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Ministry of Natural Resources and Environmental Conservation
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Taxonomic Revision of the Genus *Dalbergia* (Fabaceae) in Myanmar



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Abstract

Dalbergia L. f., with around 250 species, is a large genus of the legume family (Fabaceae). This genus belongs to tribe Dalbergieae of subfamily Faboideae (or Papilionoideae) and is distributed in tropical and subtropical regions of the world. Many *Dalbergia* species are valuable timbers traded in the market, which have driven threats by illegal logging and deforestation. Unfortunately, there is limited knowledge on distributions and threats, and it is difficult to identify the wood and/or vegetative materials to species without specialists. Myanmar is situated in mainland Southeast Asia, being included in Indo-Burma biodiversity hotspot. Although Myanmar is well endowed with biodiversity-rich areas such as tropical rainforest, coastal mangrove forest, and subtropical montane forest, the biodiversity research has still lagged other neighboring countries. There are over 11,800 species of vascular plants recorded in Myanmar. Of them, 43 species of *Dalbergia* have been recognized. My current research will critically revise species diversity of *Dalbergia* in Myanmar for the first time after the Forest flora of British Burma (1877). This study is a comprehensive taxonomic revision of *Dalbergia* in Myanmar, which will fill the floristic gap in SE Asia. To clarify the species diversity of *Dalbergia* in Myanmar, field explorations in various sites covering eight representative regions were carried out, and 150 specimens were collected. Specimens conserved at herbaria of Xishuangbanna Botanical Garden, Chinese Academy of Sciences (HITBC) in China and Forest Research Institute (RAF) in Myanmar were carefully examined. Furthermore, online specimen images from herbaria of Natural History Museum, London (BM), Royal Botanic Garden, Edinburgh (E), Royal Botanic Gardens, Kew (K), and Museum National d'Histoire Naturelle, Paris (P) were also investigated carefully. Based on extensive examinations and comparisons on *Dalbergia* materials, we have confirmed that there were 36 *Dalbergia* species from all five sections to be present. Of them, *D. wattii* is newly recorded to flora of Myanmar. We generate a new diagnostic key for all *Dalbergia* species in Myanmar, and provide detailed description, distribution, habitat of each taxon, as well as taxonomic treatments. Moreover, phylogenetic relationship of 27 accessions of *Dalbergia* spp. has assessed and compared for the taxonomic identification and classification based on molecular phylogeny. The complete plastomes provides the important information for investigations on conservation genetics and phylogenies of *Dalbergia* and Fabaceae. In summary, we have fully revised the checklist of *Dalbergia* in Myanmar and rebuilt a preliminary plastid phylogenomic framework of *Dalbergia* in this study.

Key words: *Dalbergia*, Fabaceae, Myanmar, Phylogeny, Taxonomy

မြန်မာ့တမလန်းမျိုးစုဝင် အပင်မျိုးစိတ်များ၏ အပင်ရုပ်သွင်လက္ခဏာများအား ပြန်လည်ဆန်းစစ်ခြင်း

ပြည့်ပြည့်ဝင်း၊ သုတေသနလက်ထောက်-၂
သစ်တောသုတေသနဌာန၊ သစ်တောဦးစီးဌာန

စာတမ်းအကျဉ်း

တမလန်းမျိုးစုဝင်အပင်မျိုးစိတ်များသည် Leguminosae (Fabaceae) Family တွင် မျိုးစိတ်ပေါင်း ၂၅၀ ဝန်းကျင်ရှိသည့် မျိုးစိတ်ကြွယ်ဝမှုရှိသော မျိုးရင်းတစ်ခုဖြစ်ပါသည်။ Subfamily Papilionoideae မှ ဆင်းသက်လာပြီး Dalbergieae or Faboideae tribe ဖြစ်၍ Old and New Worlds တို့၏ tropical နှင့် subtropical ဒေသများတွင် သဘာဝအလျောက် ပေါက်ရောက်ပျံ့နှံ့မှုရှိပါသည်။ တမလန်းမျိုးစိတ် အများစုသည် ဈေးကွက်ဝင်သော အဖိုးတန် သစ်မျိုးများ ပါဝင်နေပြီး တရားမဝင်ရောင်းဝယ်ဖောက်ကား ခြင်းများနှင့် သစ်တောပြုန်းတီး ခြင်းများ စသည့်ခြိမ်းခြောက်မှုများနှင့် ကြုံတွေ့နေ ရပါသည်။ မြန်မာနိုင်ငံတွင် အစာရေကြောရှိ အပင်မျိုးစိတ်ပေါင်း (၁၁,၈၀၀) ကျော် မှတ်တမ်းတင် ထားရှိပြီးသည့် အနက် တမလန်းမျိုးစု အောက်တွင် မျိုးစိတ်ပေါင်း (၄၃)မျိုး ပေါက်ရောက်မှုရှိကြောင်း တွေ့ရပါသည်။ ယင်းမှတ်တမ်း များကို ဆန်းစစ်ကြည့်ပါက အပင်မျိုးစိတ်များ ကွင်းဆင်းစာရင်းကောက်ယူခြင်း သုတေသန လုပ်ငန်းများ အလွန်နည်းပါးခဲ့ကြောင်း ဖော်ပြလျက်ရှိနေပါသည်။ မြန်မာနိုင်ငံသည် Indo-Burmese ဒေသအတွင်း အပင်မျိုးစုံမျိုးကွဲများ ကြွယ်ဝသောနိုင်ငံအဖြစ် တည်ရှိနေသော်လည်း ဗြိတိသျှခေတ် နောက်ပိုင်းမှစ၍ သိပ္ပံနည်းကျ သုတေသနပြုလေ့လာ ဖော်ထုတ်ခြင်းများ အားနည်း ခဲ့ပါသည်။ ဤသုတေသနကို မြန်မာနိုင်ငံတွင်ပေါက်ရောက်သော တမလန်းမျိုးစုဝင် အပင်မျိုးစိတ်များအား သိပ္ပံနည်းကျ အပင်အမျိုးအစားခွဲခြား နည်းစနစ်များကို အခြေခံပြီး စနစ်တကျ လေ့လာဖော်ထုတ်မှတ်တမ်းတင်ရန် ရည်ရွယ်၍ ဆောင်ရွက်ခြင်းဖြစ်ပါသည်။ ယင်းသုတေသနမှ မြန်မာနိုင်ငံတွင် တမလန်းမျိုးစိတ် (၃၆) မျိုး ပေါက်ရောက်ပျံ့နှံ့မှုရှိကြောင်း အတည်ပြုနိုင်ခဲ့ပြီး ၎င်း(၃၆) မျိုးစိတ်အတွက် ပြင်ပရုပ်သွင် လက္ခဏာ များနှင့် ရုက္ခဗေဒဆိုင်ရာ အသေးစိတ် အချက် အလက် များကို ပံ့ပိုးပေးနိုင်ခဲ့ပြီး ၎င်းတို့အနက်မှ မြန်မာနိုင်ငံမှတ်တမ်း

အသစ် New record (၁)မျိုး (*Dalbergia wattii*) မှတ်တမ်းတင်အတည်ပြုနိုင်ခဲ့ပါသည်။ ထို့အပြင် *Dalbergia mimosoides* သည် မှတ်တမ်းအသစ်မဟုတ်သော်လည်း မြန်မာနိုင်ငံ၏ Flora Checklist စာအုပ်တွင် စာရင်း သွင်းထား ခြင်း မရှိသေး သည့်အတွက် စာရင်းသွင်း နိုင်ခဲ့ပါသည်။ ဤသုတေသနတွင် *Dalbergia* မျိုးစိတ်(၂၇)မျိုးကို Phylogenetics tree တည်ဆောက်၍ traditional identification နှင့် molecular classificationကို နှိုင်းယှဉ် စစ်ဆေး တွေ့ရှိချက်များနှင့် တမလန်းမျိုးစိတ်များ၏ မြန်မာနိုင်ငံတွင် ပေါက်ရောက်နေမှုပြု Taxonomic status ကိုဖော်ထုတ် အတည်ပြု မှတ်တမ်း တင်ထား ပါသည်။

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1. Introduction

Dalbergia L.f belongs to the subfamily Faboideae of Fabaceae (Fabales) with ca. 250 species, distributed in the old and new world tropics. Of them, Asia is one of the largest diversity centers of this genus, with 92 species, about 4 species Oceania (both shared with Asia). In addition, 60-70 species occur in Africa (43 species in Madagascar, 42 of which are endemic species), 45-55 species occur in the America (Klitgaard & Lavin, 2005). Currently, newly described taxa of *Dalbergia* include seven species from Central America published by Linares and Sousa (2007) and one species from West Africa by Jongkind (2007). The genus *Dalbergia* is monophyletic clade and sister to genus *Machaerium* Pers. and *Aeschynomene* L. (Lavin et al. 2001). Phylogeny of *Dalbergia* using ITS region with Bayesian inference and maximum parsimony approaches showed that the genus could be divided into five major clades representing the biogeographical separations (Vatanparast et al. 2013). Clade I and II included the species with major distribution in America whereas clade V included the diverse distribution from Asia, Africa and America. Myanmar species located in clade IV (a, b), clade III-c and V-c. Clade III included species from Asia and America, such as, *Dalbergia pinnata* (Lour.) Prain and *D. rostrata* from III-c were sister to the American clade III-a, sect. *Ecastaphyllum* (Carvalho, 1997). The majority of species occurred in Myanmar such as *Dalbergia kurzii*, *D. oliveri*, *D. stipulacea*, *D. lanceolaria*, *D. lanceolaria* subsp. *paniculata* and *D. assamica* were in clade IV-b, sect. *Dalbergaria* (Prain, 1904). *Dalbergia latifolia* was clustered together with the African-Madagascan clade in clade IV-a. Of the subclade, parts of clade IVa and IVb, these species are wholly Asian and related to small groups of African species.

