Borneocola (Zingiberaceae), a new genus from Borneo

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Academic editor: Pavel Stoev | Received 12 July 2016 | Accepted 9 November 2016 | Published 29 November 2016

Citation: Sam YY, Takano A, Ibrahim H, Záveská E, Aziz F (2016) Borneocola (Zingiberaceae), a new genus from Borneo. PhytoKeys 75: 31–55. doi: 10.3897/phytokeys.75.9837

Abstract

A new genus from Borneo, Borneocola Y.Y.Sam, is described here. The genus currently contains eight species previously classified as members of the Scaphochlamys Baker. The finding is based on the results of the morphological and molecular studies of Scaphochlamys throughout its geographical range and its closely allied sister groups, Distichochlamys M.F.Newman and Myxochlamys A.Takano & Nagam. Borneocola is nested within the tribe Zingibereae and its monophyly is strongly supported by both ITS and matK sequence data. The genus is characterised by several thin, translucent and marcescent floral bracts, absence of coloured streaks on the labellum and capitate stigma with two dorsal knobs. The genus is distributed in northwest Borneo and all species are very rare and highly endemic.

Keywords

Distichochlamys, Myxochlamys, Scaphochlamys, morphology, phylogeny, taxonomy
Introduction

Southeast Asia is the centre of diversity for the family Zingiberaceae. Here, new taxa are continuously being discovered and named, both at the generic and specific levels. Several of the recent discoveries were further supported by the phylogenetic analyses which give a better understanding of the evolutionary relationships within the family (Kress and Larsen 2001; Kress et al. 2010; Leong-Škorničková et al. 2011). During the revision of the genus *Scaphochlamys* throughout its entire geographical range by the first author, some distinctive morphological traits were observed in several Bornean species, suggesting they might represent a separate group from the Peninsular Malaysian taxa. This hypothesis was confirmed by the phylogenetic analyses which are presented here and the eight species previously included in the genus *Scaphochlamys* are recircumscribed in this paper as a new genus, *Borneocola* Y.Y.Sam.

The genus *Scaphochlamys* was described by Baker (1892) in the Flora of British India with *Scaphochlamys malaccana* Baker from Mt. Ophir (now known as Gunung Ledang), Peninsular Malaysia, chosen as the type species. Holttum (1950) carried out the first comprehensive revision of the genus in which he recognised 19 species, all of which were recorded in the peninsula. When Smith (1987) reviewed the tribe Hedychieae in Borneo, she applied the generic delimitation defined by Holttum and recognised five *Scaphochlamys* species in Borneo. Out of the five, *S. polyphylla* and *S. petiolata* were formerly placed in the genus *Haplochorema* K.Schum. Sakai and Nagamasu (2006) discovered that *H. gracilipes* K.Schum. also have the characteristics of *Scaphochlamys* and effected the transfer. Recent years have seen a surge in the new species discovered from Borneo bringing the total number of Bornean *Scaphochlamys* to 14 (Poulsen and Searle 2005, Meekiong et al. 2011, Ooi and Wong 2014; Meekiong 2015).

*Distichochlamys* M.F.Newman and *Myxochlamys* A.Takano & Nagam. are sister genera to *Scaphochlamys* with several unique characteristics clearly separating them from *Scaphochlamys* (Newman 1995, Searle and Hederson 2000, Kress et al. 2002, Ngamriabsakul et al. 2004, Takano and Nagamasu 2007). However, the distinction, based on morphological characters, became ambiguous as several taxa described recently exhibit exceptions to the usual generic characters. For example, *S. calcicola* A.D.Poulsen & R.J.Searle, a species named in 2005 from Sarawak, has a distichous inflorescence, a distinguishing character for the genus *Distichochlamys* M.F.Newman. Larsen and Newman (2001) also reported another *Scaphochlamys* species with a distichous inflorescence from north Peninsular Malaysia. A current study on the morphology of *Scaphochlamys* also revealed that some species display the characteristics of *Distichochlamys* and *Myxochlamys*. To test the validity of the current generic concept of *Scaphochlamys* and closely related genera *Distichochlamys* and *Myxochlamys*, we have examined their relationship by utilising ITS and matK markers together with the analysis of the morphology across these genera.
Materials and methods

Morphological study

The morphological study was based on living plants in the forest, cultivated plants in the nursery of the Forest Research Institute Malaysia and specimens in the herbaria of AAU, BKF, C, FI, E, K, KEP, KLU, PSU, SAN, SAR and SING. A total of 372 herbarium specimens were examined in this study which includes 29 Scaphochlamys species and four Borneocola species (the types of another four Borneocola species were not yet deposited in the herbaria). The morphological characters examined in the study were habit; position of the rhizome, thickness and colour; height of leafy stem, its base (whether swollen to form a bulbous base); distance between leafy stems; characters of bladeless sheath such as colour, indumentum, number and length; ligule length, indumentum and shape; petiole length, indumentum, whether channelled or rounded in cross section; number of leaves per leafy stem; lamina colour on both surfaces, size, shape, venation, texture, indumentum, apex and base; length of the inflorescence and infructescence, arrangement of the floral bracts on the rachis, characters of floral bracts and bracteoles (colour, indumentum, texture, shape); size, colour and shape of calyx, floral tube, corolla lobes, labellum, staminodes, stamen, ovary.

DNA extraction, amplification and sequencing

Fresh leaves from the cultivated plants or silica-dried materials from plants collected in the field were used for genomic DNA extraction.

For the ITS, the genomic DNA was extracted using the DNeasy Plant Mini Kit (Qiagen, Valencia, California, USA) following the manufacturer’s protocol. Two primers, ITS 5P (5’-GGAAGGAGAAGTCGTAACAAGG-3’) and ITS 8P (5’-CACGCTTCTCCAGACTACA3’) (Moller and Cronk 1997) were used to amplify the ITS region during the polymerase chain reaction (PCR). The thermal cycle of PCR for the amplification of the ITS sequences is initial denaturation at 94°C for 2 minutes, 40 cycles of denaturation at 94°C for 30 seconds, primers annealing at 48°C for 2 minutes, an extension at 72°C for 45 seconds and final extension at 72°C for 7 minutes. The PCR products were then purified using MinElute Gel Extraction Kit (Qiagen, Valencia, California, USA).

For the matK, the protocols for DNA extraction, condition, purification and DNA sequencing were described previously by Takano and Nagamasu (2007). The PCR and sequencing primers for matK (cpDNA) were TA-240f (5’-GGGAAA GGATGGGGTCTCCCG-3’), TA-150r (5’-CTCAAGGAGTTTTGTGGTGC-3’), TA-470F (5’-CCCTCTCCCGTCCATATGGA-3’) (all three were designed in the present study), matK8 (Steele and Vilgalys 1994), m5r (Kress et al. 2002), matK8r (Ooi et al. 1995), trnK2621 (Liston and Kadereit 1995), TA-10F, TA-05R, TA-02F and TA-02R (all from Takano and Okada 2002).
Sequence alignment and phylogenetic analysis

Raw sequence data were assembled and edited manually using BioEdit software ver. 7.2.5 (Hall 1999). DNA sequences were aligned with the CLUSTALW 1.83 software package, with default settings and multiple alignments (Thompson et al. 1994). Alignments of the matK sequences of cpDNA and the ITS sequences of nrDNA were combined. Gaps were deleted.

