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Notes on how the morphological characters and character states were interpreted and scored for the Santalales taxa used in this study

This Appendix provides some discussion of the characters and character states used. The number of genera in both the molecular and morphological analyses are the same, i.e. 146 genera of the total 163 for the order. The missing genera are as follows: *Douradoa* (Ximeniaceae), *Cyne, Distrianthes, Lampas, Maracanthus, Oryctina, Panamanthus, Papuanthes, Pedistylis, Peristethium, Phthirusa, Pusillanthus, Thaumasianthes, Trilepidea, Trithecanthera* (Loranthaceae), *Gjellerupia* (Opiliaceae), and *Lacomucinaea* (Thesiaceae). One representative per genus was used in the molecular analysis. This species was then used as a placeholder representing all species for the genus. In the order, 56 genera are monospecific and 120 have 10 or fewer species. Thus for many genera, the description fits all or a large portion of the species within that genus. In contrast, for large and speciose genera, one description must encompass the large number of inflorescence types. The largest genera in the order are *Thesium* (346), *Phoradendron* (248), *Dendrophthora* (126), *Psittacanthus* (121), *Viscum* (120), and *Amyema* (93 species). Much intra-generic variation in inflorescence morphology occurs in *Amyema*, *Psittacanthus*, and *Thesium*, thus those descriptions must include polymorphic characters (i.e. multiple character states).

Here we use the term inflorescence to mean **the basic unit where one or more flowers, on a simple or compound shoot system (axis or axes), are arranged.** We considered using the term "synflorescence" as defined by Troll (1964) and Weberling (1989), but we agree with Endress (2010) that this term presents difficulties. Moreover, Stauffer (1963) suggested that it may best apply only to herbaceous plants. We use the term conflorescence to describe an inflorescence where the overall structure differs substantially from that of the individual branches of the

inflorescence. An example of a conflorescence is a thyrse where the main axis is racemose whereas the lateral branches are cymes. We define partial inflorescences (also called unit or uniflorescences) as the basic subunits of an inflorescence which may be single flowers, monchasia, dichasia, etc.

Scoring the Matrix

The information present in Appendix S3 was examined and taxa scored for ten morphological characters. The resulting matrix then represents our assessment of primary homology for each character (Hawkins, Hughes, and Scotland, 1997), i.e. our initial hypothesis based on gross morphology (very rarely have anatomical or developmental studies been conducted). Seven of the ten characters are binary (0 and 1) whereas three characters were multistate (chrs. 3, 8, and 9). Polymorphisms (presence of more than one state in a cell) are indicated by the "&" (and) symbol, e.g. where "0&1" means the taxon has states 0 AND 1 (Maddison and Maddison, 2000, MacClade manual p. 228). Polymorphisms can derive from different sources:

a) variation exists between species and scoring at the genus level must accommodate this

b) male and female plants of the same species have different inflorescence types (e.g. in *Anthobolus* and *Buckleya*)

c) different authors have described the same inflorescence in different ways (e.g. an umbel of two flowers vs. a reduced raceme)

A combination of different states was used to describe particular inflorescences. For example, for character 3 (inflorescence form), *Nuytsia* has a conflorescence composed of a raceme of triads that was scored 1&3 (racemose & cymose), i.e. a type of thyrse. In *Desmaria*, the conflorescence is an umbel of triads (scored 3&5). The argument could be made that "thyrse"

should be given a separate character state from raceme, cyme and umbel, but that was not done here because it would separate taxa with common inflorescence elements.

The terms corymb or corymbiform have sometimes been used to describe inflorescences (although they are not mentioned at all in Endress 2010). Rickett (1955) points out the many varied uses of corymb but indicated that the consensus from several authors was "a raceme with the flowers carried up nearly to the same level, and opening centripetally". This definition does not encompass branching of the laterals. Weberling (1989, p. 211) interprets this type as a modified panicle where all the flowers lie at the same level in an umbellate arrangement. According to Endress (pers. comm.), corymb is not defined by a specific ramification pattern but simply by the relative length of axes so that all flowers are about at the same level forming an umbrella-like structure. It can be racemose or paniculate. For some taxa (e.g. *Chaunochiton*), the inflorescence was thus scored as "paniculate", but its relative *Harmandia*, described by Sleumer (1984a) as "racemose-corymbiform," was scored as a raceme. For *Brachynema*, described by Sleumer (1984b) as "short ebracteate corymbs or subsessile fascicles", the inflorescence was scored as fasciculate based on photos and illustrations.