Dalbergia is conventionally classified into five sections based on the position of the inflorescence and fruit characters (Bentham, 1852, 1860; Kurz, 1876; Prain, 1904). Floral characters are considered as most useful for showing taxonomic relationships within the genus, although vegetative characters are also considered and discussed. This morphology-based classification reflects the phylogenetic relationships of the species. In 1860, Bentham (1860) divided the 64 species of *Dalbergia* known at that time as six series (Triptolemea Americanae, Triptolemea, Sissoae Americanae, Sissoae Gerontogee, Dalbergariae and Selenolobia). Prain (1904) described each taxonomic group of *Dalbergia* from Asia 86 species and four varieties were recorded belonging to two subgenera (subgenus *Sissoa* and subgenus *Amerimnon*), five sections (Sect. Triptolemea, Sect. Podiopetalum, Sect. Endesperm, Sect. Miscolobium and Sect. Dalbergaria), and 24 series (Nummularieae, Parviflorae, Discolor, Rimosae, Phyllanthoides, Mimosoides, Foliaceae, Cultratae, Sissoo, Rostratae, Rubiginosae, Memoides, Congestae, Polyphyllae, Velutinae, Ovatae, Latifoliae, Polyadelphia, Sericeae, Lanceolarieae, Canae, Volubilis, Stipulaceae and Reniformies), respectively.

Trade in timber products of *Dalbergia* has increased exponentially in the past few years exploring the log imports to Asian markets. For example, the Hongmu (Red Wood) trade that based on 33 species of tropical hardwood trees of which 16 species are *Dalbergia* (EIA, 2016). Of these 16 *Dalbergia* species, 7 come from Asia, 2 from Africa (D.

melanoxydon, *D. louvelli*) and 7 from Latin America (EIA, 2016). Only *D. cochinchinensis*, *D. louvelli*, *D. nigra*, *D. stevensonii*, *D. granadillo* and *D. retusa* are regulated by CITES. Far more *Dalbergia* species are presently traded than those CITES-listed. However, information on trade flows is not easily available. Rosewood species are currently in high demand by consumers and logs and sawn wood are the main products in trade in most of the producing countries. As a result of an on-going demand in the Asian markets, the rosewood species has become seriously endangered by abusive logging and habitat destruction which leads to the decline of wild populations inside and outside protected areas.

1.1 Morphological characteristics of Genus *Dalbergia*

Dalbergia spp. are small to medium sized trees, shrubs, or woody climbers and lianas with alternate, imparipinnate and compound leaves (Saha *et al.*, 2013); stipules often small and early caducous; leaflets are alternate, rarely sub-opposite, and glabrous (Saha *et al.*, 2013).

Flowers are small (2 to 20mm): corolla small, rarely fragrant, white, light yellow or purple, with light green spot at the center of the vexillum (FAUSAC- FNPV, 2015). Inflorescences are terminal or axillary, racemes or panicles, usually numerous flowered; generally, bracts and bracteoles are small, rarely persistent, sometimes scorpioid or corymbiform. The fruit is a pod/legume oblong, ligulate, winged, elliptic, or strap-shaped, rarely half-moon-shaped (Carvalho, 1997).

1.2 Conservation Status and trend of *Dalbergia*

The Red List species described in International Union for Conservation of Nature (IUCN) has assessed from (<https://www.iucnredlist.org/>) and 108 out of 250 *Dalbergia* species were assigned into threatened categories (IUCN, 2020): 8 species as Critically Endangered, 36 species as Endangered, 30 species as Vulnerable. 6 and 21 species needed elevated conservation concern assigning as Near Threatened, and Least Concern, respectively. 7 species were assigned as Data Deficient. Of which nine Myanmar species has accessed into threatened categories (IUCN, 2020): (2) species as Endangered, (1) species as Vulnerable, (1) species as Near Threatened, and (5) species as Least Concern, respectively.

Some *Dalbergia* species (e.g. Burmese rosewood (*Dalbergia oliveri*), Brazilian rosewood (*D. nigra*), Madagascar rosewood (*D. maritima*), Indian rosewood (*D. latifolia*)) are in high demand in the international tropical hardwood trade for the manufacture of furnitures. However, the wild populations of several species have experienced a major decline due to legal and illegal overexploitation. CITES regulates and protect all species of *Dalbergia* including in Appendices: one species (*Dalbergia nigra*) in Appendix I and all other species in Appendix II (CITES, 2019).

1.3 Problem statement of *Dalbergia* in Myanmar

Myanmar is located at the southern-most part of the Himalayan mountain range extensions and the vegetation types are pantropical evergreen, mixed deciduous, savannah, and alpine and sub-alpine meadow and grassland. With its wealth of plant diversity, Myanmar is one of the most botanically fascinating countries in the world (Tanaka, 2005). However,

botanical explorations were relatively less in Myanmar, particularly since 1945 (Kress et al., 2003), hence, majority of the collections in Myanmar were from the European and North American naturalists and plant hunters. In addition, Myanmar faces rapid deforestation, which urgently needs to be addressed, and is still in the process of counteraction (FAO, 2015). Kress et al. revised angiosperms and gymnosperm species containing 273 families, 2371 genera and over 11,800 species in the “A Checklist of the Trees, Shrubs, Herbs and Climbers of Myanmar”, The checklist was compiled based on the last over 100 years of study of the vegetation of Myanmar and follows the earlier botanical works of Hooker, Kurz, Lace, Rodgers and most recently H.G. Hundley and U Chit Ko Ko in their “List of Trees, Shrubs, Herbs and Principle Climbers, etc. recorded from Burma”. Of them, 43 *Dalbergia* species (including a variety) were recorded in Myanmar. However, it is not revise taxonomic status and not provide morphological descriptions. Moreover, the floristic assessment and taxonomic revision of *Dalbergia* was not yet performed in Myanmar.

However, illegal logging contributed to a major threat to *Dalbergia* species as it contains several valuable timber species, however, knowledge on distributions and level of threats is often limited and having an accurate species identification form non-experts are challenging (Hartvig et al., 2015). Moreover, some *Dalbergia* species become endangered as the consequence of illegal timber trades and additionally, the IUCN Red List has classified of *Dalbergia oliveri* from Myanmar as endangered species (IUCN, 2020). To enforce protective legislation and ensure effective conservation on *Dalbergia* species, the wood identity of the traded timber must be effective and accurate. Therefore, it would be highly desirable to develop reliable identification techniques that can be rapidly applied without *Dalbergia* specialists (Song et al. 2019). Moreover, the assessment of thereat categories for genus *Dalbergia* is urgently needed as the annual forest loss was 2 million hectares between 2002 and 2014 (Bhagwat et al., 2017) due to the rapid land transformation and land use changes in Myanmar.

1.4 Objectives

In this study, (1) *Dalbergia* will be taxonomically revised mainly based on the extensive field surveys and the morphological investigations (2) the key to all taxa occurring in Myanmar will be provided. Moreover, taxonomic discussion of each taxon of *Dalbergia* will be given in the taxonomic treatment. (3) Phylogenetic relationship of genus *Dalbergia* will be assessed and compared for the taxonomic identification and classification based on molecular phylogeny. The major aim for this study is to revise the genus *Dalbergia* for Myanmar and to contribute to the upcoming “Flora of Myanmar” and conservation planning for priority species in Myanmar. The current checklist is fundamental for plant conservation because it will provide the information regarding the number of species and its distribution ranges that could guide conservation actions.

2 Materials and methods

2.1 Study Area

Myanmar is the largest mainland country in Southeast Asia nations, with the area of 676,577 square kilometres and lies between 9° 32' N to 28° 32'N and 92° 10' E to 101° 11'E, which has extremely rich in biodiversity and a high disparity of habitats (FRA 2015).

Myanmar shares borders with Bangladesh and India to the West, and China, Laos and Thailand to the East. There are 7 administrative regions, 7 states and one union territory in Myanmar, namely: Ayeyarwady Region, Bago Region, Magway Region, Mandalay Region, Sagaing Region, Tanintharyi Region, Yangon Region, Chin State, Kachin State, Kayah State, Kayin State, Mon State, Rakhine State, Shan State, and Nay Pyi Taw Union Territory. In Myanmar, 42.92% of the country's total land area (with the area of 290407.59 km²) is covered with forests (FRA, 2015). In Myanmar, tropical mixed deciduous forests (38.20%), hill and temperate evergreen forests (26.92%), tropical evergreen forests (17.30%), dry forests (10.00%), deciduous dipterocarp forests (4.26%), scrub land (2.20%), and tidal or mangrove forests (1.12%) are the major forest types (FRA, 2015). There are three main seasons such as winter or northeast monsoon season (November – February), summer or hot weather season (March – mid-May), rainy or southwest monsoon season (mid-May – October) (Forest Department, 2015).

