**Supplementary Information**

Appendix I. Relationships between characters in each step-matrix complex employed during the study.

Summary:

7 Complexes of linked/inapplicable characters

Complex 0 (top 0): 0, 1,

Complex 1 (top 6): 6, 7, 8, 10, 11,

Complex 2 (top 15): 15, 16,

Complex 3 (top 19): 19, 21, 22, 24, 25,

Complex 4 (top 28): 28, 29, 30,

Complex 5 (top 32): 32, 33, 34, 35, 36, 37,

Complex 6 (top 38): 38, 39, 40, 41,

Complex 0 (2 characters)

The rationale of this complex is that “the type of stem core tracheid” can be scored if and only if “stem core tracheids” are present in a given taxon. Conditions are:

Char. 1 Stem core tracheids type

is inapplicable...

when

ch. 0 Stem core tracheids has

‘absent’

Complex 1 (5 characters)

This is a dynamic-dependence complex entailing the development of “perforations”, “embayments”, “dissections” and “dictyosteles” given the presence of “gaps”. The rationale is that, while leaf gaps (6) are not mandatory for the remaining character to develop, their absence makes it less likely for the other character to have a certain change. For instance, there are leaf gaps (6) without perforations (7), but the opposite (e.i., perforation with no gaps) is less frequent. Likewise, the dissected steles (10) and dictyostelic steles (11) are less likely when the cylinder (7) is ‘nearly solid’. Conditions are:

Char. 7 Metaxylem cylinder perforation

changes ‘nearly solid’ -> ‘moderately or highly perforated’ costs +2

when

ch. 6 Stele leaf gaps (peripheral invaginations/dissections) has

‘absent’

Char. 7 Metaxylem cylinder perforation

Changes ‘nearly solid’ -> ‘highly perforated’ costs +2

when

ch. 6 Stele leaf gaps (peripheral invaginations/dissections) has

‘shallow’

OR

ch. 6 Stele leaf gaps (peripheral invaginations/dissections) has

‘prominent’

Char. 8 Stele internal invaginations into metaxylem cylinder

changes ‘none’ -> ‘fewer than’ or ‘as many as…peripheral invaginations’ costs +2

when

ch. 6 Stele leaf gaps (peripheral invaginations/dissections) has

‘absent’

Char. 10 Stele dissected siphonostele condition

changes ‘absent’ -> ‘present’ costs +2

when

ch. 7 Metaxylem cylinder perforation has

‘nearly solid’

Char. 11 Stele dictyostelic condition

changes ‘absent’ -> ‘present’ costs +2

when

ch. 7 Metaxylem cylinder perforation has

‘nearly solid’

Complex 2 (2 characters)

This complex is a case of inapplicability, where “Cortex sclerenchymatic outer layer (16)” cannot be scored when “Cortex sclerenchymatous outer cortical layer (15)”. Conditions are:

Char. 16 Cortex sclerenchymatic outer layer

is inapplicable...

when

ch. 15 Cortex sclerenchymatous outer cortical layer has

‘absent’

Complex 3 (5 characters)

This complex involves characters related to the development of leaf traces and their associated xylem strands, which are intricately related. In this complex, the development of traces and strands is determined by the type and number of leaf traces and strands at the inner parts of the stem. While some characters have more obvious links [e.g., the number of protoxylem strands at the cortex (22) depends on their number at the departure from stele (19)], others are related in less obvious manners. For example, changes in leaf-trace shape (21) to state 2 in ("two individual segments") are less likely when (19) is either ‘one’ or ´two´. Only when (19) is 2 ("more than two") changes to state 2 in 21 is more likely. Similarly, the number of leaf-trace protoxylem strands upon departure from stem (24) is related to leaf traces in cortex (22) and leaf traces departing from stele (19): strands upon departure from stem tend to be more than two when the same number of strands are found in the other characters. Finally, the shape of stipe bundle after departure from stem (25) is less likely to be oblong or slightly concave when there are two individual segments (21). Conditions are as follows:

is related to 21 ("Shape of leaf trace immediately after departure from stele"):

state 0 ("oblong") in char. 25 is less likely under state 2 in 21 ("two individual segments").

