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Assessment of Zingiberaceae (Tribe Alpinieae) from North East Sarawak, Malaysia

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Abstract. Zingiberaceae is a pantropical herbaceous family from order Zingiberales. It consists of 60 genera and at least 1,500 species that are widely distributed in the tropics. Malesian region is known as the richest zone and Borneo covers 21 genera with more than 250 known taxa so far. This paper provides a preliminary assessment of Zingiberaceae particularly tribe Alpinieae from the north east of Sarawak. Taxon sampling were carried out at different localities from Bintulu to Miri divisions involving three national parks particularly Similajau, Niah and Lambir Hills National Parks. Thirty (30) species from eight (8) genera of tribe Alpinieae have been documented i.e. seven (7) species of *Amomum* Roxb., six (6) species each for *Alpinia* Roxb. and *Plagiostachys* Ridl., three (3) species each for *Elettaria* Maton and *Etlingera* Giseke, and two (2), two (2) and one (1) species each for *Elettariopsis* Baker, *Hornstedtia* Retz and *Geocharis* (K.Schum.) Ridl. Majority of the collected species are regarded as endemic to Borneo island while eight (8) species are distributed to other areas in the Malesian region. One species each of *Amomum* and *Elettariopsis* from Similajau National Park and Niah National Park, were described as possibly new to science. Findings on the new species and taxonomically uncertain species of *Plagiostachys* and *Geocharis* would probably increase the number of Alpinieae species from Sarawak. In addition, it is necessary for further field works in many more parts of Sarawak due to the large forests area and localised distribution of the ginger flora.

1. Introduction

Zingiberaceae is a ginger family that produce aromatic oils and has great potential values as food sources, spices, condiments, dyes, ornamental, medicine and pharmaceuticals. It is the largest family in Zingiberales order together with Costaceae, Cannaceae, Marantaceae, Musaceae, Strelitziaceae, Lowiaceae and Heliconiaceae; with at least 60 genera and 1,500 species. Lowland tropical rainforests of Malesian region is recorded being the richest area for Zingiberaceae. Tribe Alpinieae A. Rich. which is grouped under subfamily Alpinioideae Link is morphologically characterized by having fleshy or indehiscent fruit and lacking extrafloral nectarines [1]. The highest diversity and number of Zingiberaceae species in Borneo are come from tribe Alpinieae. There are currently 143 known taxa from nine genera of tribe Alpinieae occurred in Borneo i.e. *Etlingera* Giseke (42 spp.), *Amomum* Roxb. (36 spp.), *Alpinia* Roxb. (19 spp.), *Plagiostachys* Ridl. (15 spp.), *Hornstedtia* Retz. (15 spp.), *Elettaria* Maton (9 spp.), *Elettariopsis* Baker (3 spp.), *Geocharis* (K.Schum.) Ridl. (2 spp.), and *Geostachys* (Baker) Ridl. (2 spp.) [1, 2, 3].

Lowland forests up to 600 m altitude is the richest zone for Zingiberaceae and species richness drops at higher altitude. However, species such as *Alpinia*, *Amomum* and *Hornstedtia* are still able to



be found around the lower montane forest from 1400 – 2300 m [2, 4]. Composition of gingers at different forests types in Borneo showed that the highest number of ginger species occurred at stream banks or alluvial levees near streams (60 species) followed by limestone soils (more than 20 species), plateau areas (20 species), to the less preferred sandstone or sandy soils (average 12 species), and the least favoured heath forests and ultramafic soils (less than 5 species) [2, 4].

Systematics studies related to Bornean Alpinioideae was first started by Smith (1982 - 1986) which also reported on species at Gunung Mulu NP [5 – 8], Cowley (1999 – 2000) which studied on *Plagiostachys* and *Amomum* [9 – 10], Poulsen *et al.* (1999 - 2005) which specifically reported on *Etlingera* [11 – 12], Sakai & Nagamasu which intensively covered all Zingiberaceae species at Lambir Hills NP [13 – 15], Gobilik *et al.* which particularly studied on *Plagiostachys* from Sabah [16] and Julius *et al.* which reported on *Plagiostachys* in Sabah as well [17]. Twenty-two species of Alpinieae species were documented by Sakai & Nagamasu from Lambir Hills NP while documentation of ginger flora in Niah National Park and Similajau National Park are however still limited. Sarawak, a Malaysian state in Borneo has a land area of 124,451 km² and 8% of the total land are designated as totally protected area. Of the thirteen national parks, three of them which situated at the north east part were chosen for this study, particularly in Similajau National Park, Niah National Park and Lambir Hills National Park. The aim of this study was to preliminarily assess the ginger flora with the focus on tribe Alpinieae from different types of forests in the north east part of Sarawak.