In Myanmar, British and North American botanists have conducted extensive botanical surveys about woody plant species over half a century ago (Tanaka, 2005). This observation guided us for study sites selections, thus, our field explorations were conducted in Pin Laung township, Shan State; Nat Ma Taung National Park, Kempetlet township, Chin State; Popa Mountain Park, Kyaukpadaung township, Pyin Oo Lwin Botanical Garden, Pyin Oo Lwin township, Yeyamenn Reserve, Kyaukse township, Ngaliike Reserve, Oaktaya District, Oaktaya Thiri township at NayPyiTaw Council; Mann Reserve, Padan township, Magway Region; and Zalone Taung area, Bamouk township, Sagaing Region from 2018 December to 2019 April (5 months) (Figure 1.). The general landscape ecosystems of study areas can be described as follow;

- **Nat Ma Taung National Park**, it is located in Kanpatlet, Mindat and Matupi Townships, Mindat District, Chin State, Northwest Myanmar, 713 km², (21.2637° N. 93.88059° E) and elevation 740-3070 m. tropical montane forest occurs in this area.
- **Popa Mountain Park**, (129 km²) and (20.9237° N. 95.2076° E) is an oasis of dry zone area surrounded by dry scrub forests and situated in Kyaukpadaung Township, Nyaung-Oo District, Mandalay Region, Central Myanmar.
- **Zalong Taung Area**, it located in Katha District, Banmauk Township at Sagaing Region. Lower mixed deciduous forest, pine forest and hill forest occurs in this areas.
- **Paung Laung Reserve Forest**, Paung Laung Reserve Forest (RF) is located in central Myanmar, which extends over 1700 km², (19°45'–20°28' N. 96°22'–96°49' E) and elevation 300–1700 m a.s.l. It belongs to Mandalay Region and Shan State. Forests cover most parts of the RF, and they can be broadly classified as mixed deciduous forests and evergreen forests.
- **Yeyaman Reserve Forest**, it located in Kyauk Se District, Kyauk se Township under Mandalay Region. It covers around (826.392363 km²). The forest type is lower mixed deciduous forest type, Indaing forest type and pine forest. It extends 200 to 1500m a.s.l
- **National Botanical Gardens**, it was first established in 1915 as the Maymyo Botanical Gardens by Alex Roger, a Forest Officer. The original site was (120,000 km²), and was modelled after the Kew Gardens of England with the help of an

amateur gardener called Lady Cuffe. In 1917, the government granted it official recognition, and in 1924, the site was declared a Government Botanical Reserve. The National Kandawgyi Botanical Gardens (formerly National Botanical Gardens) is a 1.77 km² botanical garden located in the Alpine town of Pyin Oo Lwin (formerly Maymyo), Myanmar situated at an elevation of 1000 metres and 69 km by road from Mandalay. The current official name is National Kandawgyi Garden.

- **Mann Reserve Forests**, it is located in Minbu District, Ngaphae township at Magway Region. Upper and lower Mixed deciduous forest types occur in this area.
- **Ngalaik Reserve Forest**, it is located in Oaktaya District, Oaktaya Thiri township at Nay Pyi Taw Union Territory. Mixed deciduous forest types occur in this area.

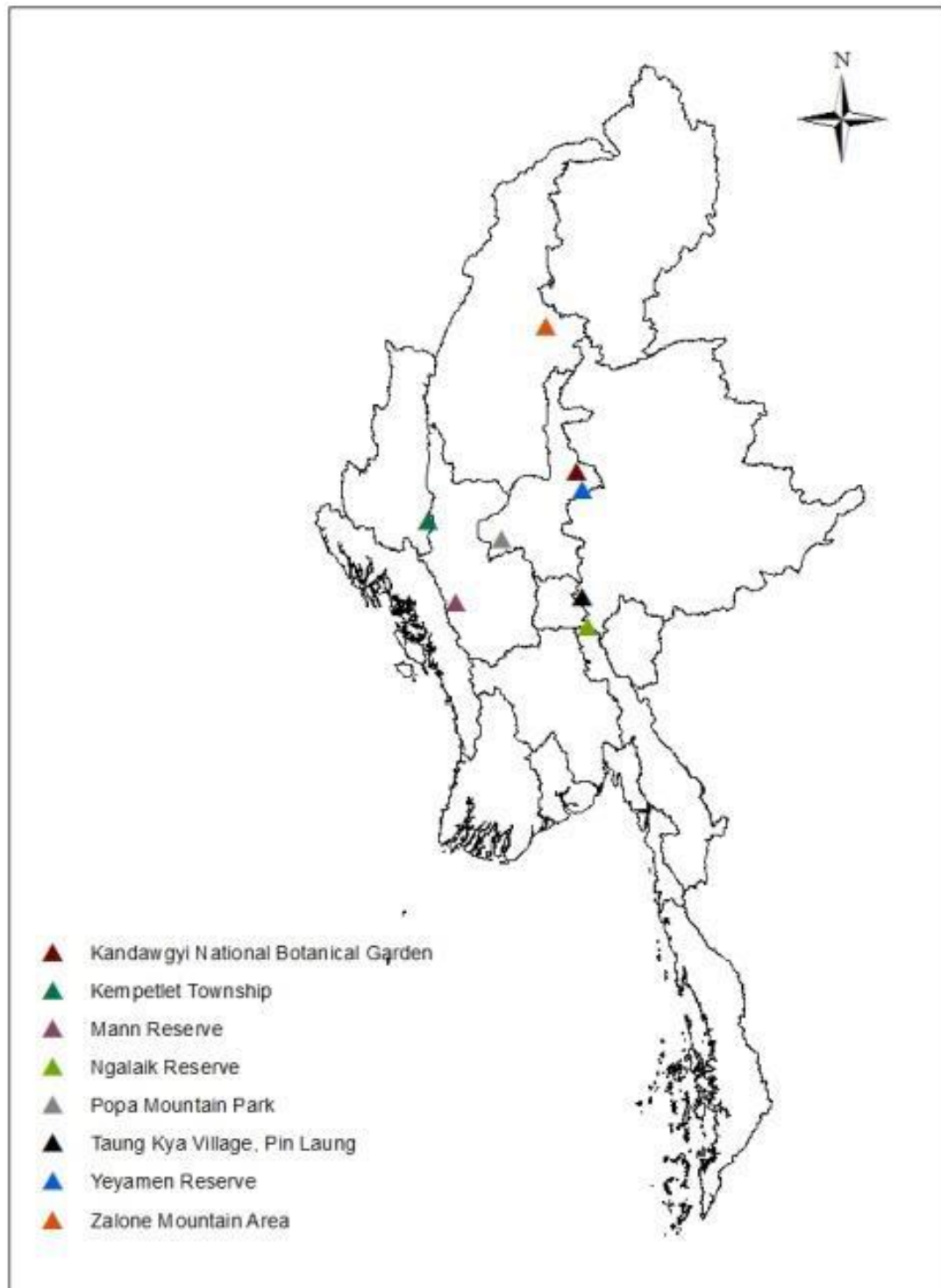


Figure 1. Location map of Study Areas for genus *Dalbergia* surveys in Myanmar

2.2 Specimens collection and preparation

Totally 50 (150 specimens including duplicates) specimens of genus *Dalbergia* were collected during the field expeditions. 2 cm x 2 cm of fresh leaves from all specimens were thoroughly clean, sometimes using water or ethanol if necessary, and sampled for molecular

analysis in silica gel. The distinguished characters of *Dalbergia* plants; number of leaf pairs, inflorescence, flowers, and fruits, were photographed and taking these data in the field notes. Detailed collection localities were taken by using GPS (Global Positioning System). Detailed vegetative and reproductive parts were measured in the laboratory using light electron microscope. Voucher specimens in this study were oven-dried and deposited in the Herbarium of Forest Research Institute (RAF), Myanmar and Herbarium of Xishuangbanna Tropical Botanical Garden, China (HITBC).

2.3 Specimens identification

The collected specimens were identified based on identification keys (leaves: shape, size, colour, secondary nerves, texture; flowers: calyx tube size, corolla colour, number of stamens; pods shape, size etc.), moreover, the comparison of herbarium specimens, relevant literatures, type specimens, herbarium specimens and online herbarium specimens such as Kew Herbarium Catalogue, Royal Botanic Garden Edinburgh Herbarium Catalogue, NYBG street Herbarium. For verification of taxonomic status of all species, all relevant literature and online databases such as ILDIS (<https://ildis.org/LegumeWeb/>) were reviewed to confirm the respective taxonomic status.

2.4 Specimens examination

All herbarium specimens were examined, including specimens of my own collection from this study and my supervisor's previous collection deposited in XTBG (HITBC) and herbaria of Forest Research Institute (RAF) specimens and specimens from online herbaria: BM, E, K, US, NY, P, NL (herbarium codes from Index Herbarium at <http://sweetgum.nybg.org/science/>).

In addition, all available datasets of herbarium specimens (ca. 600 specimens) and specimen photographs were downloaded from online herbaria and examined to enumerate the number of species and to investigate the species occurrences in Myanmar. The followings are specimen records downloaded from each online herbarium, NY (19 records), BM (records), E (181 records), K (72 records), P (9 records), US (39 records) and NL (49 records). During my field trips in Myanmar, some old herbarium specimens at RAF (148 specimens), YANG (30 records), ASM (20 records) were also examined at herbarium (RAF) of Forest Research Institute in Yezin, Nay Pyi Taw.

2.5 Taxonomic revision

The number of species in the updated checklist was a result of taxonomic attempts, mainly based on collections from current study, all available digitized herbarium specimens, checklist of Kress et al. (2003) and all relevant literatures (Roxburgh, 1814; Benthams, 1852, 1860; Baker, 1876; Kurz, 1877; Prain, 1897, 1903, 1904; Thothathri, 1972,1975 (a)(b), 1983 (a)(b); Sunarno & Ohashi, 1996, 1997; Carvalho A M. 1997; Sri Rama et al. 2000; Niyomdham, 2002; Adema, 2016; Li, 2017; Tagane, 2019). Both the number of species and its taxonomic status were verified with the reliable online databases such as International Legume Database and Information Service (ILDIS, <https://ildis.org/LegumeWeb/>), International Plant Names Index (IPNI, <https://www.ipni.org/n/990098-1>) and the Plant List

(TPL, <http://www.theplantlist.org/>). As for species occurrences, Global Biodiversity Information Facility (GBIF) and relevant online herbaria (NY, BM, K, E, P, NL, US) were also consulted to check the species occurrences of genus *Dalbergia* in Myanmar.

