

## Vasculature of *Euonymus japonica* Shoot

by

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**Abstract.** The pattern of primary vasculature in a hypocotyl-shoot axis of *Euonymus japonica* was investigated. In a young seedling, there were two independent vascular systems, which were separated from one another by a plane perpendicular to the plane including the midveins of two cotyledons. It was only one leaf trace that served each of the first pair of leaves which were at early stage of development. But, as the leaves developed, additional bundles, with which two vascular systems were interconnected, were formed and they functioned as leaf traces. Two leaf traces served each of leaves attached at the second node and the superimposed nodes from the onset of leaf formation and a typical closed system of vasculature was established in the shoot. That is, the vasculature of *E. japonica* shoot developed into a typical closed system, with the developing of seedling, not from the onset of shoot formation.

### Introduction

Satô and Matsubara (1984) have reported the vasculature found in the hypocotyl-shoot axis of the *Euonymus japonica* seedling which had only two pairs of leaves. The vasculature is summarized as in Fig. 1. The second node is of a two trace unilacunar type, though the first node is of a one trace unilacunar type. In *E. japonica*, the first pair of leaves is much smaller than the superimposed pairs of leaves. We have conjectured that this difference in the nodal structure is one of the causes by which the heterophylly is brought about. But we have not reported the structure of nodes formed above the second node and the primary vasculature in a well-developed shoot. In addition, we have reported that, after the second pair of leaves has been formed, additional bundles are produced among bundles which have already been formed in the hypocotyl-shoot axis. But the vasculature of these additional bundles has not been reported. So, we have intended to investigate further the vasculature in a hypocotyl-shoot axis of the young seedling and

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to investigate the organization of the primary vasculature in a well-developed shoot of *E. japonica*.

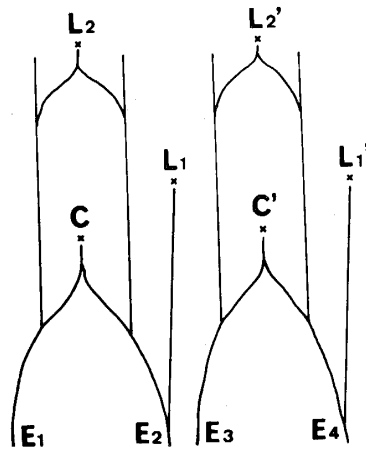


Fig. 1. The diagram, spread out on one plane, of vascular pattern of the hypocotyl-shoot axis of *Euonymus japonica*. (after Satô and Matsubara, 1984) C; cotyledonary trace, E; embryonic bundle, L; leaf trace.

### Material and Method

Many individuals of *Euonymus japonica* were gathered in Yokohama City, and planted on the campus of the Yokohama National University. The vegetative shoot were cut in lengths of about 5–10 mm and fixed in FAA at appropriate intervals from March to August in 1983–1984.

The seedlings of *E. japonica* were obtained by culturing the mature embryos excised from the seeds under sterilized condition. The excised embryos began to develop soon after they were put onto the Murashige–Skoog medium. They also were fixed in FAA at appropriate intervals after culturing.

The fixed materials were dehydrated in ethyl alcohol-*tert.* butyl alcohol series and embedded in paraffin (m.p. 57–60 C). They were sectioned serially at 6  $\mu$ m thick. The sections were stained with saffranin and fast green combination or azure B. The staining with azure B produced better results to distinguish the vascular tissue from the other tissues.

### Observation

*Primary vasculature in a well-developed shoot*—*Euonymus japonica* has a decussate phyllotaxy. At each node, two leaf traces diverge from the cylinder of vascular strands toward each of the two leaves attached at that node. Before these traces serve a leaf, they unite to form one thick compound leaf trace. A leaf gap exists