2. Methodology

2.1 Localities of Study

A preliminary survey on gingers of north east of Sarawak was carried out at three totally protected areas particularly Similajau National Park in Bintulu division, and Niah National Park and Lambir Hills National Park in Miri division. Similajau National Park (3°21.128'N, 113°9.541'E) with total area of 8,996 ha is mainly made of coastal forests with patches of heath forests and mixed dipterocarp forests. Meanwhile, Niah National Park (3°49.356'N, 113°46.142'E) with total area of 3,138 ha consists of limestone hills and dipterocarp forests. Whereas Lambir Hills National Park (4°12.118'N, 114°2.569'E) which encompasses 6,949 ha total area are covered with dense mixed dipterocarp forests with patches of heath forests. All sampling sites are considered as lowland with altitude below 600 m.

2.2 Taxon sampling

Plants collections and observations were made within six months from November 2017 to May 2018. All species of tribe Alpinieae were documented with preference to fertile material. The collected specimens were moistened with 70% ethanol to prevent fungal growth and kept in a transparent and tightly closed plastic bag. Plants specimens were identified primarily based on morphological characters i.e. floral and vegetative. The useful characters were used and compared to the published taxonomic key and descriptions in Ridley (1924) [18], Holttum (1950) [19], Smith (1982, 1984, 1985, 1986) [5 - 8], Cowley (1999 – 2000) [9 – 10], Poulsen *et al.* (1999 - 2005) [11 – 12], Sakai & Nagamasu (1998, 2000, 2003) [13 – 15], Gobilik *et al.* (2005) [16], and Julius *et al.* (2007) [17] and by comparison to readily identified species at other herbaria. For preparation of voucher specimens, the plants were pressed and dried in the oven at 70 - 80°C for three to four days. All specimens were deposited at Herbarium Universiti Malaysia Sarawak (HUMS), while the duplicates were sent to Sarawak Herbarium (SAR).

3. Results

A total of thirty (30) Alpinieae species were collected from all localities consisted of eight (8) genera. Most taxa are endemic to Borneo while the other eight (8) species are also distributed to other geographical areas in the Malesian region. *Amomum* was the largest genus collected from the fields with seven (7) species followed by *Alpinia* and *Plagiostachys* with six (6) species each. *Elettaria* and *Etlingera* represent (3) species each while *Elettariopsis*, *Hornstedtia* and *Geocharis* recorded the least number of species with two (2), two (2) and one (1) species respectively. Niah NP recorded the

highest number of taxa collected with eighteen (18) species followed by Lambir Hills NP with fifteen (15) species. Interesting finding include the discovery of possibly new species; one each from genera *Amomum* and *Elettariopsis*. Among the conspicuous vegetative and floral characters that distinguished the new *Amomum* species from Similajau NP are the deeply corrugated broadly lanceolate leaves and brownish-yellow flowers; whilst the new *Elettariopsis* from Niah NP is distinct from others by the appearances and habitat which it grows on the limestone pockets and boulders.

In Niah NP, eighteen species were retrieved consisted of five (5) species of *Alpinia*, three (3) species each of *Elettaria*, *Etlingera* and *Plagiostachys*, two (2) species for *Amomum* and one (1) each for *Elettariopsis* and *Hornstedtia*. *Plagiostachys* sp.2 resembles *P. albiflora* but need further examination especially on the inflorescence characters. *Alpinieae* species in Niah NP occurred in shady areas but open to light excess at the lower part of limestone foothills. Compared to other species retrieved from here, *Alpinia ligulata* were more commonly occurred at floodplain area and swamp.

For fifteen *Alpinieae* species occurred in Lambir Hills NP, four (4) Bornean *Amomum* were collected, followed by three (3) species of *Plagiostachys*, two (2) species each for *Etlingera*, *Hornstedtia* and *Elettaria* and one (1) species each for *Alpinia* and *Elettariopsis*. Species of *E. surculosa*, *P. albiflora*, *Plagiostachys* sp.1, and *H. scyphifera* were first recorded from Lambir NP. *Plagiostachys* sp.1 could not be properly identified due to incomplete floral parts. *Hornstedtia lenourus* from Lambir Hills NP was also first documented from Borneo by Sakai & Nagamasu (2003), which have slight differences from species in Peninsular Malaysia such as non-tubular bracteoles and anther thecae which dehisce in the upper 2/3 only. Meanwhile, *Etlingera coccinea* that grow in clumps with shoots up to 4 m were observed quite abundant especially at valleys and along trail. Most of the collected species in Lambir Hills NP were found in shady areas or near streams.