A total of 100 individuals including 54 taxa of *Scaphochlamys* and allied species were used. The three *Siphonochilus* species were used as an outgroup (Kress et al. 2002). Materials, accession numbers for the sequences, vouchers and references to the literature are presented in Table 1 at the end of this paper. Three datasets which comprise ITS, matK and ITS+matK combined, each containing 82, 78, and 61 taxa, were constructed. These three datasets were analysed using three methods: maximum parsimony, maximum likelihood and Bayesian analysis. A maximum parsimony (MP) analysis was performed with MEGA 6 (Tamura et al. 2013). Heuristic searches were conducted with RANDOM addition, SPR branch swapping and MULPARS options. Support for each branch was estimated with a bootstrap analysis, with 1000 replications (Felsenstein 1985), in a heuristic search with RANDOM addition and TBR branch swapping. The maximum likelihood (ML), based on the Tamura-Nei model (Tamura and Nei 1993), was also determined with MEGA 6 (Tamura et al. 2013). Neighbor-Join and BioNJ algorithms were applied to a matrix of pairwise distances estimated with the maximum composite likelihood approach; then, the topology that had the best log likelihood value was selected. Bootstrap analysis under the MP criterion was conducted with “fast” stepwise, addition searches, with 1000 replicates. In addition, a Bayesian analysis was carried out with MrBayes software ver. 3.1.2 (Huelsenbeck and Rohnquist 2001; Rohnquist and Huelsenbeck 2003). The best fitting substitution model (the GTR+G model for nrDNA datasets, the GTR+G model for cpDNA datasets and the GTR+I+G model for cpDNA+nrDNA datasets) was selected for Bayesian analysis based on a series of hierarchical likelihood ratio tests, implemented in MrModeltest software ver. 2.3 (Nylander 2004). The analysis was performed with the selected model and two simultaneous runs of two million generations with four chains, sampling every 100 generations. Each analysis reached stationarity (i.e. when the average standard deviation of split frequencies between runs was ≤ 0.01) well before the end of the run. Burn-in trees were discarded and the remaining trees and their parameters were saved. A 50 % majority rule consensus tree was constructed. The results of the Bayesian analysis were reported as the posterior probability (PP; Huelsenbeck and Rohnquist 2001), which is equal to the percentage of phylogenetic trees sampled when a given clade was resolved. Only PP scores above 50 % are shown.
Table 1. List of accession details, vouchers and references used in the phylogenetic analyses.