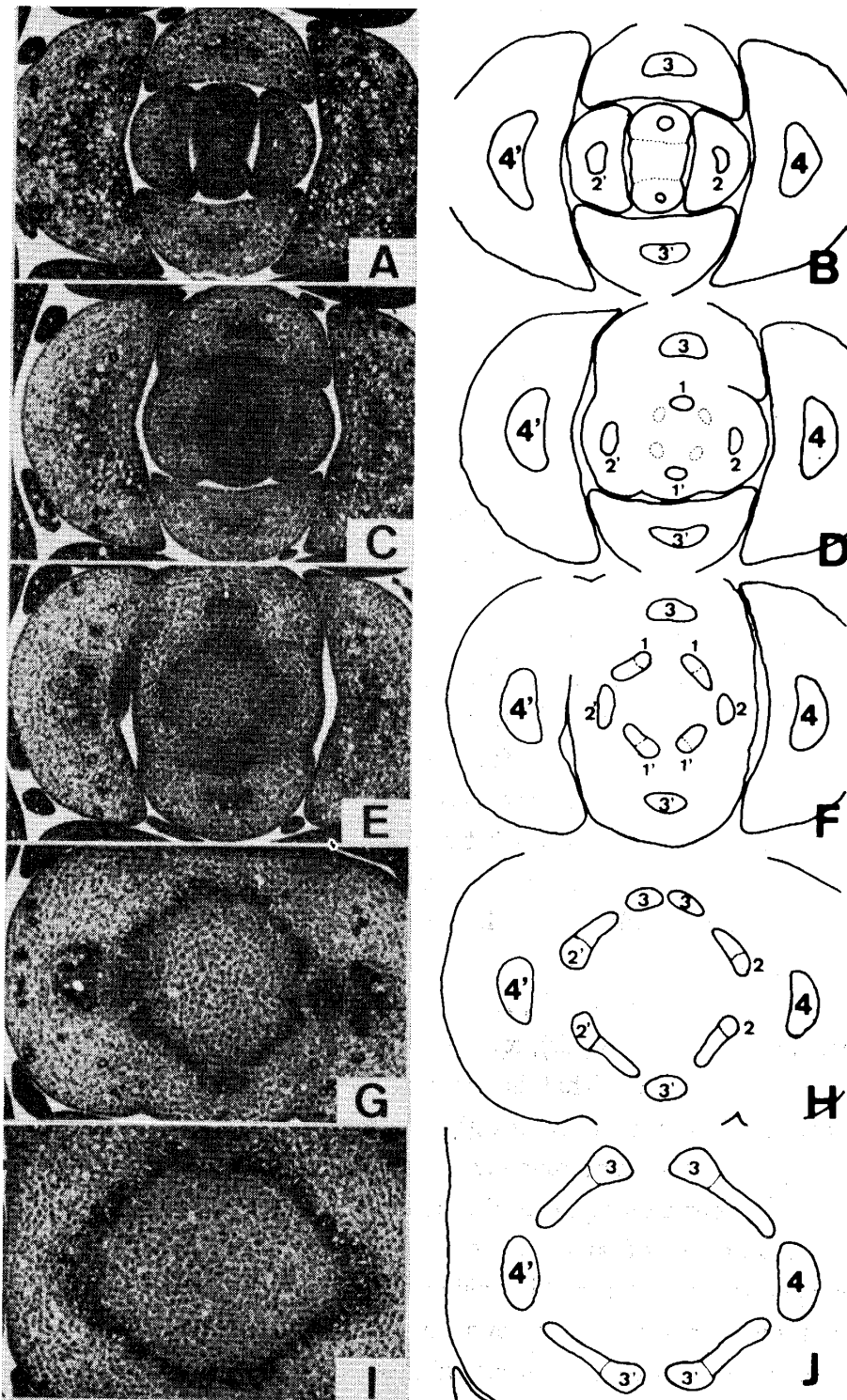


Fig. 2. Basipetal sequence of the transections from the apical zone in *Euonymus japonica* shoot. (A line drawing is traced from a left microphotograph of it.) A, B; transections of the shoot apical zone, C, D; at the node 1, E, F; at the node 2, G, H; at the node 3, I, J; at the node 4. (all  $\times 50$ )

in the vascular cylinder. That is, the nodes of the well-developed shoot of this species are of two trace unilacunar type.