Total of seven taxa from Similajau NP were recorded consisted of two (2) species for each *Alpinia* and *Amomum* and one (1) each for *Elettaria*, *Geocharis* and *Plagiostachys*. *Plagiostachys* cf. *megacarpa* have a resemblance to *P. megacarpa* A. Julius & A. Takano, however the collected species possessed attenuate leaf base, pubescent red flowers, trilobed calyx, and non-decaying and unidentate bracteoles. The later species was reported having cuneate leaf base, bilobed calyx, and partially decaying bracteoles (Julius & Takano, 2007). *Alpinia* sp.1 was only identified to genus due to the absence of inflorescence during the field work. Meanwhile, for *Geocharis* sp., although only the pinkish-red flower buds were managed to be collected, the morphological characters did not even match to the three Bornean *Geocharis* taxa; *Geocharis rubra* var. *rubra*, *Geocharis rubra* var. *puberula* and *G. fusiformis* var. *borneensis*. Most of the gingers in Similajau NP were found in shady areas, on sandy-clay soils with thick leaf litter on the ground, and near streams and valleys for *Amomum xanthophlebium*. The occurrence of *Alpinia aquatica* in Similajau NP and Niah NP is quite common due to the coastal, riparian, hill and limestone vegetation. Table 1 listed in detail the occurrence of each collected species at the three study sites. Figure 1 (a-l) show several species studied from the fields.

Table 1. Occurrence of *Alpinieae* gingers at studied localities.

No.	Genera	Niah NP, Miri	Lambir Hills NP, Miri	Similajau NP, Bintulu
1.	<i>Alpinia aquatica</i> (Retz.) Roscoe (1807) ^(b)	Main trail ^(c)	-	Near beach & chalet ^(d)
2.	<i>Alpinia galanga</i> (L.) Willd. ^(b)	Near main trail ^(f)	-	-
3.	<i>Alpinia glabra</i> Ridl. (1899) ^(a)	Bukit Kasut trail ^(e,g,h)	-	-
4.	<i>Alpinia ligulata</i> K. Schum. (1899) ^(a)	Main trail & trail to Rumah Panjang ^(e,f,g)	Waterfall trail ^(e)	-

5.	<i>Alpinia nieuwenhuizii</i> Valeton ^(a)	Main trail & trail to Rumah Panjang (e,g)	-	-
6.	<i>Alpinia</i> sp.1 ^(a)	-	-	Main trail ^(e)
7.	<i>Amomum bilabiatum</i> S. Sakai & Nagam. (1998) ^(a)	-	Pantu trail ^(e)	-
8.	<i>Amomum coriaceum</i> R.S. Sm. (1982) ^(a)	-	Main trail ^(e,f)	-
9.	<i>Amomum gyrolophos</i> R. M. Sm. (1985) ^(a)	-	Latak Waterfall trail ^(e,f)	-
10.	<i>Amomum roseisquamosum</i> S. Sakai & Nagam. (1996) ^(a)	Main trail ⁽ⁱ⁾	Latak Waterfall trail ⁽ⁱ⁾	-
11.	<i>Amomum xanthophlebium</i> Baker (1892) ^(b)	-	-	Batu Anchau trail (e)
12.	<i>Amomum</i> sp. nov.? ^(a)	-	-	Main trail ^(e)
13.	<i>Amomum</i> cf. <i>borneense</i> ^(a)	Main trail ⁽ⁱ⁾	-	-
14.	<i>Elettaria longipilosa</i> S. Sakai & Nagam. (2000) ^(a)	Main trail ^(e,f)	-	Main trail ^(e)
15.	<i>Elettaria longituba</i> (Ridl.) Holt. (1950) ^(a)	Bukit Kasut trail (e,f,g,h)	Pantu trail ^(e)	-
16.	<i>Elettaria surculosa</i> (K. Schum.) B.L. Burt & R.M. Sm. (1972) ^(b)	Bukit Kasut trail (e,f,g,h)	Pantu trail ^(e)	-
17.	<i>Elettariopsis kerbyi</i> R.M. Sm. (1990) ^(a)	-	Pantu trail ^(e)	-
18.	<i>Elettariopsis</i> sp. nov.? ^(a)	Bukit Kasut trail (g,h,j)	-	-
19.	<i>Etilingera coccinea</i> (Blume) S. Sakai & Nagam (2003) ^(b)	Bukit Kasut trail (e,f,g,h)	Main trail ^(e)	-
20.	<i>Etilingera fimbriobracteata</i> (K. Schum.) R.M. Sm. (1986) ^(a)	Bukit Kasut trail (e,f,g,h)	Trail to 52ha ecology plot ^(e)	-
21.	<i>Etilingera foetens</i> (Blume) R.M. Sm. (1986) ^(a)	Bukit Kasut trail (e)	-	-
22.	<i>Geocharis</i> sp.1 ^(a)	-	-	Main trail ^(e)
23.	<i>Hornstedtia leonurus</i> (J. König) Retz. (1791) ^(b)	-	Main trail ^(e)	-
24.	<i>Hornstedtia scyphifera</i> (J. Koenig) Steud. (1840a) ^(b)	Bukit Kasut trail (e,f,g,h)	Pantu trail ^(e)	-
25.	<i>Plagiostachys albiflora</i> Ridl. (1908) ^(b)	Madu trail ^(e,f,g)	Main trail ^(e)	-
26.	<i>Plagiostachys crocydocalyx</i> (K. Schum.) B.L. Burt & R.M. Sm. (1972) ^(a)	-	Latak Waterfall trail ^(e)	-
27.	<i>Plagiostachys glandulosa</i> S. Sakai & Nagam. (2003) ^(a)	Main trail & Madu trail ^(e,f,g)	-	-
28.	<i>Plagiostachys</i> cf. <i>megacarpa</i> A. Julius & A. Takano (2007) ^(a)	-	-	Main trail & Batu Anchau trail ^(e)