| No | Subfamily    | Tribe         | Species                                      | ITS     | matK     | References/Voucher                      |
|----|--------------|---------------|----------------------------------------------|---------|----------|----------------------------------------|
| 1  | Alpinioideae | Alpinieae     | *Alpinia blepharocalyx* K.Schum.             | AF478709| AF478809 | Kress et al. 2002                      |
| 2  |              |               | *Alpinia elegans* K.Schum.                   | AF478713| AF478813 | Kress et al. 2002                      |
| 3  | Alpinioideae | Alpinieae     | *Amomum villosum* Lour.                     | –       | AF478824 | Harris et al. 2000 (ITS), Kress et al. 2002 (matK) |
| 4  |              |               | *Amomum yunnanense* S.Q.Tong.                | –       | –        | Xia et al. 2004                         |
| 5  |              | Measn.        | *Elettariopsis kerbyi* R.M.Sm.               | AF414496| AF478845 | Pedersen 2004 (ITS)/Kress et al. 2002 (matK) |
| 6  |              |               | *Renalinia battenbergiana* Cummins ex Baker  | AF478779| AF478880 | Kress et al. 2002                      |
| 7  | Siphonochiloe| Siphonochiloe | *Siphonochilus aethiopicus* (Schweinf.) B.L.Burtt | AF478792| AF478893 | Kress et al. 2002                      |
| 8  | W.J.Kress    |               | *Siphonochilus decorus* (Druten) Lock        | AF478793| AF478894 | Kress et al. 2002                      |
| 9  |              |               | *Siphonochilus kirkii* (Hook.) B.L.Burtt     | AF478794| AF478895 | Kress et al. 2002                      |
| 10 | Tamijioideae | Tamijieae      | *Tamijia flagellaris* S.Sakai & Nagam.       | AF478797| AF478898 | Kress et al. 2002                      |
| 11 | Zingiberoideae | Zingibereae | *Boesenbergia pulcherrima* Kuntze            | AF478725| AF478825 | Kress et al. 2002                      |
| 12 | Haask.       | Meisn.        | *Boesenbergia rotunda* (L.) Mansf.           | AF478727| AF478826 | Kress et al. 2002                      |
| 13 |              |               | *Borneocola biru* (Mecking) Y.Y.Sam          | –       | LC148403 | FRI 50290 (KEP)                        |
| 14 |              |               | *Borneocola calcicola* (A.D.Poulson & R.J.Searle) Y.Y. Sam | LC148062| LC148380 | FRI 50290 (KEP)                        |
| 15 |              |               | *Borneocola sp. FRI 50295*                  | LC148085| LC148404 | FRI 50295 (KEP)                        |
| 16 |              |               | *Borneocola sp. S 99106*                    | LC148086| LC148405 | S 99106 (SAR)                          |
| 17 |              |               | *Borneocola stenophyllus* (Oot & S.Y.Wong) Y.Y.Sam | LC148084| LC148400 | FRI 50288 (KEP)                        |
| 18 |              |               | *Borneocola petiolatus* (K.Schum.) Y.Y.Sam   | LC148075| LC148395 | FRI 50291 (KEP)                        |
| 19 |              |               | *Borneocola reticosa* (Ridl.) Y.Y.Sam        | LC148078| LC148398 | FRI 50294 (KEP)                        |
| 20 |              |               | *Camptandra parvula* Ridl.                   | AF478730| AF478830 | Kress et al. 2002                      |
| 21 |              |               | *Caulokaempferia saxicola* K.Larsen          | AF478732| AF478831 | Kress et al. 2002                      |
| 22 |              |               | *Caulokaempferia avansantiflora* J.Mood & K.Larsen | AF478734| AF478833 | Kress et al. 2002                      |
| 23 |              |               | *Caulokaempferia spuricata* Baker            | AF478735| AF478834 | Kress et al. 2002                      |
| 24 |              |               | *Curtiskaempferia aurantiiflora* J.Mood & K.Larsen | AF478736| AF478835 | Kress et al. 2002                      |
| 25 |              |               | *Carica bicolor* J.Mood & K.Larsen          | AF478737| AF478837 | Kress et al. 2002                      |
| 26 |              |               | *Carica rosacea* Wall.                      | AF478739| AF478837 | Kress et al. 2002                      |
| 27 |              |               | –                                            | –       | AB047741 | Kress et al. 2002 (ITS)/Cao et al. unpublished (matK) |
| 28 |              |               | *Distichochlamys citrea* M. F. Newman        | –       | –        | Ngamriabsakul et al. 2004              |
| 29 |              |               | *Distichochlamys citrea* M. F. Newman 2      | –       | –        | Ngamriabsakul et al. 24 (E)            |
| No | Subfamily | Tribe | Species | ITS       | matK       | References/ Voucher |
|----|-----------|-------|---------|-----------|------------|---------------------|
| 32 | Zingiberoideae | Zingiberae | Distichochlamys sp. AS18 | AB552947 | AB553309 | Adele Smith 18 (E) |
| 33 | Zingiberoideae | Zingiberae | Distichochlamys sp. Kress01-6848 | AF478745 | AF478844 | Kress et al. 2002 |
| 34 | Zingiberoideae | Zingiberae | Haniffia alliflora K.Larsen & J.Mood | AF478756 | AF478855 | Kress et al. 2002 |
| 35 | Zingiberoideae | Zingiberae | Hedychium longicornatum Griff. ex Baker | AF478761 | AF478860 | Kress et al. 2002 |
| 36 | Zingiberoideae | Zingiberae | Hedychium villosum Wall. | AF478762 | AF478861 | Kress et al. 2002 |
| 37 | Zingiberoideae | Zingiberae | Hitchenia glauca Wall. | AF478765 | AF478864 | Kress et al. 2002 |
| 38 | Zingiberoideae | Zingiberae | Kaempferia parviflora Wall. | – | AB232052 | Searle and Hedderson 2000 |
| 39 | Zingiberoideae | Zingiberae | Kaempferia rotunda L. | AF478767 | AF478868 | Kress et al. 2002 |
| 40 | Zingiberoideae | Zingiberae | Kaempferia sp. Kress98-6289 | AF478768 | AF478869 | Kress et al. 2002 |
| 41 | Zingiberoideae | Zingiberae | Myxochlamys mulieriensis A.Takano & Nagam. | AB245522 | AB269791 | Takano and Nagamasu 2007 |
| 42 | Zingiberoideae | Zingiberae | Myxochlamys nobilis Nagam. ined. | AB552948 | AB553310 | Nagamasu 8274 (BO, KYO) |
| 43 | Zingiberoideae | Zingiberae | Pommereshea lackneri Witm. | – | AF478877 | Kress et al. 2002 |
| 44 | Zingiberoideae | Zingiberae | Pygophyllum yunnanense (Gagnep.) T.L.Wu & Z.Y.Chen | AF478777 | AF478878 | Kress et al. 2002 |
| 45 | Zingiberoideae | Zingiberae | Rhynchanthus beesianus W.W.Sm. | AF478784 | AF478885 | Kress et al. 2002 |
| 46 | Zingiberoideae | Zingiberae | Roscoea caudatae Od Gagnep. | AF478736 | AF478887 | Kress et al. 2002 |
| 47 | Zingiberoideae | Zingiberae | Roscoea purpurea Sm. | AF478787 | AF478888 | Kress et al. 2002 |
| 48 | Zingiberoideae | Zingiberae | Scaphochlamys abdullahii Y.Y.Sam & Saw | LC148054 | – | FRI 44375 (KEP) |
| 49 | Zingiberoideae | Zingiberae | Scaphochlamys abdullahii Y.Y.Sam & Saw | LC148055 | LC148374 | FRI 50198 (KEP) |
| 50 | Zingiberoideae | Zingiberae | Scaphochlamys atroviridis Holttum | LC148056 | – | FRI 68924 (KEP) |
| 51 | Zingiberoideae | Zingiberae | Scaphochlamys baenkensii Y.Y.Sam | LC148057 | – | FRI 68955 (KEP) |
| 52 | Zingiberoideae | Zingiberae | Scaphochlamys biloba (Ridl.) Holttum | LC148059 | – | FRI 46606 (KEP) |
| 53 | Zingiberoideae | Zingiberae | Scaphochlamys biloba (Ridl.) Holttum | LC148081 | – | FRI 50224 (KEP) |
| 54 | Zingiberoideae | Zingiberae | Scaphochlamys biloba (Ridl.) Holttum | LC148083 | – | FRI 66331 (KEP) |
| 55 | Zingiberoideae | Zingiberae | Scaphochlamys biloba (Ridl.) Holttum 1 | LC148084 | LC148385 | FRI 50171 (KEP) |
| 56 | Zingiberoideae | Zingiberae | Scaphochlamys biloba (Ridl.) Holttum 2 | LC148085 | – | FRI 44984 (KEP) |
| 57 | Zingiberoideae | Zingiberae | Scaphochlamys breviscapa Holttum | LC148060 | LC148376 | FRI 68928 (KEP) |
| 58 | Zingiberoideae | Zingiberae | Scaphochlamys burkillii Holttum | LC148061 | – | FRI 46504 (KEP) |
| 59 | Zingiberoideae | Zingiberae | Scaphochlamys burkillii Holttum | LC148062 | – | FRI 46504 (KEP) |
| 60 | Zingiberoideae | Zingiberae | Scaphochlamys concinna (Baker) Holttum | AY478889 | – | Kress et al. 2002 |
| 61 | Zingiberoideae | Zingiberae | Scaphochlamys concinna (Baker) Holttum | AY478889 | – | Kress et al. 2002 |
| 62 | Zingiberoideae | Zingiberae | Scaphochlamys concinna (Baker) Holttum | AY478889 | – | Kress et al. 2002 |
| 63 | Zingiberoideae | Zingiberae | Scaphochlamys cordata Y.Y.Sam & Saw | LC148064 | – | FRI 44306 (KEP) |
| 64 | Zingiberoideae | Zingiberae | Scaphochlamys endauensis Y.Y.Sam & Ibrahim | LC148083 | – | FRI 50243 (KEP) |
| 65 | Zingiberoideae | Zingiberae | Scaphochlamys endauensis Y.Y.Sam & Ibrahim | LC148083 | – | FRI 50243 (KEP) |
| 66 | Zingiberoideae | Zingiberae | Scaphochlamys erecta Holttum | LC148065 | – | FRI 44987 (KEP) |
| 67 | Zingiberoideae | Zingiberae | Scaphochlamys grandis Holttum | – | LC148384 | FRI 47184 (KEP) |
| 68 | Zingiberoideae | Zingiberae | Scaphochlamys grandis Holttum | LC148066 | LC148385 | FRI 50171 (KEP) |
| No | Subfamily | Tribe | Species | ITS | matK | References/Voucher |
|----|-----------|-------|---------|-----|------|-------------------|
| 69 | | | Scaphochlamys johorensis Y.Y.Sam | LC148082 | – | FRI 66566 (KEP) |
| 70 | | | Scaphochlamys klossii (Ridl.) Holttum | LC148067 | LC148387 | FRI 50238 (KEP) |
| 71 | | | Scaphochlamys kunstleri (Baker) Holttum | AF478789 | AF478890 | Kress et al. 2002 |
| 72 | | | Scaphochlamys kunstleri (Baker) Holttum var. rubra C.K.Lim | AB552950 | AB553312 | Anon C 8003 & C. Ngamriabsakul 25 (E) |
| 73 | | | Scaphochlamys kunstleri (Baker) Holttum var. kunstleri | – | LC148388 | FRI 68926 (KEP) |
| 74 | | | Scaphochlamys kunstleri (Baker) Holttum var. speciosa C.K.Lim | LC148068 | – | FRI 68936 (KEP) |
| 75 | | | Scaphochlamys lanceolata (Ridl.) Holttum | LC148069 | LC148390 | FRI 50130 (KEP) |
| 76 | | | Scaphochlamys lassa Y.Y.Sam & Saw | – | LC148391 | FRI 68961 (KEP) |
| 77 | | | Scaphochlamys longifolia (Ridl.) Holttum | LC148070 | LC148392 | FRI 47065 (KEP) |
| 78 | | | Scaphochlamys malaccana Baker | – | LC148393 | FRI 50203 (KEP) |
| 79 | | | Scaphochlamys malaccana Baker | LC148071 | – | FRI 50208 (KEP) |
| 80 | | | Scaphochlamys minutiflora Jenjitt. & K.Larsen | – | LC148394 | 3175 |
| 81 | | | Scaphochlamys obcordata P.Siriruga & K.Larsen | AJ388286 | – | Searle and Hederson 2000 |
| 82 | | | Scaphochlamys oculata (Ridl.) Holttum | LC148072 | LC148396 | FRI 50262 (KEP) |
| 83 | | | Scaphochlamys polyphylla (K.Schum.) B.L.Burtt & R.M.Sm. | LC148076 | LC148397 | FRI 50289 (KEP) |
| 84 | Zingiberoidae | Haask. | Scaphochlamys pusilla Y.Y.Sam | LC148077 | – | FRI 50260 (KEP) |
| 85 | Zingiberaceae | Meisn. | Scaphochlamys rubromaculata Holttum | – | LC148399 | FRI 50178 (KEP) |
| 86 | | | Scaphochlamys rubromaculata Holttum | LC148079 | LC148378 | FRI 50172 (KEP) |
| 87 | | | Scaphochlamys samunsaensis Meekiong & Hidir | – | LC148401 | MK 2344 (HUMS) |
| 88 | | | Scaphochlamys sp.nov. | – | LC148402 | FRI 68983 (KEP) |
| 89 | | | Scaphochlamys sub-biloba (Burkill ex Ridl.) Holttum | – | LC148375 | FRI 75334 (KEP) |
| 90 | | | Scaphochlamys sylvestris (Ridl.),Holttum | LC148087 | – | FRI 50197 (KEP) |
| 91 | | | Scaphochlamys tenuis Holttum | LC148088 | – | FRI 47233 (KEP) |
| 92 | | | Schaphochlamys cf. gracilipes (K.Schum.) S.Sakai & Nagam. | – | LC148386 | K.Meekiong (HUMS) |
| 93 | | | Smithatris supraneanae W.J.Kress & K.Larsen | AF478795 | AF478896 | Kress et al. 2002 |
| 94 | | | Stahlianthus involucratus (King ex Baker) R.M.Sm. | AF478796 | AF478897 | Kress et al. 2002 |
| 95 | | | Zingiber gramineum Noronha | AF478800 | AF478902 | Kress et al. 2002 |
| 96 | | | Zingiber sulphureum Burkell ex I.Thelade | AF478801 | AF478904 | Kress et al. 2002 |
| 97 | | | Zingiber urayii Prain ex Ridl. | AF478802 | AF478905 | Kress et al. 2002 |
Results

Phylogenetic analyses

The ITS datasets for 82 individuals with 29 taxa of Scaphochlamys and 6 taxa of Borneocola contained 786 characters after alignment, which decreased to 769 after gaps were deleted; 319 of these were parsimony-informative. Likelihood analysis resulted in a ML tree with $-\ln L = 10438.212$. Parsimony analysis produced three parsimonious trees with 1865 steps, a consistency index (CI) of 0.391 and retention index (RI) of 0.609. The ML, MP and Bayesian trees had similar topology; the ML tree is shown with bootstrap (BS) and MP-BS, and Bayesian Posterior Probability (PP) support in Figure 1 below.