2.6 Species distribution of *Dalbergia* in Myanmar

The herbarium specimens can provide the species occurrence and distribution information, which was especially crucial for Myanmar to trace the locality of the historical collection as most of species recorded in Myanmar has lack of the georeferencing information. The available species distribution of *Dalbergia*, i.e. downloaded the data from GBIF (<https://www.gbif.org/>), the assigned coordinates from the locality of herbarium specimens and combined with my filed collection were used for species distribution mapping. We generated the species distribution map using Arcgis (10.5).

2.7 DNA extraction and phylogenetic analysis

Fresh leaves were collected from selected area. Genomic DNA were extracted from silica gel dried leaves using a modified CTAB method (Doyle and Doyle 1987). Then, the purified DNA was fragmented to approximately 350 bp in size for library construction, and 150 bp pair-end reads were generated by Illumina NovaSeq 6000 (Annoroad, Beijing). The raw reads were *de novo* assembled using GetOrganelle toolkit (Jin et al., 2018). The plastomes were annotated using CPGAVAS2 (Shi et al. 2019), then manually adjusted in Geneious (Kearse et al. 2012). The whole plastome sequences with one IR region were aligned using MAFFT. The maximum likelihood tree was reconstructed by RAxML (Stamatakis, 2014) using GTRGAMMAI model with 1000 bootstrap replicates on CIPRES (<https://www.phylo.org/>). The trees were visualized and with the TreeGraph (Stover and Muller 2010).

3. Results

3.1 Species distribution, new species and new records of *Dalbergia* in Myanmar

In total, fifteen *Dalbergia* species were recorded from eight study sites: four species in Popa Mountain Park, five species in Zalong Taung Area, eight species in Pin Laung Reserve Forest, four species in Yeyaman Reserve Forest, four species in Maymyo Botanical Gardens, six species in Mann Reserve Forests, and seven species in Ngalaik Reserve Forest, respectively. As the result of this extensive field works and identifications of these materials collected, have so far confirmed presence of 36 *Dalbergia* species from five sections to be presented. We recorded potentially new species that is *D. oliverioides* in Myanmar, Chin State, Kenpetlet Township, Kenpetlet to Saw roadside in 2019, however, the vegetative part was lacking. Additionally, we recorded the Indian endemic species, *D. wattii* C. B. Clarke., in the Central Dry Zone of Myanmar.

According to the database of GBIF (<https://www.gbif.org/>), online herbarium specimens and geo-referenced data of my field inventory, we generated the species distribution map for individual species using Arcgis (**Figure. 2**). According to the relevant literature, online databases, herbarium specimens and currently field data collection, we found that three species; *D. peguensis* Thoth., *D. prainii* Thoth. and *Dalbergia pseudo-ovata*

Thoth., were endemic to Myanmar (ILDIS; Thothathri 1975 a & b). In addition, *Dalbergia kingiana* Prain. was distributed only in Kachin State and *Dalbergia prainii* Thoth. was distributed in Chin State.

3.2 Updated checklist

The current study presented an updated checklist of genus *Dalbergia* of Myanmar including 36 species currently known from Myanmar. The number of species was decreased by seven species less than the checklist of Kress et al., 2003. Additionally, we updated taxonomic status of genus *Dalbergia* with International Legume Database and Information Service (<https://ildis.org/LegumeWeb/> ILDIS) version 10.

The updated checklist provided the updated taxonomic status for each taxon, their respective distribution in Myanmar, voucher specimens and conservation status. Species distribution ranges (usually provincial level) in Myanmar are provided for almost all species. Specific locality information was also provided if there is available data. Voucher specimen citations were provided for all species, except *Dalbergia cumingiana*, *D. henryana*, *D. junghuhnii*, *D. kerrii*, *D. latifolia* and *D. rubiginosa*. The final confirmation for the occurrence of these species and actual distribution status was needed in Myanmar. In current study, I attached the taxonomic treatment for all species entitled “Key to Myanmar *Dalbergia* Species”.

3.3 Comparison of traditional classification and molecular phylogeny

Phylogenetic analysis showed that the backbone of Faboideae was well resolved, and four major clades were full supported (**Figure 3**). Clade I, *Dalbergia mimosoides* is sister to clade II, III and IV. In clade II with 100% bootstrap values, *Dalbergia cultrata* is closely related with *D. fusca* and sister to *D. sissoo*, *D. rimosa*, *D. odorifera* and *D. hainanensis*. In clade III, *D. ovata* and *D. lacei* is closely related and sister to *D. tonkinensis* and *D. obtusifolia*. In clade IV subclade included, *D. wattii*, *D. volubilis* and *D. stipulacea* support of bootstrap value than the other clade, that is 51 bootstrap value and the subclade of included *D. oliveri* and *D. oliverioides* is closely related and sister to *D. assamica*, *D. lanceolaria*, *D. peguensis* and *D. reniformis*, that have bootstrap value of 85% (**Figure 3**).

Clade I and II were assigned in subgenus *Sissoa*, section *Triptolemea* and *Podiopetalum* respectively and clade III and IV were assigned in subgenus *Amerimnon*, section *Dalbergaria* and section *Miscolobium* respectively (**Table.1**). *D. mimosoides* was assigned in clade I and subgenus *Sissoa*, section *Triptolemea*. *Dalbergia cultrata*, *D. fusca*, *D. sissoo*, *D. rimosa*, *D. odorifera* and *D. hainanensis* were assigned in clade II and the same subgenus *Sissoa*, section of *Triptolemea* and *Podiopetalum*. *Dalbergia ovata*, *D. lacei*, *D. tonkinensis* and *D. obtusifolia* were assigned in clade III and the same subgenus *Amerimnon*, section of *Miscolobium*. *Dalbergia wattii*, *D. volubilis*, *D. stipulacea*, *D. oliverioides*, *D. oliveri*, *D. assamica*, *D. lanceolaria*, *D. peguensis* and *D. reniformis* were assigned in clade IV and the same subgenus *Amerimnon*, section of *Dalbergaria*. Therefore, the present study confirms the coincidence of molecular phylogeny and traditional classification.