Char. 21 Leaf-trace shape immediately after departure from stele

changes ‘oblong’ or ‘strongly concave’ -> ‘two individual segments’ costs +1

when

ch. 19 Number of leaf-trace protoxylem strands upon departure from stele has

‘one’

OR

ch. 19 Number of leaf-trace protoxylem strands upon departure from stele has

‘two’

Char. 24 Number of leaf-trace protoxylem strands upon departure from stem

changes ‘one’ -> ‘two’ costs -1

when

ch. 19 Number of leaf-trace protoxylem strands upon departure from stele has changes

‘one’ > ‘two’

AND

ch. 22 Number of leaf-trace protoxylem strands in central part of cortex has changes

‘one’ > ‘two’

Char. 24 Number of leaf-trace protoxylem strands upon departure from stem

changes ‘two’ -> ‘more than two’ costs -1

when

ch. 19 Number of leaf-trace protoxylem strands upon departure from stele has changes

‘two’ > ‘more than two’

AND

ch. 22 Number of leaf-trace protoxylem strands in central part of cortex has changes

‘two’ > ‘more than two’

Char. 25 Shape of petiolar vascular bundle immediately after departure from stem

changes ‘oblong’ or ‘strongly concave’ -> ‘oblong or slightly concave’ costs +2

when

ch. 21 Leaf-trace shape immediately after departure from stele has

‘two individual segments’

Complex 4 (3 characters)

Sclerenchyma in stipe bundle concavity (29) and the appearance of the sclerenchyma in stipe bundle concavity (30) depend on their presence (28). Conditions are:

Char. 29 sclerenchyma in trace concavity special states

is inapplicable...

when

ch. 28 sclerenchyma in leaf-trace concavity adaxially has

‘absent’

Char. 30 origination of sclerenchyma associated with leaf trace

is inapplicable...

when

ch. 28 sclerenchyma in leaf-trace concavity adaxially has

‘absent’

Complex 5 (6 characters)

A complex combining static dependence (inapplicability) and dynamic dependence. The presence of a sclerenchyma ring (32) determines the applicability of the type of sclerenchyma ring at the petiole base (33). In turn, the remaining transformations in other characters are penalised when the type of sclerenchyma ring is homogeneous. Conditions are as follows:

Char. 33 Sclerenchyma ring of petiole base

is inapplicable...

when

ch. 32 Sclerenchyma ring has

‘absent’

Char. 34 Abaxial arch differentiating into ring

changes ‘no’ -> ‘yes’ costs +1

when

ch. 33 Sclerenchyma ring of petiole base has

‘homogenous’

Char. 35 Abaxial arch differentiating into two masses

changes ‘no’ -> ‘yes’ costs +1

when

ch. 33 Sclerenchyma ring of petiole base has

‘homogenous’

Char. 36 Abaxial arch or two masses differentiating into three masses

changes ‘no’ -> ‘yes’ costs +1

when

ch. 33 Sclerenchyma ring of petiole base has

‘homogenous’

Char. 37 Two masses differentiating further into adaxial arch

changes ‘no’ -> ‘yes’ costs +1

when

ch. 33 Sclerenchyma ring of petiole base has

‘homogenous’

Complex 6 (4 characters), conditions:

In this complex, scattered sclerenchyma clusters in stipular expansions (39) are inapplicable when stipular expansions are absent or developed into spines (38). Distinct sclerenchyma masses in stipular expansions (40) are less likely when sclerenchyma clusters tend to be scattered (39). Distinctively elongate-shaped masses of sclerenchyma (41) can be observed only when there are stipular expansions (38) or when sclerenchyma is organised in masses (40). Conditions are:

Char. 39 Scattered sclerenchyma clusters in stipular expansions

is inapplicable...

when

ch. 38 Stipular wings or spines has

‘absent’

OR

ch. 38 Stipular wings or spines has

‘spines’

Char. 40 Distinct sclerenchyma clusters in stipular expansions

changes ‘absent’ -> ‘one mass’ or ‘ two or more masses in each wing’ costs +1

when

ch. 39 Scattered sclerenchyma clusters in stipular expansions has

‘present’

Char. 41 Elongate shape or arrangement of distinct sclerenchyma masses in stipular wing

is inapplicable...

when

ch. 38 Stipular wings or spines has

‘absent’

AND

ch. 40 Distinct sclerenchyma clusters in stipular expansions has

‘absent’

**Fig. S1.** Topologies inferred under extended implied weighting and using character dependencies. From left to right: concavity 5, 10, 15, and 20. Subfamilies highlighted in each tree in colour: (light red) Thamnopteroideae, (dark red) Itopsidemoideae, (blue) Guairoideae, (green) Osmundoideae. Groups in black are either incertae sedis or non-osmundalean fossils.