Scaphochlamys formed a well supported clade (ML-BS/MP-BS/BA-PP support, 84/87/1.00). Each Myxochlamys and Borneocola consisted of a well supported subclade and became sisters to each other and they also became sister to the Scaphochlamys clade. Distichochlamys species formed a well supported subclade and became sister to the Myxochlamys + Scaphochlamys + Borneocola clade (ML-BS/MP-BS/BA-PP 99/100/1.00).

The matK datasets for 78 individuals including 25 taxa of Scaphochlamys and 7 taxa of Borneocola contained 1,599 characters after alignment; 182 of these were parsimony-informative. Likelihood analysis resulted in a ML tree with $-\ln L = 5952.438$. Parsimony analysis produced ten parsimonious trees with 557 steps, a consistency index (CI) of 0.613 and retention index (RI) of 0.080. The ML, MP and Bayesian trees had similar topology; the ML tree is shown with BS and MP-BS, PP support in Figure 2 below.

Each of the two Myxochlamys species and seven Borneocola species formed a strongly supported subclade and became sisters to each other. Scaphochlamys became sister to them, but bootstrap or probability support was weak. The Distichochlamys species formed a well supported subclade, but all the genera that belong to subfamily Zingiberoideae became sisters to Scaphochlamys + Myxochlamys + Borneocola clade and not only to Distichochlamys.

The combined ITS and matK datasets for 61 individuals including 13 taxa of Scaphochlamys and 6 taxa of Borneocola, resulted in 2,336 characters, 488 of these were parsimony-informative (Figure 3 below). Likelihood analysis resulted in a ML tree with $-\ln L = 16671.531$. Parsimony analysis produced the most parsimonious trees with 2247 steps, a CI of 0.440 and a RI of 0.635. The ML, MP strict consensus and Bayesian trees had almost the same topology; the ML tree is shown with MP-BS, ML-BS and BA/PP support in Figure 3.

Two Myxochlamys species and six Borneocola species formed a strongly supported subclade each and became sisters to each other. Scaphochlamys became sister to them and the bootstrap or posterior probability support was moderate. Distichochlamys species formed a well supported subclade and became sister to Scaphochlamys + Myxochlamys + Borneocola clade.
Morphology

The Borneocola and Scaphochlamys species look similar in their vegetative morphologies. They are mostly small-sized gingers without the conspicuous pseudostem, with one to several leaves arranged spirally and tightly on a very short stem at the base. So far, all the Borneocola species examined are unifoliolate. Similarly, most of the Scaphochlamys species also bear one leaf except for several species which have leafy shoots composed of multiple leaves, for example, S. grandis, S. lanceolata, S. kunstleri, S. malaccana and S. minutiflora. The basal part of the leaves is covered with a few bladeless sheaths which are rather different for both groups in terms of their texture and colour. For Scaphochlamys, the sheaths are coriaceous, green, green with a red tinge or red and mostly persistent until the end of flowering (Figure 4A, B). On the other hand, the sheaths of Borneocola are thinner in texture with a lighter shade of green or brown. The thin sheaths normally dry up early (Figure 4C) and sometimes they are completely shredded during the time of flowering.

The inflorescences of Borneocola and Scaphochlamys are terminal, stalked and consisted of few to many floral bracts. The differences lie in the characteristics of the floral bracts and flowers. Borneocola species have thin, translucent, early decaying and marcescent floral bracts. The colours of the bracts can be pink, pale brown, pale or light green (Figure 5A). On the contrary, the bracts of Scaphochlamys are coriaceous and sometimes hard in texture. They are usually green, green tinged red, red or reddish brown and remain fresh throughout the flowering (Figure 5B, C).

Besides the characteristics of the floral bracts, the variegation on the labellum can give a quick guide to the two genera. Most Scaphochlamys have white flowers with a yellow median band and lilac, purple, red streaks or patches flanking the band on the labellum (Figure 5D, E). However, there is no such variegation on the labellum of Borneocola (Figure 5F). The whole labellum of Borneocola is pale pink, lilac, violet or white with a light yellow or greenish yellow median band.

Both Borneocola and Scaphochlamys have a long slender floral tube which is mostly puberulent externally in Borneocola (except for B. calcicola) but glabrous for Scaphochlamys. Another marked difference observed is in the stigma shape. Scaphochlamys has a funnel-shaped or beak-like stigma (Figure 6A, B) while it is almost oblate with two dorsal knobs in Borneocola (Figure 6C).

**Taxonomic treatment**

*Borneocola* Y.Y.Sam, gen. nov.

urn:lsid:ipni.org:names:77158811-1

**Diagnosis.** Similar to Scaphochlamys and Myxochlamys. Borneocola has thin, translucent and marcescent floral bracts, absence of coloured streaks on labellum and two dorsal knobs on the stigma versus the coriaceous and persistent floral bracts, coloured streaks
Figure 1. Molecular phylogenetic analysis of the ITS sequence data by the Maximum Likelihood method. Numbers above branches indicate bootstrap values of ML and MP and posterior probability of Bayesian Analysis.
Figure 2. Molecular phylogenetic analysis of the matK sequence data by the Maximum Likelihood method. Numbers above branches indicate bootstrap values of ML and MP and posterior probability of Bayesian Analysis.
Figure 3. Molecular phylogenetic analysis of the ITS+matK sequence data by the Maximum Likelihood method. Numbers above branches indicate bootstrap values of ML and MP and posterior probability of Bayesian Analysis.
Borneocola (Zingiberaceae), a new genus from Borneo

Type species. **Borneocola reticosus** (Ridl.) Y.Y.Sam, comb. nov. *Gastrochilus reticosa* Ridl., J. Straits Branch Roy. Asiat. Soc. 44: 195 (1905).

Description. Terrestrial rhizomatous herb, evergreen, rarely exceeding 50 cm in height. Rhizome creeping on the ground, terminal decumbent, rhizome elements short or long; roots fine, extensive, not tuberous. Leafy stem unifoliate, enclosed by a few bladeless sheaths at base, bladeless sheaths linear, papery, glabrous to hairy, light green or light brown, decaying early, leaf sheath glabrous or hairy, base swollen, margin thin and narrow; ligule membranous, inconspicuous, decaying early; petiole channelled in cross section, glabrous, lamina narrowly ovate to elliptic, rarely oblong, asymmetric, margin entire, smooth.

Inflorescence flowering from base to apex; peduncle short, usually hidden within leaf sheath; spike composed of compact rachis and 2–5 (–13) fertile bracts, bracts spirally and closely overlapping (rarely distichous), boat-shaped, 2-keeled, pink, pale brown, pale or light green, thin, translucent, glabrous or hairy, decaying early, marcescent, amplexicaul at the base of the bract, cincinni compact, 2–3 flowers in each cincinnus. First bracteole directly opposite floral bract and enclosing all the flowers and subsequent bracteoles, linear-shaped, 2-keeled, shorter than bracts, rarely same length. Flowers thin, delicate, ephemeral. Calyx tubular, splitting unilaterally on one side, floral tube long slender, usually puberulent externally, inner surface with a groove enveloping the style, corolla lobes 3, triangular ovate, translucent, glabrous, dorsal lobe apex hooded, lateral lobes 2, narrower than dorsal lobe. Staminodes elliptic to

on labellum and absence of dorsal knobs on the stigma in *Scaphochlamys*. The mucilage on the floral bracts and the versatile anther of *Myxochlamys* are absent in *Borneocola*.