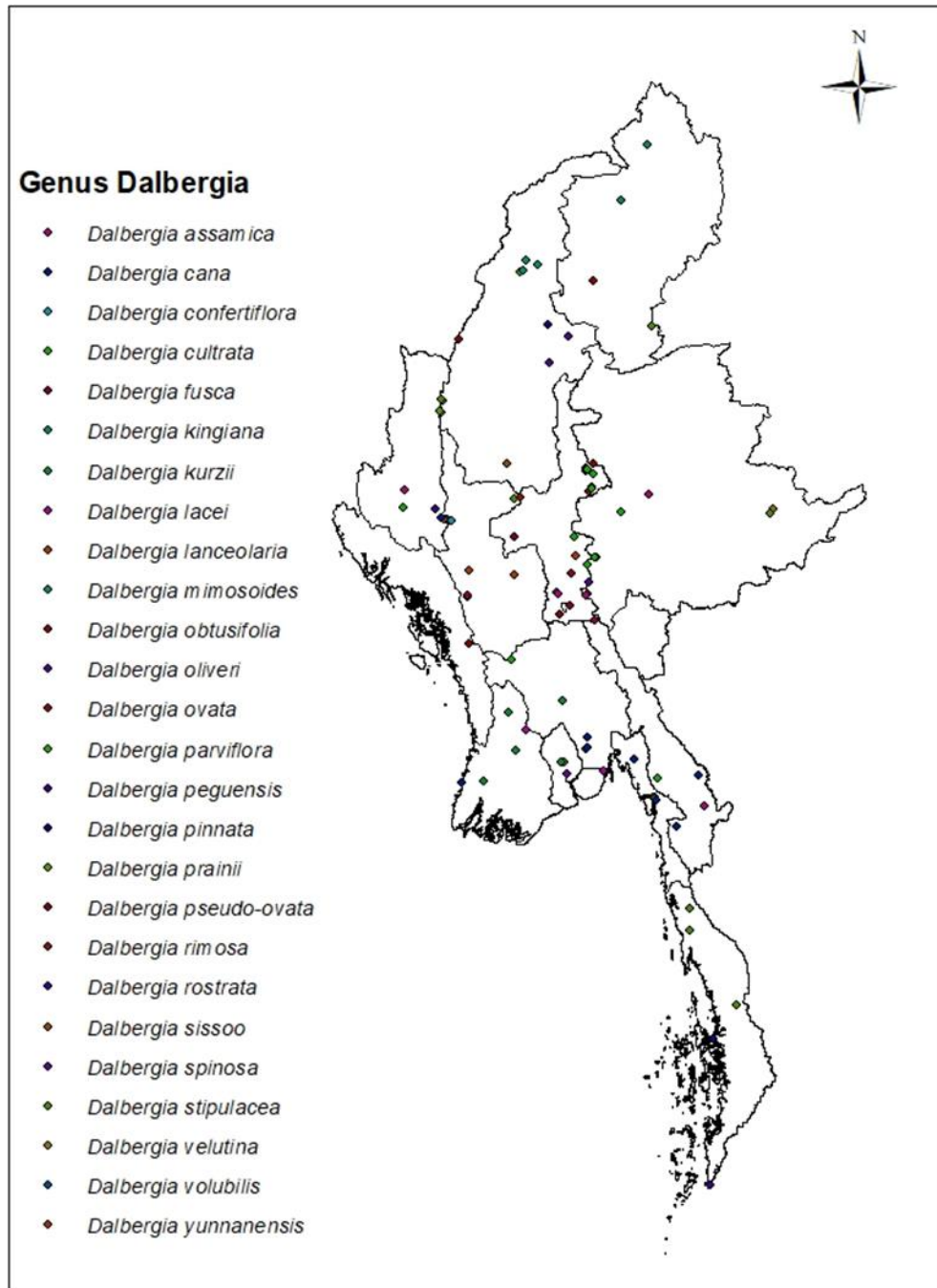


Figure 2. Species distribution map of genus *Dalbergia* in Myanmar

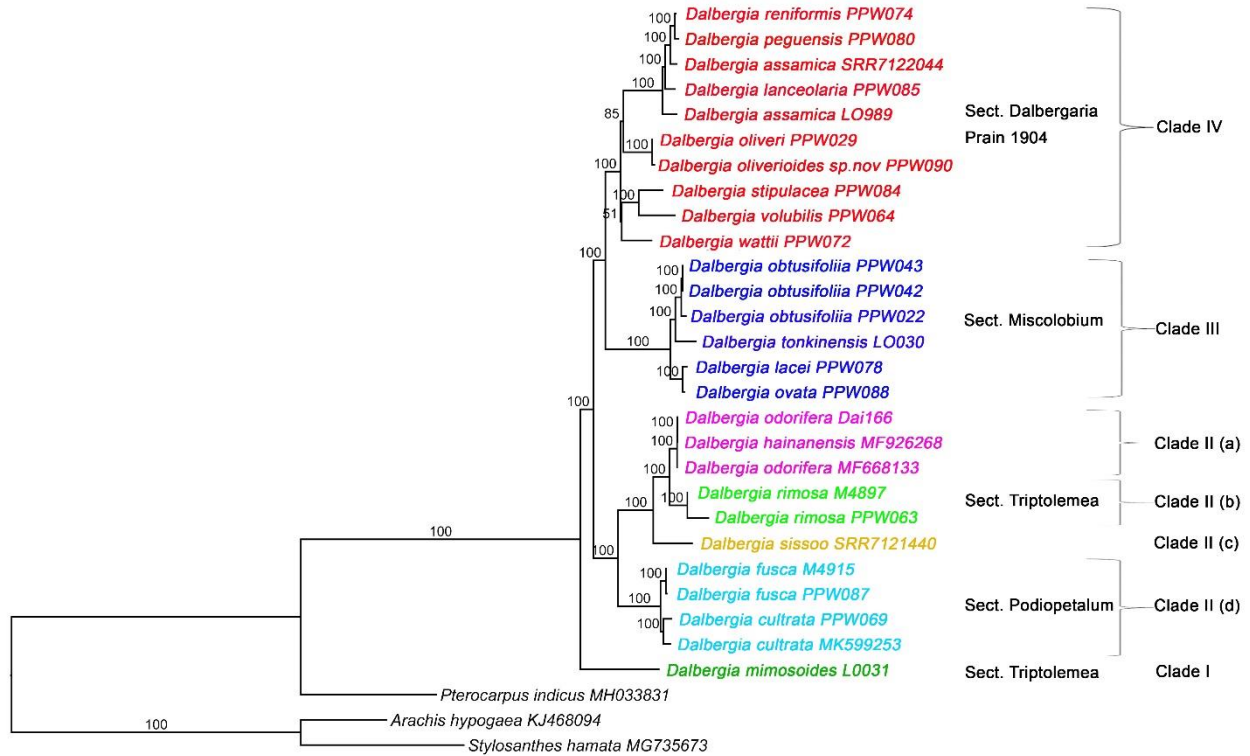


Figure.3 The consensus tree resulting from Maximum Likelihood method for 21 *Dalbergia* species collected in SE Asia: numbers on branches indicate posterior probabilities 100 percent. Representing traditional classification based on Prain 1904; Clade I includes in Section. Triptolemea, Clade II in Section. Triptolemea and podiopetalum, Clade III in Section. Micolobium and Clade IV in Section. Dalbergaria. Out groups are *Pterocarpus indicus* and *Arachis hypogaea* + *Stylosanthes hamata*.

Table 1. Comparison of traditional classification and molecular classification of genus *Dalbergia* based on D. Prain, 1904.

No.	Scientific Name	Clade	Subgenus	Section
1.	<i>Dalbergia reniformis</i> PPW 074	IV	<i>Amerimnon</i>	<i>Dalbergaria</i>
2.	<i>Dalbergia peguensis</i> PPW 080	IV		
3.	<i>Dalbergia assamica</i> SRR 122044	IV	<i>Amerimnon</i>	<i>Dalbergaria</i>
4.	<i>Dalbergia lanceolaria</i> PPW 085	IV	<i>Amerimnon</i>	<i>Dalbergaria</i>
5.	<i>Dalbergia assamica</i> L0989	IV	<i>Amerimnon</i>	<i>Dalbergaria</i>
6.	<i>Dalbergia oliveri</i> PPW 029	IV	<i>Amerimnon</i>	<i>Dalbergaria</i>
7.	<i>Dalbergia oliverioides</i> sp.nov PPW 090	IV		

8.	<i>Dalbergia stipulacea</i> PPW 084	IV	<i>Amerimnon</i>	<i>Dalbergaria</i>
9.	<i>Dalbergia volubilis</i> 064	IV	<i>Amerimnon</i>	<i>Dalbergaria</i>
10.	<i>Dalbergia wattii</i> PPW 072	IV	<i>Amerimnon</i>	<i>Dalbergaria</i>
11.	<i>Dalbergia obtusifolia</i> PPW 043	III	<i>Amerimnon</i>	<i>Miscolobium</i>
12.	<i>Dalbergia obtusifolia</i> PPW 042	III	<i>Amerimnon</i>	<i>Miscolobium</i>
13.	<i>Dalbergia obtusifolia</i> PPW 022	III	<i>Amerimnon</i>	<i>Miscolobium</i>
14.	<i>Dalbergia tonkinensis</i> L 0030	III	<i>Amerimnon</i>	<i>Miscolobium</i>
15.	<i>Dalbergia lacei</i> PPW 078	III		
16.	<i>Dalbergia ovata</i> PPW 088	III	<i>Amerimnon</i>	<i>Miscolobium</i>
17.	<i>Dalbergia odorifera</i> Dai 166	II		
18.	<i>Dalbergia hainanensis</i> MF 926268	II		
19.	<i>Dalbergia odorifera</i> MF 668133	II		
20.	<i>Dalbergia rimosa</i> M 4897	II	<i>Sissoa</i>	<i>Triptolemea</i>
21.	<i>Dalbergia rimosa</i> PPW 063	II	<i>Sissoa</i>	<i>Triptolemea</i>
22.	<i>Dalbergia sissoo</i> SRR 7121440	II	<i>Sissoa</i>	<i>Podiopetalum</i>
23.	<i>Dalbergia fusca</i> M 4915	II	<i>Sissoa</i>	<i>Podiopetalum</i>
24.	<i>Dalbergia fusca</i> PPW 087	II	<i>Sissoa</i>	<i>Podiopetalum</i>
25.	<i>Dalbergia cultrata</i> PPW 069	II	<i>Sissoa</i>	<i>Podiopetalum</i>
26.	<i>Dalbergia cultrate</i> MK 599253	II	<i>Sissoa</i>	<i>Podiopetalum</i>
27.	<i>Dalbergia mimosoides</i> L0031	I	<i>Sissoa</i>	<i>Triptolemea</i>

3.4 Taxonomic treatment

Dalbergia L. f., Suppl. Pl. 52, 316. 1781; Roxb., Pl. Coromandel 2: 7. 1798 & Hort. Beng. 53. 1814 & Fl. Ind. 3: 220. 1832; DC., Prodr. 2: 416. 1825; Wight & Arn., Prodr. Fl. Ind. Orient. 1: 264. 1834; Benth. in Miq., Pl. Jungh. 1: 254. 1852; Miq., Fl. Ind. Bat. 1: 126. 1855; Benth., J. Linn. Soc., Bot. 4(Suppl.): 28. 1860 & in Mart., Fl. Brazil 15(1): 217. 1862; Baker in Hook. f., Fl. Brit. Ind. 2: 230. 1876; Prain, J. Asiat. Soc. Bengal. Pt. 2, Nat. Hist. 66(2): 112, 442. 1897 & 70(2): 39. 1901 & Ann. Roy. Bot. Gard. (Calcutta) 10(1): 25. 1904; Merr., Philip. J. Sci. 5: 95. 1910 & Enum. Philip. Pl. 2: 294. 1923; Hutch. & Dalz., Fl. West Trop. Afr. 1: 513. 1954; Thoth., Ind. For. 96: 15. 1970 & J. Jap. Bot. 46: 73. 1971 & 50: 52. 1975 & Reinwardtia 8: 329. 1972 & J. & Tax. Revis. Dalbergieae Ind. 20. 1987; Gillett, Polhill & Verdcourt, Fl. Trop. East Afr. 95. 1971; T. C. Chen, Fl. Reip. Pop. Sin. 40: 98. 1994 & Fl. China 10: 121. 2010; Niyomdham et al., Fl. Camb. Laos Vietn. 29: 3. 1997; Niyomdham, Thai For. Bull. (Bot.) 30: 124. 2002

Trees, erect or scandent shrubs to woody climbers, sometimes spiny, with or without red sap. Leaves imparipinnate, rarely unifoliolate; stipules present, caducous, very rarely

persistent; stipellae absent; leaflets usually alternate. Inflorescences axillary, terminal or raminascent, racemes or panicles. Bracts subpersistent or caducous. Bracteoles present, caducous or (sub)- persistent. Calyx campanulate, 5-lobed, the upper pair of lobes usually broader than the others and often partially connate, the lowest lobe usually narrower and the longest. Corolla papilionaceous, white, cream, yellow, purple or violet; standard petal ovate, obovate, orbicular or panduriform, usually emarginated at the apex, its claw long or short; wings oblong, obovate or rarely $\pm$ ovate, usually auriculate at the base of the blade; keel-petals very often slightly shorter than wings, their blades obtuse, oblong or sometimes obovate, usually auriculate at the base of the blade, always connate on the lower side of the apex. Stamens 9–10, monadelphous, or diadelphous; anthers all equal, fertile. Ovary stipitate; ovules few; stigma terminal. Fruits oblong to oblong-elliptical, samaroid, crescent- or kidney shaped, or orbicular to suborbicular, membranaceous, subcoriaceous, thickened over the seed cavity or thickened throughout. Seeds reniform, compressed; radicle inflexed.

