. 11–14: Middle of leaf lamina, ×70. Figs. 15–17: Upper end of leaf lamina, ×70, (×120 for fig. 17),

Symbols: M: Median foliar trace. L3, L3′: Lateral foliar traces for lower level of laminar venation. *l*3, *l*3′: Lateral veins derived from traces L3 and L3′. L2, L2′: Lateral foliar traces for middle level of laminar venation. *l*2, *l*2′: Lateral veins derived from traces L2 and L2′. L1, L1′: Foliar ventral traces. m, m′: Foliar ventral traces derived from adaxial branches of median trace M. v, v′: Traces derived by adnation of L1 to m and L1′ to m′, respectively. V: ventral trace derived by fusion of traces v and v′. S: Stipular trace which arose directly from axial stele on the side opposite to the median foliar trace.



paraffin embedding were followed, and serial cross sections cut at 10–15 μ and stained with Heidenhain's iron-alum haematoxylin, safranin and fast green. Leaf material was also cleared for general understanding of whole scope of leaf vascularization.

Observation Eight traces depart from the axial stele leaving eight gaps at the node of the young shoot. Seven traces enter the petiole base as foliar traces while a single trace opposite to the foliar median enters the stipule. Additional stipular traces are derived laterally from the lowest foliar lateral traces (Fig. 18-A). At the base of the petiole the seven foliar traces are not aggregated but remain independent and distinguishable as median, lateral and ventral traces, arranged in a circle to form a stelar ring (Fig. 3, 4).

Just above the node where foliar traces have diverged from the axial stele, a median trace M and three pairs of lateral traces (L1, L1′; L2, L2′; L3, L3,) are recognized in their original positions (Fig. 1). At a slightly higher level, median trace M gives rise adaxially to a bundle which becomes inverted in orientation; this bifurcates to become ventral traces m and m′. At this level, traces L1 and L1′ also change their position to the adaxial side, and occur at the flanks of traces m and m′. Thus four ventral traces can be recognized at the base of the petiole (Fig. 2, 3).

As illustrated in Fig. 1 to 4, the stelar ring of the petiole is composed of median trace M, lateral traces L2, L2′, L3 and L3′ as well as ventral traces L1, L1′, m and m′. Lateral traces L3 and L3′ are biginning to divide to give rise to the veins supplying the lower leaf lamina (Fig. 6-9). At this level no branching takes place in median trace M, lateral traces L2, L2′ or the ventral traces (Fig. 4-10). The four ventral traces tend to unite in pairs (L1+m and L1′+m′) to form two bundles v and v′ near the base of the leaf lamina (Fig. 5, 6). In the lower portion of the leaf lamina, the pair of ventral traces anastomose again to form a single ventral strand, trace V (Fig. 7).

At the middle of the leaf lamina, lateral traces L3 and L3′ leave the stelar ring (Fig. 11, 12) and enter the lamina, then lateral traces L2 and L2′ start branching (Fig. 13, 14). Both median trace M and ventral trace V remain undivided. A little above this level, ventral bundle V becomes reduced in size and gradually vanishes without branching (Fig. 12-14). Now the stelar ring has been converted into an arc-shaped vascular strand (Fig. 14, 15).

Toward the upper end of the leaf lamina, vascular tissue consists of median trace M with lateral traces L2 and L2′ united to it laterally to give rise to a large single strand in which three are still distinguishable (Fig. 15). At this level, lateral veins are derived from the flanks of the vascular arc which are basically lateral bundles L2 and L2′ (Fig. 15).