29.	<i>Plagiostachys</i> sp.1 ^(a)	-	Bukit Pantu trail ^(e)	-
30.	<i>Plagiostachys</i> sp.2 ^(a)	Madu trail ^(f,g,h)	-	-

Notes on distribution: ^(a) Borneo, ^(b) Borneo and several areas in the Malesian region

Notes on type of soils/landforms/habits: ^(c) Riparian, ^(d) Sandy soil, ^(e) Sandy clay soil, ^(f) Clay peat soil

^(g) Floodplain area, ^(h) Limestone foothill, ⁽ⁱ⁾ Epiphytic on trees, ^(j) Litophytic on limestone



Figure 1 (a-l). Inflorescences and infructescences of species studied in the fields. (a) *Alpinia aquatica*, (b) *Amomum xanthophlebium*, (c) *Amomum coriaceum*, (d) *Amomum gyrolophos*, (e) *Amomum* sp. nov?., (f) *Elettaria longipilosa*, (g) *Etlingera coccinea*, (h) *Hornstedtia leonurus*, (i) *Plagiostachys glandulosa*, (j) *Plagisotachys* cf. *megacarpa*, (k) *Plagiostachys* sp.1, (l) *Plagiostachys* sp. 2

4. Discussion

The occurrence of ginger flora especially tribe Alpinieae in Niah NP was relatively higher compared to other studied sites. The cool and shady environment of the mixed dipterocarp forests, swampy areas and patches of limestone provides suitable growth conditions for gingers. Similajau NP showed the least record for gingers in which the mixed dipterocarp area only forms small patches out of the major coastal sandy forest. So far, majority of the collected Alpinieae species occurred at sandy clay soils followed by clay peat soils. However, it is too soon to conclude the species composition at the three national parks since many areas particularly in Lambir Hills NP are yet to be explored.

The high number of *Amomum* collected in this study was also in line with Sakai & Nagamasu (1998-2003) on their study on subfamily Alpinioideae from Lambir Hills NP which documented the highest number of *Amomum* with twelve species [13 – 15]. Genera *Amomum*, *Plagiostachys* and *Hornstedtia* in Borneo are also considered under-explored since many species in the genera are yet to be described and unverified in the fields and various herbaria. Findings on the likely new species of *Amomum* and *Elettaria* and taxonomically uncertain species of *Plagiostachys* and *Geocharis* are something to ponder upon. The number of species from tribe Alpinieae is likely to increase from Sarawak. So far, genus *Plagiostachys* is less studied in Sarawak and systematics studies of the genus were more intensively done in Sabah. The characters states such as mucilaginous inflorescence, fragile flower that hinders close examination in dried specimens and also incomplete floral parts in herbarium specimens have somewhat contributed to the issue [9, 16].

Although the study covered the north east of Sarawak and involved short period of sampling, the discovery of likely new species indicates the study is worthwhile and necessitates further field works especially in many more parts of Sarawak due to its large forests area of and localised distribution of the ginger flora. The low diversity of gingers collected might be due to the sampling intensity, as according to Magurran (1988) [20], species count and species diversity increase with sampling intensity. Longer period of sampling and wider coverage area may also increase probability of finding more diverse species.

Intensive assessment of ginger flora of Sarawak is required to further measure the threats and conservation status such as by using the Malaysian Red List Categories and IUCN systems. It is needed that Malaysia's biodiversity heritage to be given ample attention and protection to prevent mass extinction in the future.

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