**Figure 4.** Bladeless sheaths A Green and coriaceous in *Scaphochlamys klossii* (Peninsular Malaysia) B Red and coriaceous in *Scaphochlamys abdullahii* (Peninsular Malaysia) C Papery and marcescent in *Borneocola calcicola* (Sarawak). (Photographs by Y.Y. Sam).
Figure 5. A–C Floral bracts A Green and coriaceous in *Scaphochlamys klossii* B Red and coriaceous in *Scaphochlamys pusilla* C Scarious and marcescent in *Borneocola petiolatus* D–F Variegation on labellum D White labellum with purple lines beside the median band in *Scaphochlamys malaccana* E White labellum with red streaks beside the band in *Scaphochlamys concinna* F Lilac labellum without coloured streaks beside the band in *Borneocola petiolatus*. (Photographs by Y.Y. Sam)

Figure 6. Stigma A Funnel-shaped in *Scaphochlamys endauensis* B Beak-like in *Scaphochlamys biloba* C Capitate in *Borneocola petiolatus*. (Photographs by A & C N.M. Aidil, B Y.Y. Sam)

narrowly obovate, white, light yellow or green, spreading laterally, lined with translucent veins from base to apex, covered with glandular hairs on adaxial surface. Label-lum obovate, flat, bilobed distally, rarely entire, translucent veins spread from base to
apical part, pale white, pink, lilac or violet, median band light yellow or greenish yellow, without coloured streaks or patches beside the band, adaxial surface covered with glandular hairs. Stamen bends forward over labellum, usually white and covered with glandular hairs on abaxial surface, filament grooved, short, anther thecae 2, linear, dehiscing along entire length, basal ending with or without short spur, anther crest short, not recurved. Ovary ellipsoid, glabrous or sparsely hairy, unilocular, with basal placentation, less than 10 locules. Stigma small, held at apex of thecae, near oblate, 2 dorsal knobs, ostiole forward facing, ciliate. Epigynous glands 2, filiform, yellow. Fruit a capsule, ellipsoid or ovoid. Seeds not seen.

**Etymology.** This new genus is named after the island of Borneo and *-cola* (Latin) means dweller or inhabitant. This is to recognise the extremely rich and unique biodiversity that is found in Borneo.

**Distribution.** Borneo. The genus is currently known to occur only in the north-west and possibly central Borneo. Eight species are recorded from Sarawak, Malaysia and many more are undescribed.

**Key to Borneocola species** *(modified from Ooi and Wong 2014)*

1. Adaxial lamina with distinctly raised tessellate venation .............................................. *

2. Adaxial lamina without distinctly raised tessellate venation ........................................

3. Lamina broadly oblanceolate and elliptic to oblong, lateral veins conspicuously raised on adaxial surface.......................................................... *

4. Lamina linear, lanceolate to broadly ovate and elliptic, lateral veins not conspicuously raised on adaxial surface..........................................................

5. Lamina linear to very narrowly lanceolate, < 3 cm wide .............................................. *

6. Lamina lanceolate, ovate to elliptic, > 3 cm wide ..........................................................

7. Leaf sheath plus petiole < 10 cm long; lamina apex broadly acute to rounded, base cuneate..................................................................................

8. Leaf sheath plus petiole > 10 cm long; lamina apex acute to acuminate, base attenuate, cordate, rounded or truncated ..............................................

9. Lamina lanceolate to ovate, < 7 cm wide........................................................................

10. Lamina elliptic to broadly elliptic and ovate, > 7 cm wide............................................

11. Basal lamina rounded to truncated; inflorescence stalk 3–9 cm long; labellum pale lilac.......................................................... *

12. Basal lamina attenuate; inflorescence stalk 1–2 cm long; labellum purplish blue .......................................................... *

13. Inflorescence about 3 cm long; labellum pale pink..........................................................

14. Inflorescence > 7 cm long; labellum white ..............................................................
1. *Borneocola argenteus* (R.M.Sm.) Y.Y.Sam, comb. nov. 
urn:lsid:ipni.org:names:77158824-1

*Scaphochlamys argentea* R.M.Sm., Notes Roy. Bot. Gard. Edinburgh 44: 209 (1987). 
*Scaphochlamys depressa* Mas Izzaty, A.Ampeng & K.Meekiong, Folia Malaysiana 14(2): 19 (2013).

**Type.** MALAYSIA. Sarawak, First Division, Lundu, near foot of Gunung Perigi, 6 Aug 1962, Burtt B2700 (holotype: E!).

**Notes.** It is one of the most distinctive species, either in the field or herbarium sheet. This dainty plant has a long creeping rhizome and well spaced leafy shoots, prominently stiff lateral veins raised on its adaxial lamina, both on living plants and dried specimens. 

*Scaphochlamys depressa* Mas Izzaty, Ampeng & Meekiong is unmistakably the same as *S. argentea* with its prominent raised lateral veins, broadly elliptic lamina and well spaced leafy shoots. Meekiong (2015) explained that the inflorescence of *S. depressa* which exerted from the petiole is different from *S. argentea* where the inflorescence emerges from the base of the petiole. This observation is incorrect as all gingers have terminal inflorescences.

2. *Borneocola biru* (Meekiong) Y.Y.Sam, comb. nov. 
urn:lsid:ipni.org:names:77158812-1

*Scaphochlamys biru* Meekiong, Folia Malaysiana 16(1): 37 (2015).

**Type.** MALAYSIA. Sarawak, Kuching Division, Matang Wildlife Centre, 21 May 2014 Meekiong et al. s.n. (holotype: SAR; isotype: Herbarium, Universiti Malaysia Sarawak. Types not yet deposited as of 5 May 2016).

**Notes.** *Borneocola biru* is the most recent species described from Sarawak. It has a deep purplish blue labellum, different from all other *Borneocola* species which are white or in lighter shades.

3. *Borneocola calcicola* (A.D.Poulsen & R.J.Searle) Y.Y.Sam, comb. nov. 
urn:lsid:ipni.org:names:77158813-1

*Scaphochlamys calcicola* A.D.Poulsen & R.J.Searle, Gard. Bull. Singapore 57: 29 (2005).

**Type.** MALAYSIA. Sarawak, Kuching Division, Bau area, Gunung Tai Tion, 1°24’N, 110°8’E, 20 June 2003, Poulsen, Jugah & Clausager 2022 (holotype: SAR; isotypes: AAU, E!, K!, L).

**Notes.** *Borneocola calcicola* is the largest amongst the *Borneocola* species. Poulsen and Searle (2005) observed that the distichous inflorescence is one of the character-
istics of the plant. However, a recent collection of *B. calcicola*, Sam FRI 50290, from Seromah, Bau, showed spirally arranged floral bracts. There was a mixture of spirally and distichously arranged floral bracts in its population in Bau, Sarawak.

4. **Borneocola iporii** (Meekiong & A.Ampeng) Y.Y.Sam, comb. nov. urn:lsid:ipni.org:names:77158814-1

*Scaphochlamys iporii* Meekiong & A.Ampeng, Folia Malaysiana 12(1): 19 (2011).

**Type.** MALAYSIA. Sarawak, Kapit, Lanjak Entimau Wildlife Sanctuary, Bukit Menyarin, 3 April 2008, Meekiong MK1839 (holotype: SAR; isotype Herbarium, Universiti Malaysia Sarawak. Types not yet deposited as of 5 May 2016).

**Notes.** *Borneocola iporii* is a small ginger creeping on the humus rich forest floor. It is most similar to *B. argenteus* with both having a unifoliate shoot, leafy shoots far apart, broad lamina, short inflorescence and compact rachis. However, the conspicuously raised lateral veins of *B. argenteus* can readily distinguish it from *B. iporii*.