Type specimen: *Dalbergia lanceolaria* L.f.

About 100 species in pantropical region. Thirty-six native species in Myanmar.

Note. *Dalbergia kerrii* Craib. was incompletes information.

Key to Myanmar *Dalbergia* species

1. Tree

2. Maximum leaflet number not more than 8

3. Seeds oblong in shape; pods up to 12 cm in length -----23. *D. pseudo-ovata*

3. Seeds reniform; pods not more than 11 cm in length

4. Calyx puberulous; wing oblanceolate; 1-4 seeded pods -----28. *D. sissoo*

4. Calyx glabrous; wing broadly ovate or obovate; 1-2 seeded pods

5. Inflorescence axillary and with sparsely flowered; bracts and bracteoles early caduceus; pedicles glabrous -----14. *D. latifolia*

5. Inflorescence terminal or subterminal and with densely flowered; bracts and bracteoles persistent; pedicles rusty pubescent -----16. *D. obtusifolia*

2. Maximum leaflet number more than 8

6. Samara fruit -----22. *D. prainii*

6. Not samara fruit

7. Stamens monadelphous

8. Pods obliquely oblong, with 1-4 seeds -----5. **D.**
cultrata
8. Pods ligulate lanceolate or ligulate oblong or oblong, with not more than 1-2 seeds
9. Leaflet number 9-13; leaflet base slightly unequal; -----2. **D.**
burmanica
9. Leaflet number 7-9 or 7-10; leaflet base rounded to nearly rounded or cunneate
10. Pods oblong with acute apex and narrow base -----13. **D.**
lacei
10. Pods ligulate lanceolate with narrowed to both ends but more abruptly to apex-----
-----7. **D.**
fusca
7. Stamens diadelphous (5+5)
11. Corolla white or lavender or pale rose
12. Leaflet number 9-13, ovate oblong to ovate; pods oblong -----20. **D.**
peguensis
- Leaflet number 9-11, lanceolate, lenth: width more than 3 times-----33. **D.**
wattii
12. Leaflet number 7-11, ovate to elliptic oblong or obovate oblong to oblong; pods sickle shaped or flat oblong lanceolate
13. Stipules ovate lanceolate in shape, caducous; corolla absolutely white; ovule 1-3 ----
-----24. **D.**
reniformis
13. Stipules obtuse or acute, deciduous; corolla white or pale rose; ovule 1-2 often solitary -----
11. **D. kurzii**
11. Corolla not absolutely white
14. Minimum leaflet number more than 10; standard narrowly obovate in shape; ovule number 1-2 -----3. **D.**
cana
14. Minimum leaflet number not more than 10; standard orbicular in shape; ovule number 3-4 or 4
15. Lateral veins 5-7 pairs; pods oblong in shape -----1. **D.**
assamica
15. Lateral veins 9-12 or 9-13; pods lanceolate in shape
16. Inflorescence axillary and 8-5 cm long; seed dark brown in color -----
-----13. **D.**
lanceolaria

16. Inflorescence terminal and 10-15 cm long; seed reddish brown in color -----
-----17. **D.**
oliveri
1. Shrub or climber
17. Stamen diadelphous
18. Bract lanceolate in shape; stamen number 9; ovary glabrous -----8. **D.**
junghuhnii
18. Bracts oblong in shape; stamen number 10; ovary hairy
19. Leaflet number 5-9; bracts early caducous; ovule number only one -----15. **D.**
spinosa
19. Leaflet number 9-13 or 15-25; bracts persistent; ovule number 2, 3-4
20. Lateral veins 6-8 pairs; leaflets oblong with rounded to more or less emarginated apex; seed dark brown in color -----29. **D.**
stipulacea
20. Lateral veins 10- 12 pairs; leaflets ovate to elliptic oblong with obtuse and short mucronate apex; seed reddish brown in color -----32. **D.**
volubilis
17. Stamens monadelphous
21. Maximum leaflet number more than 30
22. Bracts and bracteoles early caducous; standard obovate in shape -----15. **D.**
mimosoides
22. Bracts and bracteoles persistent; standard orbicular in shape -----21. **D.**
pinnata
21. Maximum leaflet number not more than 20
23. Shrub
24. Standard obovate in shape; ovary glabrous; seeds light brown in color -----18. **D.**
ovata
24. Standard broadly ovate to orbicular in shape; ovary hairy; seeds reddish brown in color -----26.
D. *rostrata*
23. Woody vein or lianas or scandent shrub
25. Maximum leaflet number more than 15
26. Bracts and bracteoles persistent; calyx densely pubescent; pods membranous in texture -----31.
D. *velutina*

26. Bracts and bracteoles early caducous; calyx sparsely pubescent or glabrous; pods leathery in texture -----34. **D.**

yunnanensis

25. Maximum leaflet number not more than 15

27. Standard orbicular in shape

28. Leaflet number 7-9; bracts caducous; stamen number 10 -----10. **D.**

kingiana

28. Leaflet number 3-7; bracts persistent; stamen 9 -----27. **D.**

rubiginosa

27. Standard broadly ovate or ovate or round or obovate in shape

29. Calyx glabrous; pods falcate in shape, 1-4 seeded -----19. **D.**

parviflora

29. Calyx hairy; pods oblong in shape, 1-2 seeded

30. Scandent shrub; lateral veins 10- 15 pairs -----25. **D.**

rimosa

30. Woody vein; lateral veins 6 or 6-9 or 8-10 pairs

31. Stamen number 10; ovary glabrous -----6. **D.**

cumingiana

31. Stamen number 9; ovary pubescent or hairy along the suture

32. Leaflet leathery in texture; bracteoles persistent; wings ovate in shape -----
-----8. **D.**

henryana

32. Leaflet papery in texture; bracteole caducous; wings oblong in shape -----
-----4. **D.**

confertiflora

Dalbergia rostrata Graham ex Prain., J. Asiat Bengal, Pt. 2, Nat. Hist. 70(2): 45. 1901; Tagane et al., Nat. Hist. Bull. Siam Soc. 63(2): 141-151, 2019.

Scandent shrub to 5 m tall; young shoots and inflorescences puberulous to pubescent. Stipules small, caducous. Leaves 10-25 cm long; petioles 1-2 cm long; rachis 2-5 cm long, puberulous. Leaflets 3-5, elliptic to elliptic oblong, 5-12 by 3-7 cm, apex abruptly long acuminate, base obtuse to broadly cuneate, upper surface glabrous, lower surface globrous to puberulous; lateral veins 5-7 pairs, thin, tertiary veins and reticulation distinct on lower surface; petiolules 4-5 mm long. Inflorescences usually in leaf axils, sometimes subterminal, paniculate, 3-8 cm long; bracts and bracteoles small, caducous; pedicels ca 2.5 mm long. Calyx ca 5mm long, puberulous. Corolla white; standard broadly ovate to orbicular, ca 3 by 3 mm, emarginated, claw ca 2 mm long; wings ca 4.5 by 2mm, claw ca 2.5 mm long; keel ca 4 by 2 mm, claw ca 2.5 mm long. Stamens 9, in one bundle. Ovary hairy; ovules 2. Pods

oblong, 6-7.5 by 1.5-1.8 cm (immature), membranous, 1-2 seeded. Seeds reniform, ca 15.5 by 7 mm, reddish brown.

Distribution and habitat. India and Myanmar. According to the Tagane et al., Nat. Hist. Bull. Siam Soc. 63(2): 141-151, 2019, this species occurs in Myanmar, Taninthary Region, Mwae Taw Island. Kawthaung Township, 9°58' 41" N and 98°33' 26" E. In open wet places along margins of evergreen forests; near sea level to 800 m.

Selected specimen examined. Myanmar, Tanintharyi Region, Mwae Taw Island. Kawthaung Township, 9°58' 41" N and 98°33' 26" E., 17 May 2017, Tagane et al. MY 1946 (KYO! RAF! TNS!)

Dalbergia wattii C. B. Clarke, J. Linn. Soc., Bot. 25: 17. pl. 5. 1889; Prain, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 66(2): 451. 1897 & 70: 53. 1901 & Ann. Roy. Bot. Gard. (Calcutta) 10(1): 95. pl. 78. 1904; Thoth., Tax. Revis. Dalbergieae Ind. 177. 1987. Type: India, Manipur, Mayung, C. B. Clarke 42034 (holo-, K! iso-, CAL! K!).