For purpose of convenience, the following terms are used in this section and Figs. 2—3. Nodes are numbered in order from the youngest node to older nodes. An internode between the node  $n$  and the node  $n+1$  is termed the internode  $n$ . Two leaves attached at the node  $n$  are termed the leaves  $n$  and  $n'$ . Both traces to a leaf  $n$ , which do not unite yet, are termed the trace  $n$ , and a compound leaf trace to the leaf  $n$ , which is formed by the union of two traces termed the trace  $n$ , is termed the compound trace  $n$ .

In the transverse section of the node 4 (Figs. 2-I, J), four bundles exist besides two compound trace 4 and 4'. These four bundles extend upward through the internode 3 and increase in width tangentially. At the node 3 (Figs. 2-G, H), they branch off to produce two pairs of traces termed the traces 3 and 3'. The two traces termed the trace 3 unite to form a compound trace 3, which serve a leaf 3 (Figs. 2-E, F). The remaining two termed the trace 3' behave similarly to the trace 3, so that the leaf 3' is served by them. Four bundles, which remain at the center of shoot axis, extend upward through an internode 2. Although two leaves are attached at the node 2 as well, they are at right angles to the plane of the leaves 3 and 3'. Just below the node 2, four bundles which have extended through the internode 2 increase in width tangentially like the bundles which have existed just below the node 3 and from which traces 3 and 3' have not diverged yet. They separate the traces 2 and 2' from the opposite side to the side where traces 3 and 3' have branched off at the node 3. The leaves 2 and 2' are served by the traces 2 and 2' as the leaves 3 and 3' have been served by the traces 3 and 3'. Four bundles which remain at the center of shoot axis, further, extend upward through an internode 1. In the internode 1 (Figs. 2-C, D), xylary cells and phloic cells do not differentiate within these bundles yet. That is, they are still in a procambial strand. Two leaves attached at the node 1 are at right angles to the plane of the leaves 2 and 2'. That is, they are in the same plane as that of the leaves 3 and 3'. Four bundles in the center of shoot axis separate the traces 1 and 1' at the node 1, as the traces 3 and 3' have branched off at the node 3. Traces termed the traces 1 and 1' unite to form compound traces 1 and 1' by which the leaves 1 and 1' are served, respectively. Both of these traces and compound traces are in a state of procambium. The four bundles in center of shoot axis extend upward further, and they continue to the residual meristem of shoot apex (Figs. 2-A, B).

The pattern of primary vascular system in the well-developed shoot of *E. japonica* is shown diagrammatically as in Fig. 3. Thus, there are four sympodia in the shoot and adjoining sympodia are interconnected with leaf traces. That is, the

primary vasculature in the well-developed shoot of *E. japonica* is of a closed type.

*Vasculature in a hypocotyl-shoot axis*—The vasculature in hypocotyl-shoot axis of the seedling with two pairs of leaves has been shown in Fig. 1 already. After such a vascular pattern has been established, two additional bundles are formed between the leaf trace  $L_1$  and the embryonic bundle  $E_3$  and between  $L_1'$  and  $E_1$  (Fig. 4: dashed line). As a result, two traces serve each of the first pair of leaves. In addition, four other additional bundles are formed between four bundles from which the leaf traces serving the second pair of leaves diverge and four leaf traces serving the first pair of leaves (Fig. 4: dashed line).

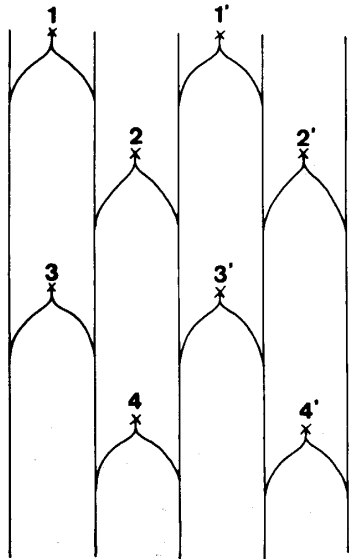


Fig. 3. The diagram of vascular pattern in the well-developed shoot of *Euonymus japonica*.