5. **Borneocola petiolatus** (K.Schum.) Y.Y.Sam, comb. nov. urn:lsid:ipni.org:names:77158815-1

*Haplochorema petiolatum* K.Schum. in Engler, Pflanzenr. IV, 46 (Heft 20): 90 (1904).

*Scaphochlamys petiolata* (K.Schum.) R.M.Sm., Notes Roy. Bot. Gard. Edinburgh 44: 210 (1987).

**Type.** MALAYSIA. Sarawak, First Division, Mt. Singhi (= Gunung Singai), Dec 1892, Haviland 2026 (lectotype: K! designated by Searle 2010; islectotype: E!, SAR!).

**Notes.** *Borneocola petiolatus* is distinguished by its long petiole and narrow leaves from the other species. Its lamina length is almost 3 times the width (12–21.5 × 3.1–7.1 cm). Smith (1987) found that *B. petiolatus* has small inflorescences as in *B. argenteus*. However, both can be easily separated by their leaf characters. *Borneocola petiolatus* has much longer petioles compared to *B. argentea* (12.7–31.5 cm versus 3–6 cm). *Borneocola argenteus* also has prominently raised lateral veins on the adaxial surface of lamina, more conspicuous on dried specimens than fresh materials. This character is lacking in *B. petiolatus*.

6. **Borneocola reticosus** (Ridl.) Y.Y.Sam, comb. nov. urn:lsid:ipni.org:names:77158816-1

*Gastrochilus reticosa* Ridl., J. Straits Branch Roy. Asiat. Soc. 44: 195 (1905). *Boesenbergia reticosa* (Ridl.) Merr., Bibl. Enum. Born. Pl. 122 (1921). *Scaphochlamys reticosa* (Ridl.) R.M.Sm., Notes Roy. Bot. Gard. Edinburgh 44: 209 (1987).
Type. Cultivated in Singapore Botanic Gardens, originally from Borneo, Sarawak, First Division, Bidi, 22 Nov 1904, Ridley s.n. (holotype: SING!).

Notes. Borneocola reticosus is chosen as the type species as it is the easiest to recognise in the genus. Its reticulate lamina readily distinguishes it from other Borneocola species.

7. Borneocola salahuddinianus (Meekiong, A.Ampeng & Ipor) Y.Y.Sam, comb. nov. urn:lsid:ipni.org:names:77158817-1

Scaphochlamys salahuddiniana Meekiong, A.Ampeng & Ipor, Folia Malaysiana 12(1): 22 (2011).

Type. MALAYSIA. Sarawak, Kapit, Ulu Katibas, Lanjak Entimau Wildlife Sanctuary, Bukit Sepali, 30 April 2008, Meekiong MK1856 (holotype SAR; isotype Herbarium, Universiti Malaysia Sarawak.. Types not yet deposited as of 5 May 2016).

Note. Borneocola salahuddinianus is unique amongst the Bornean species with its broadly elliptic or ovate lamina held by a long slender petiole. It is doubtful that B. salahuddinianus is a lithophyte as observed by Meekiong et al. (2011). The plants are more of an opportunist growing on humus-rich substrate accumulated on the rocks.

8. Borneocola stenophyllus (I.H.Ooi & S.Y.Wong) Y.Y.Sam., comb. nov. urn:lsid:ipni.org:names:77158818-1

Scaphochlamys stenophylla I.H.Ooi & S.Y.Wong, Willdenowia 44(2): 241-245 (2014).

Type. MALAYSIA. Sarawak, Kuching Division, Bau, Gunung Buan, 1°33’28.9"N, 10°08’35.2”E, 92 m, 21 Nov 2013, Ooi Im Hin & Jepom ak Tisai OIH74 (holotype: SAR. Type not yet deposited as of 5 May 2016).

Note. Borneocola stenophyllus is another new species recently discovered from Sarawak. Its grass-like leaves instantly separate it from other species in the genus.

Incompletely known species

Scaphochlamys anomala (Hallier f.) R.J.Searle, Edinburgh J. Bot. 67: 85 (2010).
Kaempferia anomala Hallier f., Bull. Herb. Boissier 6: 357 (1898). Gastrochilus anomalum (Hallier f.) K.Schum. in Engler, Pflanzenr. IV, 46 (Heft 20): 92 (1904). Boesenbergia anomalala (Hallier f.) Schltr., Repert. Spec. Nov. Regni Veg. 12: 315 (1913). Gastrochilus hallieri (Hallier f.) Ridhl., J. Straits Branch Roy. Asiatic Soc. 32: 109 (1899), nom. illegit.
**Type.** INDONESIA. Cultivated in Bogor, originally from Liang Gagang, Kalimantan Borneo, Hallier s.n. (original material: BO, specimen lost; lectotype (designated by Searle, 2010) Figure drawn from original Hallier’s material and published as t. IX, fig. 3, Bull. Herb. Boissier 6: 357 (1898).

**Notes.** The type, the only specimen ever collected, was lost. However, Hallier (1898) gave a very detailed description and drawing of the plant and this has convinced Searle (2010) to place it in the genus *Scaphochlamys*. The drawing, which is based on the type specimen and designated by Searle as the lectotype, is the only material that gives a glimpse of the appearance of the species. In the drawing, the flower and spirally arranged floral bracts are typical of both *Scaphochlamys* and *Borneocola*. Until another specimen is collected and is available for close examination, we prefer to retain this imperfectly known species in *Scaphochlamys*.

**Discussion**

The phylogenetic analyses confirm the distinctive character of *Borneocola* and *Scaphochlamys* and their placement in the tribe Zingibereae (Figures 1, 2, 3). The *Borneocola* species form a monophyletic group which is sister to *Myxochlamys*. It is surprising to find *Borneocola* having a closer affinity to *Myxochlamys* than to *Scaphochlamys*, considering it shares more morphological similarities with *Scaphochlamys* than with *Myxochlamys*.

Morphologically, *Myxochlamys* is very different from *Borneocola*. There are two *Myxochlamys* species named so far: *M. amphiliaxa* and *M. mullerensis* (Takano and Nagamasu 2007; Searle and Newman 2010) and a third undescribed species, also from Borneo. All three *Myxochlamys* species are very robust plants that can attain a height of 70 cm. Most *Borneocola* species examined so far are small-sized (not more than 50 cm tall), except for *B. calcicola* which can grow to 60 cm tall. *Myxochlamys* has 3–10 large leaves (50–60 cm long) in each shoot whereas *Borneocola* are unifoliate and the leaves are small (less than 20 cm long except for *B. calcicola*). The leaves of *Myxochlamys* are sessile compared to the conspicuously stalked leaves in *Borneocola*. The most marked difference is in the inflorescence structure. *Borneocola* has small inflorescences consisting of less than 15 fertile bracts but *Myxochlamys* has large torch-like inflorescences with easily more than 40 bracts. The bracts of *Borneocola* are membranous and marcescent, often measuring less than 2 cm long (except for *B. calcicola* measuring 2.5–3.2 cm long). By contrast, the floral bracts of *Myxochlamys* are coriaceous, persistent, measuring 2.5–5 cm long and most notably are covered with transparent slimy mucilage. In addition, the unique versatile anthers of *Myxochlamys*, a rare feature in the Zingiberaceae, are distinct from the adnate anthers in *Borneocola* and also from all its sister genera. Based on morphological features, *Myxochlamys* is more similar to *Scaphochlamys*, the closest being *S. grandis*. Both have large sessile leaves and decurrent lamina base, large, coriaceous
and persistent floral bracts, their bracts being concave with reflexed and spreading apices.

Based on morphology, *Borneocola* is also similar to *Distichochlamys*. However, *Distichochlamys* is distinguished from *Borneocola*, *Myxochlamys* and *Scaphochlamys* by its unique tubular bracteoles, floral tube without a groove on the inner surface and trilocular ovary (Newman 1995). Other characteristics such as distichous floral bracts, 2-keeled bracteoles, thecae without basal spurs have been observed in the three closely allied sister genera in this study (Table 2).