Small trees, up to 10m high, branches glabrous. Leaves 12.5-17cm, petiole 1.5-2.5cm, rachis 6-7cm; stipules ovate-lanceolate; leaflets 9-11, subleathery, lanceolate, (4-7) by (1-1.5) cm, alternate or near-opposite, apex tapering, base tapering, glabrous above, puberulent below, more hair on midvein, the secondary veins ca. 10 pairs, not obvious, tertiary veins more obvious; petiole 1-2mm long. Inflorescences Panicles axillary, 3.5-5.5cm long, inflorescence branches, and pedicel are densely rusty pubescent; bracts lanceolate, bracteoles ovate-lanceolate, persistent; flower 6-8mm; pedicel 2-3mm; calyx ca. 2.5 mm long, glabrescent or sparsely pubescent; corolla white, orbicular, emarginated, ca. (5-6) by (5-6) mm, reflexed, claw ca. 2.5 mm, wings irregularly oblong, ca. 6 by 3 mm, oriculate, claws ca. 2.5mm, keel half-moon shape, ca. 5 by 2.5 mm, claws ca. 2.5mm long, oriculate; stamens 10 (5+5) diadelphous, ovary stipitate, glabrous; ovules 1-4. Pod oblong, (6-7) by (1.6-1.7) cm, apex blunt to sharp, base gradually narrows to a circle, leathery, glabrous, obvious reticulation to the seed, smooth; one seeded, reniform, ca. 9 by 5mm.

Distributin and habitat. India and Myanmar. Myanmar; Magway Region, Minbu District, Ngaphae township, Mann Reserved. Mixed deciduous forest.

Phenology. Flowering time is May. Fruiting time is November.

Selected Specimen examined. Myanmar, Magway Region, Minbu District, Ngaphae township, Mann Reserved, Pyae Pyae Win et al. PPW 072. (RAF! HITBC!)

Note. This species is endemic to India and newly record for Myanmar.

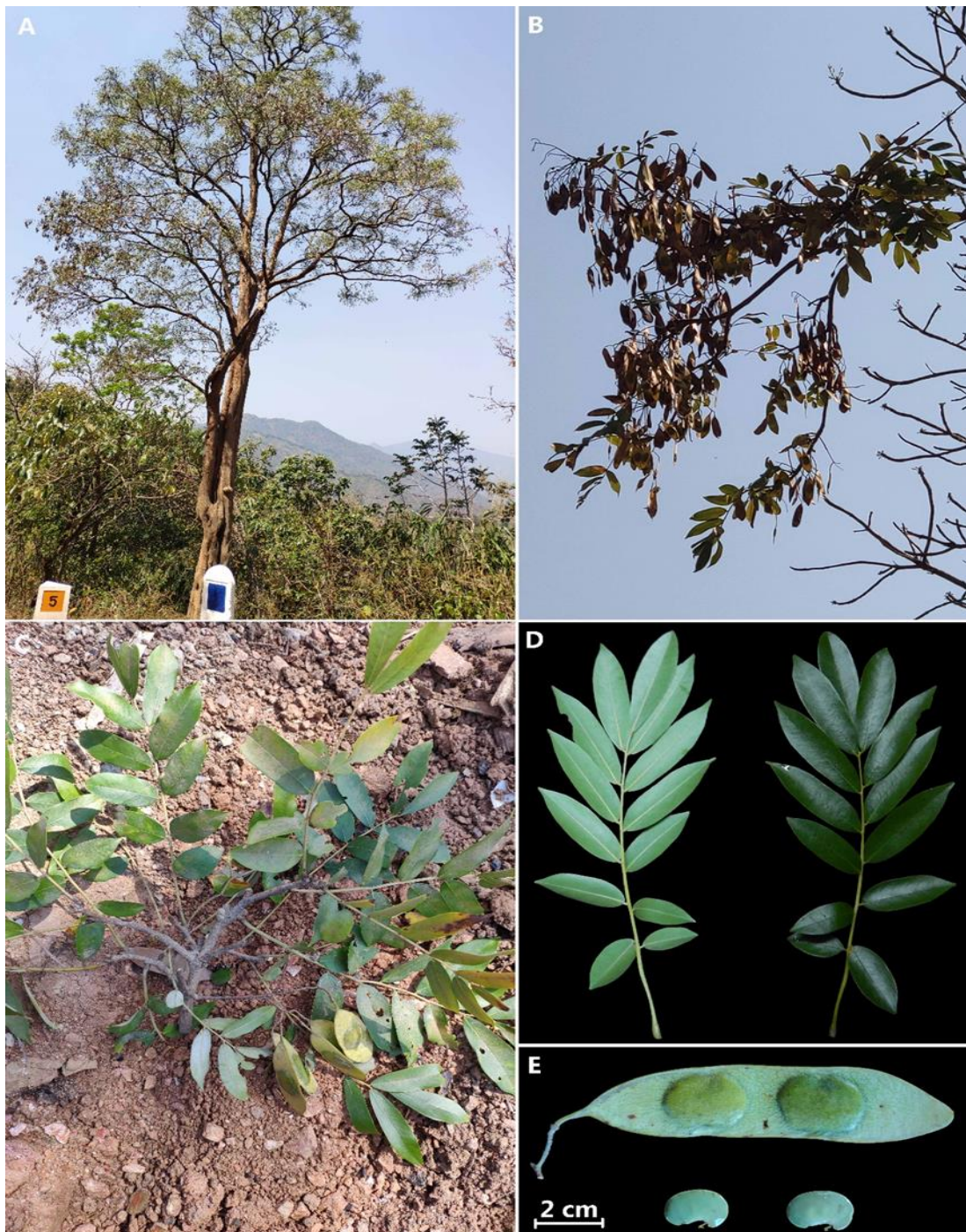


Figure 4. *Dalbergia wattii* C. B. Clarke. A. Tree; B. Leaf twig with fruits; C. Leaf twig with fruits D. Leaf E. Fruit and seeds. Photographs by Pyae Pyae Win.

Dalbergia mimosoides Franch., Pl. Delavay. 1: 187. 1890; Prain, J. Asiat. Soc. Bengal, Pt. 2, Nat. Hist. 70(2): 2, 56. 1901 & Ann. Roy. Bot. Gard. (Calcutta) 10(1): 49. pl. 25. 1904; T. C. Chen, Fl. Reip. Pop. Sin. 40: 104. 1994.

Shrubs, 4-6m tall, sometimes woody vines, branched glabrous, with lenticels, young branches densely rusty pubescent. Leaf is 6-10cm long, the petiole is 1-2cm long, and the leaf axis is 7-

9cm long, rusty pubescent; the stipules are ovate, early falling; leaflets 25-35 leaves, papery, linear oblong, (6-15) mm by [(2.5-) 3-5] mm, alternate, apex truncate, blunt or notched, base rounded or broadly wedge-shaped, sparsely rusty pubescent on both sides when young, falling off gradually, secondary veins 6-8 pairs, below color deep and obvious. The petiole is about 0.5 mm long and rusty pubescent. Inflorescences panicles axillary, 1.5-5cm long, shorter than compound leaves, Flowers are dense; inflorescence branches and pedicels are rust-colored pilose; bracts and bracteoles ovate, early fall; flower length is about 10mm; pedicel length is 1.5-2mm, pedicel apex is jointed; calyx campanulate, calyx tube length is about 2mm, Sparsely rusty puberulent, 5 calyx teeth, lowermost 1 lanceolate, longer than the remaining calyx teeth, 2 above connate, calyx teeth with marginal hairs; corolla white or yellowish, petals with long claws (flags have shorter claws), standard oblong-ovate, apex depression, (3.5-4) mm × (2-2.5) mm, straight, claw ca 1mm, wing flap obovate oblong, 3mm by 1.5mm, claw length is about 1.5mm, keel oval, 3mm by 1.5mm, claw 1.5mm; 9 (-10) stamens, monadelphous, the ovary is stipitate, hairy at along the suture, 2-3 ovules,. Pods oblong to band-shaped, [2.8-4 (-6)] cm by (0.9-1.2) cm, apex acute, often beak-shaped, base blunt or wedge-shaped, leathery, darker in color and densely reticulated at the seed, with the reticulate extending to the edges; 1 (-2) seeds, reniform, ca 10mm by 6mm.

Distribution. China, India, Bhutan and Myanmar. Myanmar: Kachin State, Putao District, near Naung Mung Village; Sagaing Region, Hkamti District, Hkamti Township, Htamathi Village, Nam Pa Gon and Htamathi Wildlife Sanctuary, Nam E Zu section. Tropical rainforest.

Phenology. Flowering time March-May; Fruiting time July-October.

Vernacular. Tawmagyi-nwe

Selected specimen examined. Myanmar, Kachin State, Putao District, near Naung Mung Village, Tan Yun-Hong et al. M 1627, 5-11-2017 (RAF! HITBC); Sagaing Region, Hkamti District, Hkamti Township, Htamathi Village, Nam Pa Gon, Yun-Hong et al. M 6087, 4 Dec:2019 (RAF! HITBC!); Htamathi Wildlife Sanctuary, Nam E Zu section, Yun-Hong et al. M 6429, 17 Dec: 2019. (RAF! HITBC!); Sagaing Region, Katha District, Bamauk Township, Zalone mountain area, Pyae Pyae Win et al. PPW 081, 24-3-2019 (RAF! HITBC!).