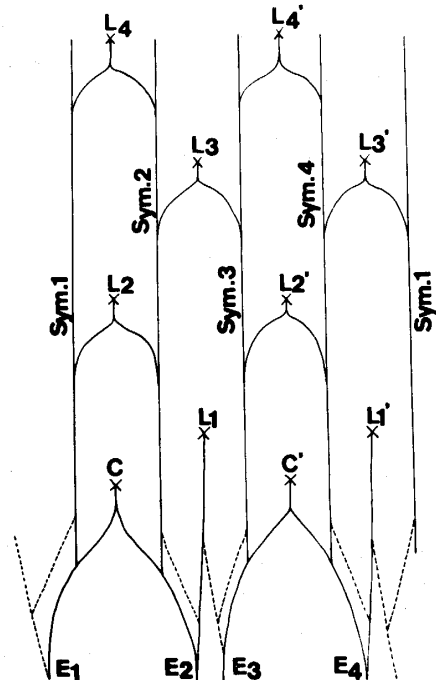


Fig. 4. The primary vasculature of *Euonymus japonica*. C; cotyledary trace, E; embryonic bundle, L; leaf trace, Sym.; sympodium, Dashed line; additional bundle.

### Discussion

The primary vascular system of *Euonymus japonica* is summarized as in Fig. 4. It is two traces that serve each of leaves attached at the second node and the superimposed nodes. They diverge from sympodia which extend longitudinally in the hypocotyl-shoot axis, and they serve the leaf after they have united to form a thick compound leaf trace. That is, the structure of the first node and the superimposed nodes is invariably two trace unilacunar. But at the early stage of the seedling ontogeny,

only one trace which has diverged from the embryonic bundle serves each of the first pair of leaves. An additional bundle is formed after the formation of this leaf trace. The formation of similar bundles is reported for the vasculature of several species. By this formation, the nodal structure is modified in various ways among nodes of a plant (Larson, 1984). Larson (1979) investigated in detail the development and organization of the primary vasculature in *Populus deltoides*. According to him, the developmental direction of these bundles, which develop bidirectionally from the base of leaf primordium, is different from the original leaf trace, which develops acropetally. Unfortunately it is uncertain in *E. japonica*. However, if these additional bundles of *E. japonica* are regarded as a leaf trace, the structure of the first node changes from one trace unilacunar type to two trace unilacunar type. It is certain that such an anatomical difference found in the early development of seedling causes the heterophylly in *E. japonica*.

There are two independent primary vascular systems in the very young seedling, where additional bundles are not formed in it yet. They are separated from one another by a longitudinal plane perpendicular to the plane including the midveins of two cotyledons and an interconnection does not establish between them yet. As the seedling develops further, they are interconnected with these additional bundles. That is, a very young seedling has a vasculature intermediate between the closed system and the open system. As the seedling develops further, the vasculature develops into a typical closed system of vasculature, which occurs universally in the shoot with a decussate phyllotaxy (Balfour and Philipson, 1962). The phylogenetic relationship between the closed system and the open system has been discussed by many anatomists (Jensen, 1968), but it is still the question in debate even now. From the ontogeny of primary vasculature found in *E. japonica*, a closed system of vasculature is considered to be a secondarily derived condition. This may support the contention that an open system of vasculature is primitive.

## マサキのシュートにおける管束の走行様式

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### 摘 要

マサキのシュートにおける一次管束の走行様式について調査した。マサキは対生葉序をもつが、第1節に付く葉は極端に小さく、異形葉性がみられる。第2節に葉が形成される

までの若い実生の下胚軸とシュートを結ぶ軸の中には、2つの独立した管束系が存在する。この2つの系は2枚の子葉の中肋を含む面に直交する面によって分けられている。第2節より上の節に付く葉には、シンポジウムから分枝した2本の葉跡が、その葉の形成開始と同時に供給され、節は初期から2葉跡1葉隙型である。しかし第1節に付く葉には、その葉の形成開始時には1本の葉跡しか供給されないが、後に二次的に葉跡が形成される。第1節は初期には1葉跡1葉隙型であるが、後に2葉跡1葉隙型に変わる。このような解剖学的な相違が異形葉性をもたらせる原因の一つと考えられる。またこの二次的に後に形成される葉跡によって軸中の2つの管束系が結び付けられる。この連絡が完成して、マサキは典型的な閉鎖型の管束走行をもつことになる。

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