*Haplochorema* K.Schum. is another small-sized genus endemic to Borneo, which can be mistaken for *Borneocola*. It has short and few-flowered inflorescences as in *Borneocola* but its flowers appear somewhat quadrate with the labellum and lateral staminodes held flat, more resembling *Kaempferia* L. *Haplochorema* has distichous floral bracts, single-flowered cincinni and the flowering proceeds from apex to base, to name some of the characters which distinguish it from *Borneocola*. In fact, the genus is more allied to *Boesenbergia* Kuntze than *Borneocola*.

*Borneocola* is morphologically most similar to *Scaphochlamys* but both can be distinguished by the texture of the bladeless sheath and floral bracts, variegation on the labellum, indumentum on the floral tube and the stigma shape. The current study recognises eight *Borneocola* species while *S. gracilipes*, *S. polyphylla* B.L.Burtt & R.Sm., *S. limiana* Meekiong & K.Yazid and *S. samunsamensis* Meekiong & Hidir from Borneo remain in the genus *Scaphochlamys*. There are no recent collections of *S. gracilipes* but the lax inflorescence and persistent floral bracts in the type specimens clearly distinguish it from the *Borneocola* species. *Scaphochlamys polyphylla*, *S. limiana* and *S. samunsamensis* can be readily distinguished from the *Borneocola* species by their papery bladeless sheath and large, green or green tinged red, coriaceous floral bracts. This shows that the distinct morphologies that separate *Borneocola* and *Scaphochlamys* are significant and are also supported by the phylogenetic analyses (Figures 1, 2 and 3). An anatomical study on the leaves also discovered some characteristics that separate *Borneocola* from *Scaphochlamys* (Norhati, pers. comm).

The morphology of *Borneocola* is very similar to *Scaphochlamys* but, combining both, necessitates synonymising *Myxochlamys* and possibly *Distichochlamys* and this will result in a very heterogenous genus. A similar situation is observed in the naming of *Newmania* N.S. Lý & Škorničk, a genus very similar in morphology to *Haniffia* Holttum but appears as its sister group in the molecular phylogenetic analyses. The authors decided against placing *Newmania* under *Haniffia* which would create a heterogenous group. The current description of *Borneocola* is further supported by the chromosome number with 2n=10 (Šída et al., unpublished data), different from *Distichochlamys* (2n=26) and *Scaphochlamys* (2n=28). Such significant differences in molecular data and chromosome number have conclusively supported the circumscription of the new genus *Borneocola*. 
Table 2. Comparison between the morphological characters of *Borneocola*, *Distichochlamys*, *Myxochlamys* and *Scaphochlamys*.

| Morphology                        | *Borneocola* | *Distichochlamys* | *Myxochlamys* | *Scaphochlamys*                      |
|-----------------------------------|--------------|-------------------|---------------|--------------------------------------|
| Plant height (cm)                 | to 50(–60)   | to 60 cm          | 70 cm         | to 100 cm                            |
| Number of leaf in each leafy shoot | 1            | 1–3               | 3–10          | 1–7                                  |
| Bladeless sheath                  | Papery, drying fast | Papery, decaying fast | Not mentioned | Coriaceous, persistent                |
| Leaf (cm)                         | 6–37 × 1–18; petiolate | 15–28 × 8.3–14.5; petiolate | 50–65 × 7–17; sessile | 9–50 × 3–24; petiolate or sessile    |
| Inflorescence height (cm)         | 3–11.5       | to 15.5           | 6.5–18        | 4–28                                 |
| Number of floral bracts           | 3–13         | 7–13              | c. 40         | 4–44                                 |
| Arrangement of floral bracts      | Spiral, rarely distichous | Distichous         | Spiral        | Spiral, rarely distichous            |
| Floral bracts                     | Thin, translucent, without mucilage; drying fast | Without mucilage; persistent | Coriaceous, with mucilage; persistent | Coriaceous, without mucilage; persistent |
| Flowers                           | In cincinni  | In cincinni       | Solitary      | In cincinni                          |
| First bracteole                   | Open to base, 2-keeled | Tubular, 2-keeled | Open to base, 2-keeled | Open to base, 2-keeled |
| Floral tube                       | With a groove in inner surface, glabrous to puberulent externally | Without a groove in inner surface, glabrous externally | With a groove in inner surface, glabrous externally | With a groove in inner surface, glabrous externally |
| Labellum                          | Bilobed, rarely entire, not concave; without coloured streaks beside median band | Bilobed, not concave; without coloured streaks beside median band | Not bilobed, entire, concave; without coloured streaks beside median band | Bilobed, rarely entire, not concave; with coloured streaks beside median band |
| Thecae                           | Spurs absent or with short free basal spurs | Spurs absent | Spurs present and long | Spurs absent or with short free basal spurs |
| Anther                           | Adnate       | Adnate            | Versatile     | Adnate                               |
| Ovary                            | Unilocular with basal placentation | Trilocular with axile placentation | Unilocular with basal placentation | Unilocular with basal placentation |
| Chromosome number                 | 2n=10 (Šída et al., unpublished data) | 2n=26 | — | 2n=28 |
| Geographical distribution         | Borneo       | Vietnam           | Borneo        | Southern Thailand, Peninsular Malaysia, Sumatra, Borneo |
Key to the genera of the Zingibereae tribe in Borneo

1 Inflorescence arising directly from the rhizome on a leafless shoot .................. 2
– Inflorescence emerging at the terminal of the leafy shoot ............................... 3

2 Distinct swelling at the base of the petiole; anther with long extended crest wrapped around the style .................................................. *Zingiber*
– No swelling at the base of the petiole; anther crest short, not long extended and not wrapped around the style ........................................... *Haniffia*

3 Flowers with versatile anther ........................................................................... 4
– Flowers with adnate anther ............................................................................. 5

4 Inflorescence with few to many floral bracts, bracts mucilage .... *Myxochlamys*
– Inflorescence with one single large floral bract, bracts not mucilage ................

5 Flowers opening from top to bottom of inflorescence ........................................ 6
– Flowers opening from bottom to top of inflorescence ........................................ 7

6 Flowers appearing quadrate with the two petaloid staminodes .... *Haplochorema*
– Flowers no quadrate appearance, staminodes not petaloid .......................... *Boesenbergia*

7 Flowers with long narrow corolla lobes and long exserted stamens ..............
– Flowers without such features ........................................................................ 8

8 Floral bracts coriaceous and persistent, labellum with coloured streaks on both sides of the median band ........................................... *Scaphochlamys*
– Floral bracts thin, translucent and marcescent, labellum without coloured streaks on both sides of the median band ................................. *Borneocola*

Acknowledgements

The authors wish to thank the Forestry Department of Peninsular Malaysia and its State Forestry Departments, Sarawak Forestry Department, Department of Wildlife and National Parks and Johor Parks Corporation for permission to conduct research in their forests; herbaria of AAU, BKF, C, FI, E, K, KEP, KLU, PSU, SAN, SAR and SING for the loan of specimens; Lucy Chong and Julia Sang from the Sarawak Forestry Corporation, Wong Sin Yeng and Peter C. Boyce from Universiti Malaysia Sarawak, Sarawak for their hospitality and logistics help in Sarawak. We are also grateful to Kalu Meekiong from the Universiti Malaysia Sarawak, Sarawak and John Mood for the leaf samples for the molecular study; J.F. Veldkamp for advice on the genus and epithet names; Jana Leong-Škorničková, Richard C.K. Chung, Leng Guan Saw, Ruth Kiew and the reviewers for their critical comments and suggestions to improve the manuscript. This work is supported by the Malaysian Ministry of Higher Education through the Fundamental Research Grant Scheme (FRGS FP 075/2007C) and Special Research University Grant (FR 150/2007A), University of Malaya, the Ministry of Science, Technology and Innovation (Project No. 01-04-01-0000 Khas2), the Ministry of Natural Resources and
Environment under the 10th and 11th Malaysian Plans (SPPII No. P23085100010021 & P23085100018003 respectively) and Grants-in-Aid (KAKENHI) for Scientific Research (No.26440227) from the Japan Society for the Promotion of Science.

References

Baker JG (1892) Scitamineae. In: Hooker JD (Ed.) Flora of British India 6. Reeve & Co., London, 225–264.