We use the term partial inflorescence for a lateral subunit to the main inflorescence (= unit florescence, uniflorescence). Determining the type of partial inflorescence across all inflorescences in Santalales is not straightforward. Reductional and compounding processes that have taken place during the course of inflorescence evolution have resulted in morphologies that obscure partial inflorescence types. For example, a two-flowered condition may be a form of monochasium or it may be a dyad resulting from the loss of the terminal flower of a triad; these two conditions therefore do not exhibit primary homology.

Characters Used

1. Trios. (0) absent, (1) present. This character is the combination of characters 5 and 6; however, we do not consider dichasia and triads to be synonymous (see separate definitions of these terms, Appendix S10). Because of uncertainty as to which triads represent dichasia and which do not (mainly in Loranthaceae), we took a liberal approach (any grouping of three flowers) to address the hypothesis that dichasia are plesiomorphic in Santalales.

2. Inflorescence position. (0) axillary and (1) terminal, as well as the polymorphic condition (0/1) where both occur.

3. Inflorescence form overall. (0) fascicles (see definition in Appendix S10), (1) racemes (flowers with pedicels or peduncles - these may be described as monads), (2) spikes (flowers sessile on the main axis), (3) cymes (including monochasial and dichasial types), (4) panicles, (5) umbels, (6) capitula (heads), and glomerules (sessile flowers on an axis with very short internodes).

4. Conflorescence. (0) absent, (1) present. This character compares the branching pattern at the primary level with that at the secondary and and higher orders. This character is intended to extract more information out of character 2 where polymorphism sometimes reflects a conflorescence (see discussion above about thyrse). This character does not capture all cases of compound inflorescences (e.g. the compound racemes of *Coula* and *Santalum*) where the branching pattern of the primary and secondary axes are the same.

5. Dichasia. (0) absent, (1) present. The dichasium is here considered a partial inflorescence, thus it was not listed as a type under character 2 (basic inflorescence form). Several morphological criteria were used to determine whether this partial inflorescence describes the condition seen in various Santalales (see text). This information was used to scrutinize cases listed by various authors, e.g. Polhill and Wiens (1998) for *Viscum*, and thereby determine whether application of the term is appropriate. We consider a triad as a more generalized

partial inflorescence, separate from dichasium, and therefore scored it as a distinct character (no. 5).

6. Triads. (0) absent, (1) present. In the most inclusive meaning, a triad is a cluster of three flowers in no particular relation to each other. Like dichasium, it is a partial inflorescence that occurs laterally on a main inflorescence and indeed some types may be synonymous with dichasia (see text). The term has been applied by various workers to partial inflorescence seen in Loranthaceae and may also apply to *Agonandra* (Opiliaceae). As a partial inflorescence, the triad does not occur in Viscaceae.

7. Bract/bracteole presence. (0) absent, (1) present. In many genera of Santalales, a primary bract and two bracteoles subtend a flower. These structures are considered together here, a generalization necessary to avoid interpretive problems associated with losses and fusions of these organs.

8. Bract/bracteole persistence. (0) persistent, (1) caducous. This features was scored as a separate character from bract/bracteole presence following the arguments made in Hawkins, Hughes, and Scotland (1997). In the case of bract/bracteole absence, the character "?" was used.

9. Plant sexuality. (0) synoecious, (1) monoecious, (2) dioecious, (3) polygamous. For polygamous we include andromonoecy, androdioecy, gynomonoecy, gynodioecy, and trioecism. The exact form of plant sexuality for most members of Santalales has not been investigated. For the whole plant sexual condition, where all flowers are bisexual, the term synoecious is being used. This is to avoid using the term bisexual for both the whole plant (species) condition vs. the condition of an individual flower. Generally, synoecious means male and female organs in (or on) the same structure, and in that sense it is synonymous with bisexual when the structure being considered is the receptacle. A desirable feature of this

term is that it has the same suffix (-*ecious*) as the other whole plant sexuality terms monoecious and dioecious.

10. Flower sex. (0) bisexual, (1) unisexual. This character is obviously related to plant sexuality, but presents the information in binary form. For polygamous plants, the scoring would be 0&1.

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