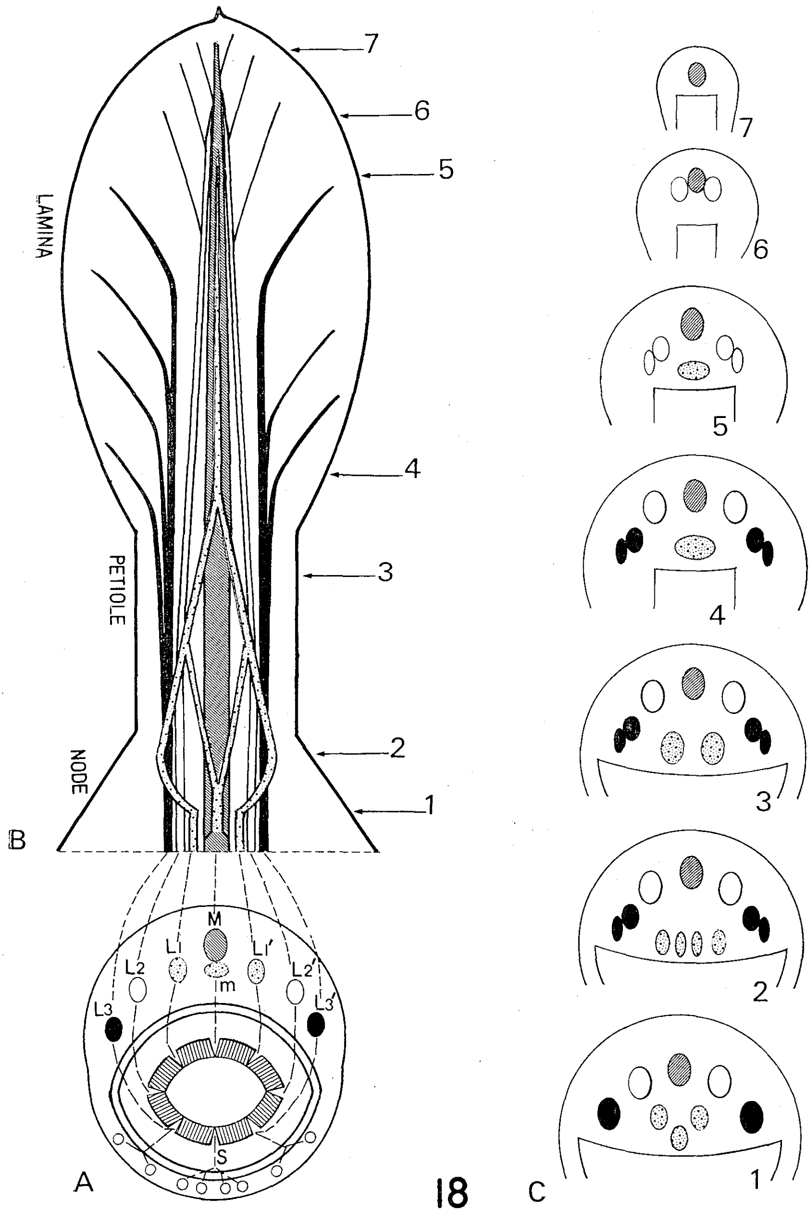
At the tip of the leaf lamina where the lateral traces have diverged from the vascular arc (Fig. 16) and only the median trace remains, the latter begins to branch supplying veins and veinlets to the upper end of the leaf lamina (Fig. 17). At the very tip of the lamina, median trace M gradually becomes smaller and eventually disappears.

Discussion In summing up the foregoing observations, two groups of foliar traces, a median and a lateral, are recognizable in "node to leaf" vascularization of *M. virginiana.* The median group consists of median trace M and four ventral traces L1, L1′, m and m′, while the lateral group includes lateral traces L2, L2′, L3 and L3′.

The ventral traces, which are derived from two different sources, show a characteristic disposition. Ventral traces m and m′ arise as adaxial branches of median trace M (Fig. 18–A), while the other pair of ventral traces, L1 and L1′, are derived directly from the axial stele on either side of median trace M, move adaxially, and become reoriented (Fig. 18–C1). The four ventral traces unite first, in the petiole, to form a pair of traces v and v′ (Fig. 18–C3) and, later, at the base of the leaf lamina to form a single ventral trace V (Fig. 18–C4). It runs unbranched for a certain distance in the costa, gradually reduces in size at the upper end and ultimately vanishes without giving rise to any lateral venation (Fig. 18–C5, C6).

It is significant that the ventral trace never sends lateral veins into any level of the leaf lamina and its sole function is similar to median trace M which also remains unbranched up to the level where lateral traces L2 and L2′ have formed lateral veins (Fig. 18–B7). Thus, median trace takes little, and the ventral takes no part in laminar lateral venation; they should be included in a single group of median traces.

Principal lateral venation is closely associated with the two pairs of foliar lateral traces L2, L2′ and L3, L3′. The lower part of the lamina is vascularized by lateral traces L3 and L3′ (Fig. 18–C4). In the middle where lateral traces L3 and L3′ diverge completely into the lamina lateral



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traces L2 and L2′ start branching (Fig. 18–C5).

It is suggestive that the two sets of lateral traces function identically in foliar vascularization in contrast to the median group of traces which send only few lateral veins into a restiricted area of the lamina.