Felsenstein J (1985) Confidence limits on phylogenies: an approach using the bootstrap. Evolution 39: 783–791. doi: 10.2307/2408678

Hall TA (1999) BioEdit: a user-friendly biological sequence alignment editor and analysis program for windows 95/98/NT. Nucleic Acids Symposium Series 41: 95–98.

Hallier H (1898) Neue und Bemerkenswerte Pflanzen. Bulletin de l’Herbier Boissier, 6, 348.

Harris DJ, Poulsen AD, Frimodt-Møller C, Preston J, Cronk QCB (2000) Rapid radiation in *Aframomum* (Zingiberaceae): evidence from nuclear ribosomal DNA internal transcribed spacer (ITS) sequences. Edinburgh Journal of Botany 57(3): 377–395. doi: 10.1017/S0960428600000378

Holttum RE (1950) The Zingiberaceae of the Malay Peninsula. Gardens’ Bulletin Singapore 13: 1–249.

Huelsenbeck JP, Ronquist F (2001) MRBAYES: Bayesian inference of phylogeny. Bioinformatics 17: 754–755. doi: 10.1093/bioinformatics/17.8.754

Kress WJ, Larsen K (2001) *Smithatris*, a new genus of Zingiberaceae from Southeast Asia. Systematic Botany 26(2): 226–30. doi: 10.1043/0363-6445-26.2.226

Kress WJ, Mood J, Sabu M, Prince L, Dey S, Sanoj E (2010) *Larsenianthus*, a new Asian genus of Gingers (Zingiberaceae) with four species. PhytoKeys 11: 15–32. doi: 10.3897/phytokeys.1.658

Kress WJ, Prince LM, Williams KJ (2002) The phylogeny and a new classification of the gingers (Zingiberaceae): evidence from molecular data. American Journal of Botany 89(10): 1682–1696. doi: 10.3732/ajb.89.10.1682

Larsen K, Newman M (2001) A new species of *Distichochlamys* from Vietnam and some observations on generic limit in Hedychieae (Zingiberaceae). Natural History Bulletin of Siam Society 49: 77–80. doi: 10.1007/BF00984630

Leong-Škorničková J, Lý NS, Poulsen AD, Tosh J, Forrest A (2011) *Newmania*: A new ginger genus from central Vietnam. Taxon 65(5): 1386–1396.

Liston A, Kadereit JW (1995) Chloroplast DNA evidence for introgression and long distance dispersal in the desert annual *Senecio flavus* (Asteraceae). Plant Systematics and Evolution 197(1–4): 33–41.

Meekiong (2015) Three new *Scaphochlamys* species from Sarawak, Malaysia. Folia Malayaiana 16(1): 31–44.

Meekiong K, Ipor I, Tawan CS, Ibrahim H, Norhati MR, Lim CK, Ampeng A (2011) Five new ginger species (Zingiberaceae) from the eastern part of Lanjak Entimau Wildlife Sanctuary, Sarawak, Borneo. Folia Malayaiana 12(1): 9–26.
Moller M, Cronk Q (1997) Origin and relationships of Saintpaulia (Gesneriaceae) based on ribosomal DNA internal transcribed spacer (ITS) sequences. American Journal of Botany 84(7): 956–965. doi: 10.2307/2446286

Newman MF (1995) Distichochlamys, a new genus from Vietnam. Edinburgh Journal of Botany 52: 65–69. doi: 10.1017/S096042860000192X

Ngamriabsakul C, Newman MF, Cronk QCB (2004) The phylogeny of tribe Zingibereae (Zingiberaceae) based on ITS (nrDNA) and trnL-F (cpDNA) sequences. Edinburgh Journal of Botany 60(3): 483–507.

Nylander JAA (2004) MrModeltest v2. Program distributed by the author, Evolutionary Biology Center, Uppsala University.

Ooi IH, Wong SY (2014) Scaphochlamys stenophylla (Zingiberaceae): a new species from Sarawak, Malaysian Borneo. Willdenowia 44(2): 241–245. doi: 10.3372/wi.44.44205

Ooi K, Endo Y, Yokoyama J, Murakami N (1995) Useful primer designs to amplify DNA fragments of the plastid gene matK from angiosperm plants. Journal of Japanese Botany 70(6): 328–331.

Pedersen LB (2004) Phylogenetic analysis of the subfamily Alpinioideae (Zingiberaceae), particularly Etinglera Giseke, based on nuclear and plastid DNA. Plant Systematics and Evolution 245: 239–258. doi: 10.1007/s00606-004-0126-2

Poulsen AD, Searle RJ (2005) Scaphochlamys calcicola (Zingiberaceae): a new and unusual species from Borneo. The Gardens’ Bulletin Singapore 57: 29–35.

Rohnequist F, Huelsenbeck JP (2003) MRBAYES 3: Bayesian phylogenetic inference under mixed models. Bioinformatics 19: 1572–1574. doi: 10.1093/bioinformatics/btg180

Sakai S, Nagamasu H (2006) Systematic studies of Bornean Zingiberaceae V. Zingiberoideae of Lambir Hills, Sarawak. Blumea 52: 95–115. doi: 10.3767/000651906X622364

Searle RJ (2010) The genus Scaphochlamys (Zingiberaceae - Zingibereae): A field compendium for the field worker. Edinburgh Journal of Botany 67(1): 75–121. doi: 10.1017/S0960428609990254

Searle RJ, Hedderson TAJ (2000) A preliminary phylogeny of the Hedychieae tribe (Zingiberaceae) based on ITS sequences of the nuclear rRNA cistron. In: Wilson KL, Morrison DA (Eds) Monocots: Systematics and Evolution. CSIRO, Collingwood, 710–718.

Searle RJ, Newman M (2010) Myxochlamys amphiloaxa (Zingiberaceae): A new species from Central Kalimantan, Indonesia. Edinburgh Journal of Botany 67(2): 347–352. doi: 10.1017/S0960428609990053

Smith RM (1987) A review of Bornean Zingiberaceae: III (Hedychieae). Notes of the Royal Botanic Gardens Edinburgh 44: 203–232.

Steele KP, Vilgalys R (1994) Phylogenetic analysis of Polemoniaceae using nucleotide sequences of the plastid gene matK. Systematic Botany 19: 126–142. doi: 10.2307/2419717

Takano A, Nagamasu H (2007) Myxochlamys (Zingiberaceae), a new genus from Borneo. Acta Phytotaxonomica et Geobotanica 58: 19–32.

Takano A, Okada H (2002) Multiple occurrences of triploid formation in Globba (Zingiberaceae) from molecular evidence. Plant Systematics and Evolution 230: 143–159. doi: 10.1007/s006060200001
Tamura K, Nei M (1993) Estimation of the number of nucleotide substitutions in the control region of mitochondrial DNA in humans and chimpanzees. Molecular Biology and Evolution 10: 512–526.

Tamura K, Stecher G, Peterson D, Filipski A, Kumar S (2013) MEGA6: Molecular Evolutionary Genetics Analysis version 6.0. Molecular Biology and Evolution 30: 2725–2729. doi: 10.1093/molbev/mst197

Thompson JD, Higgins DG, Gibson TJ (1994) CLUSTALW: improving the sensitivity of progressive multiple sequence alignment through sequence weighting, position-specific gap penalties and weight matrix choice. Nucleic Acids Research 22: 4673–4680. doi: 10.1093/nar/22.22.4673

Williams KJ, Kress WJ, Manos PS (2004) The phylogeny, evolution and classification of the genus Globba and tribe Globbeae (Zingiberaceae): Appendages do matter. American Journal of Botany 91: 100–114. doi: 10.3732/ajb.91.1.100

Wood TH, Whitten WM, Williams NH (2000) Phylogeny of Hedychium and related genera (Zingiberaceae) based on ITS sequence data. Edinburgh Journal of Botany 57(2): 261–270. doi: 10.1017/S0960428600000196

Xia YM, Kress WJ, Prince LM (2004) Phylogenetic analyses of Amomum (Alpinioideae: Zingiberaceae) using ITS and matK DNA sequence data. Systematic Botany 29(2): 334–344. doi: 10.1600/036364404774195520