A similar venation pattern has been described previously by several authors. In *Sarcandra* and *Chloranthus* (Chlorantaceae) and *Kadzura* (Schizandraceae) the medial trace was described by Swamy (1950), Nakazawa (1956) and Yamazaki (1965) as an unbranched trace which became progressively indistinct in the costa and ultimately disappeared. Yamazaki (1965) pointed out that in *Liliodendron tulipifera* (Magnoliaceae) the median trace had little relation to the lateral venation.

So far as has been reported, an almost unbranched median trace seems to be characteristic among primitive dicotyledons. Before conclusions can be drawn on the phylogenetic significance of foliar venation, it is essential to assemble more comprehensive and reliable information concerning "node to leaf" vascularization, particularly among the primitive dicotyledons.

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Fig. 18. Diagrammatic interpretation of "node to leaf" vascularization in *Magnolia virginiana* L. A: Cross sectional view of nodal vasculature. Foliar traces leave seven gaps in the axial stele and enter petiole base. Stipule receives several bundles from main stipular trace which diverges separately from the axial vascular cylinder and also lateral branches from foliar lateral traces L3 and L3′. Externally, stipule is adnate to the adaxial side of petiole and encloses vegetative shoot above. B: Tangential view of "node to leaf" vasculature. Levels indicated by arrows correspond to the cross sectional view at successive levels from node to tip of leaf lamina. Levels are shown by arrows in B.

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ヒメタイサンボク (*Magnolia virginiana*) の茎から葉への維管束を追跡した。茎の節からは 8 本の葉跡が生じ，内 7 本は各々独立したままで維管束環をつくり葉身へ入る。残りの 1 本は，これとは別に側脈 L3, L3′ から由来する分枝の一部と共に托葉へ入る。

8 本の葉跡は中央脈 M, 側脈 L1, L1′, L2, L2′, L3, L3′ と托葉脈 S よりなる。中央脈 M は葉柄へ入る前に向軸側に m を分枝しすぐ二分されて m, m′ を生じる。側脈 L1, L1′ は m, m′ と同様に導管組織が逆転したのち葉の腹面に移行し葉の維管束環の腹脈となる。やがて m と L1, m′ と L1′ は各々ゆ合し v, v′ となり，更に葉身中央部でゆ合して V となる。L2, L2′, L3, L3′ の二対の側脈は順に葉身へ葉脈をおくりだす。まず外側に位置する L3, L3′ が葉身の基部への葉脈を配し遂に側脈として維管束環からでていくと，次に L2, L2′ が葉脈を分枝しはじめて葉身中央部に側脈を配する。L3, L3′ が側脈として葉身へ送りだされたのち V は葉身への分枝を全くださないままで維管束環の向軸側で消える。残された中央脈 M と側脈 L2, L2′ は孤状維管束となる。葉の先端近くでは M のみが残り，ここで初めて葉脈の分枝を始める。中央脈も次第に細くなり遂に消失する。

すでに報告されているように原始的な群に属する双子葉植物において茎から葉への維管束の走り方には非常に特徴があり興味ある問題が含まれているように思われる。この植物群において維管束は各々ゆ合しないか或は葉の中央部から先端にかけてのみゆ合しており葉脈の分枝を出す側脈と基本的には葉身へ分枝を出さない中央脈に区別される。Chloranthaceae の *Sarcandra, Chloranthus* では中央脈は分枝せず，葉身の中央部で消失し，その両側の側脈のみが葉の先端まで届いている。Magnoliaceae の *Liliodendron*, Schizandraceae の *Kadzura* においては中央脈は分枝せずはっきりと葉の先端まで走っている。ここに報告した *Magnolia virginiana* の茎から葉への維管束の走行はこれらの諸例と同じ傾向を示すが，これまでに知られた例と異なる点がある。即ち中央脈Mとそれに最も近い位置にある側脈 L1, L1′ が同様に行動し，L1, L1′ は葉柄で向軸側へ移行したのちも分枝をださずに葉身の中程の位置で消滅する。つまり L1, L1′ はみかけの側脈であるが本質的には中央脈に属するものと考えられる。この様に葉身を走る葉脈にも 2 つの傾向，中央脈的と側脈的，が区別されるがこの系統学的に意味するところは残された課題であり，これは原始的双子葉植物群について茎から葉への維管束の走行例を広く知ることによって明らかにされると考える。