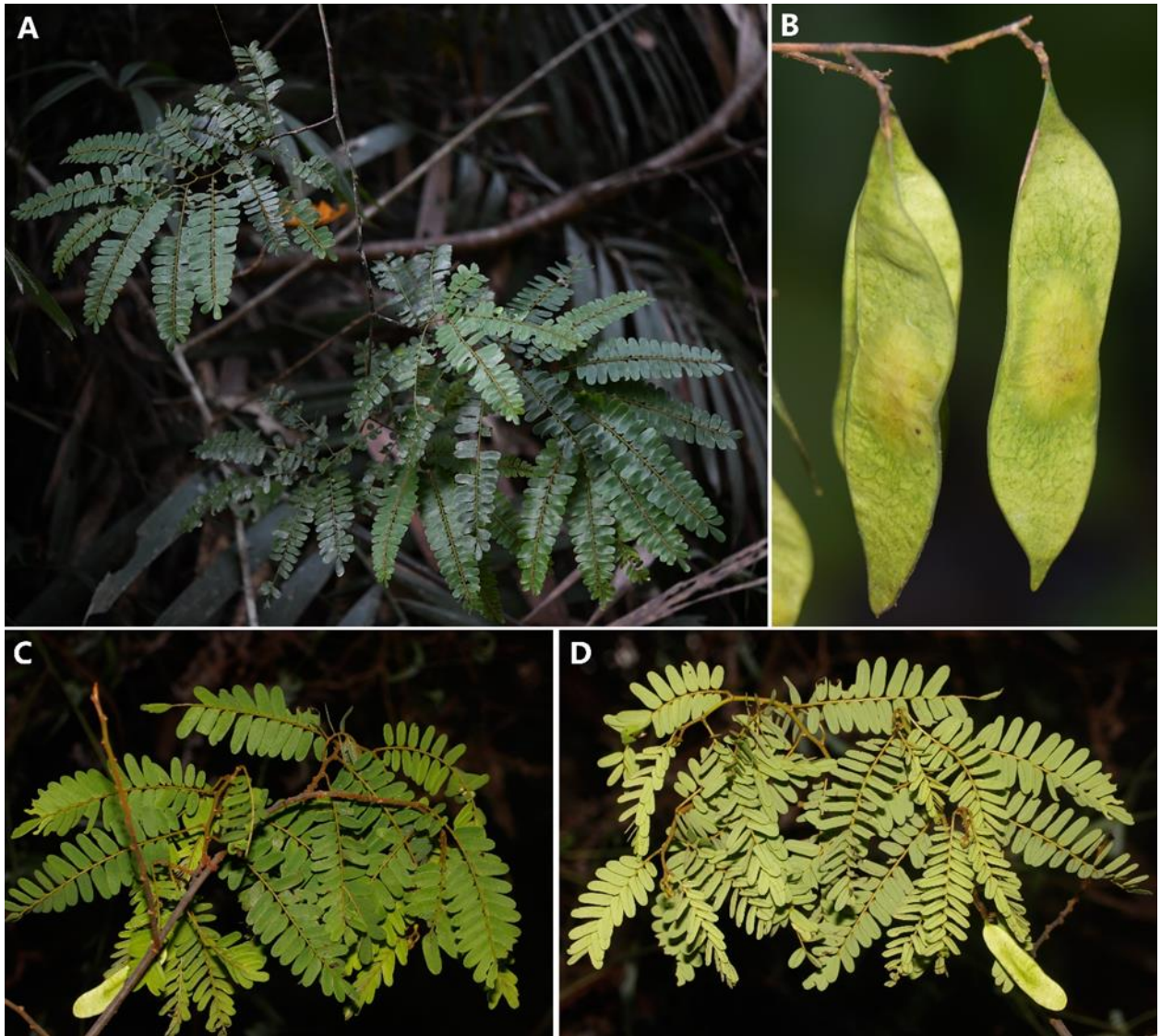


Figure 5. *Dalbergia mimosoides* Franch. A. Leaf twig; B. Fruit; C. Leaf twig; D. Leaf twig with fruit. Photographs by Ding Hong-Bo.

4. Discussion

In accordance with materials collected from this extensive field works and identifications, this study has confirmed presence of 36 *Dalbergia* species from five sections to be presented, and *D. wattii* C. B. Clarke. is newly recorded in this study for Myanmar. *Dalbergia oliverioides* sp. nov is potentially new species by sharing some morphological characters with *D. oliveri*, however the color of the bark and density of hardwood were different, moreover, the molecular phylogeny showed very close relationship between *D. oliverioides* and *D. oliveri*. Therefore, we determined as potentially new species, however, due to incomplete information for this species, we need to further study in the future for confirmation. *D. mimosoides* is similar to *D. stipulacea* and *D. pinnata*. According to the database of ILDIS, GBIF, JSTOR and TROPICOS, this species is distributed in China, Yunnan provenance to India (Assam) and Bhutan. There is lack of distribution data for Myanmar and specimens are not found in K, BM, NL, E, US, P and NY herbarium, moreover,

D. mimosoides is not included in the checklist of Myanmar. However, Thothathri, 1987 and Li, 2017 has recorded the distributed in Myanmar in their publication, although the depository of specimen is not mentioned. We have confirmed the occurrence of *D. mimosoides* in northern Myanmar (near around Naung Mung Village, Putao District, Kachin State, in 2017) and Sagaing Region (Nam Pa Gon and Htamathi Wildlife Sanctuary, Nam E Zu section, Htamathi Village, Hkamti District, Hkamti Township, in 2019 and Zalone mountain area, Bamouk Township, Katha District, in 2019) and it possible extend to north part of Laos and Thailand, and the specimens collected in Myanmar are deposited in the RAF and HITBC. However, according to the Thothathri, 1987, Li, 2017 and website database of ILDIS and GBIF, *D. candentensis* and *D. millettii* were distributed in Myanmar and the depository of specimens are not mentioned in herbarium of (RAF, ASM, RANG) Myanmar, herbarium of HITBC, China and online herbaria, such as (K, E, BM, US, NY). The species distribution in Myanmar has not confirmed yet, hence calls further study and floral survey for confirmation. *D. wattii* is endemic to India and now we found it in Myanmar, Magway region, Minbu District, Ngaphae township, Mann reserved in 2019. Additionally, we were counted *D. rostrata* into the checklist of Myanmar, it was published as new recorded for Myanmar (Tagane, 2019). This species has been recorded widely from India and Sri Lanka in the west to western New Guinea in the east (Adema et al., 2016; Gardner et al., 2016). They collected in Tanintharyi Region, Mwae Taw Island, Kawthaung Township, Myanmar. *D. prainii* Thoth., *Dalbergia pseudo-ovata* Thoth. and *Dalbergia glomeriflora* Kurz. have high potential to be endemic to Myanmar and *D. prainii* is local endemic to Chin State, however, further investigation is needed.

The *Dalbergia* species occurrences in higher political units, i.e. states and regions, and the local names are listed in angiosperms and gymnosperms checklist of Myanmar (Kress, 2003), moreover, the list is lack of identification keys. However, genus *Dalbergia* in this checklist was not followed the modern revision as it was based on the previous checklist published in 1954 and the complexity of the taxonomic treatment and changes over last century (Baker, J. G. treated Flora of British India Vol.2 and described (11) species from Myanmar in 1876; Bentham, Kurz, W.S. (1877) treated Flora of British Burma Vol.1 included 15 Myanmar *Dalbergia* species; Prain, D. 1904. The species of *Dalbergia* of Southeastern Asia; Thothathri, K. 1972. Studies in Leguminosae 15. New taxa of *Dalbergia* Linn.f. from India and Burma; Thothathri, K. 1975 (a) Studies in Leguminosae 20. Three new species of *Dalbergia* L.f. from Myanmar; Thothathri, K. 1975 (b). Studies in Leguminosae 25. New taxa in the genus *Dalbergia* Linn.f.; Thothathri, K. 1983 (a). Critical notes on the genus *Dalbergia* Linn.f; Thothathri, K. 1983 (b). Studies in Leguminosae 31. New taxa and notes on *Dalbergia* Linn.f. and Derris Lour; Tagane, S. 2019. Contribution to the flora of Myanmar III: New records of 10 woody species from the Mergui Archipelago of southern Myanmar). In this study, we excluded *D. congesta* from the checklist of Myanmar, J. C. Prager collected from Myanmar and D. Prain identified as a *D. congesta* in 1904. On the other hand, *D. congesta* was climber and J. C. Prager collected is as a tree. In 1975, K. Thothathri published “Three new species of genus *Dalbergia* from Myanmar” and one of the species is *D. prainii*. It was the species that D. Prain misidentified as a *D. congesta* in 1904. He described as a *D. prainii* in his paper in 1975 and *D. prainii* is endemic species for Myanmar. Moreover, *D. kerrii*, *D. cumingiana*, *D. henryana*, *D. junghuhnii*, *D. latifolia* and *D. rubiginosa* were listed

in the checklist of Myanmar based only on Kress (2003) and also no herbarium specimens are available for Myanmar. Although the final polishing is needed for the monograph publication, the taxonomic revision of genus *Dalbergia* has accomplished in this study, and we have aggregated the synonyms of *D. purpurea* into *D. Kurzii*, *D. paniculata*, *D. nigrescens*, *D. hemsleyi* and *D. maymyensis* into *D. lanceolaria*, *D. prazeri* into *D. oliveri*, *D. glomeriflora* into *D. ovata*, *D. foliacea* into *D. rimosa* and *D. collettii* into *D. yunnanensis* respectively following relevant literature and International Legume Database and Information Service (<https://ildis.org/LegumeWeb/> ILDIS) version 10. For example, Thothathri (1975 b) described seven new varieties and two new forma in the genus *Dalbergia*, and Thothathri (1983 b) published the taxonomic revision in “Critical Notes On the Genus *Dalbergia* Linn.f.”.

The results of comparison of the traditional classification and molecular phylogeny provides confirms the coincidence of molecular phylogeny and traditional classification. The phylogenetics analysis provides the important information for investigations on conservation genetics and phylogenies of *Dalbergia* and Fabaceae.

5. Conclusion

The present study is the preliminary step into future studies of *Dalbergia* in Myanmar. The present study updated the checklist of genus *Dalbergia* of Myanmar. It provides the number of species, local distribution ranges and respective conservation status. The present study is mainly based on my own collections of specimens, herbarium specimen sheets available, relevant literature and online databases. This study critically revealed the species diversity of genus *Dalbergia* in Myanmar for the first time after British Burma. Additionally, we generated the occurrence map of genus *Dalbergia* in Myanmar with Argic software, thus, this study provided the distribution range and species richness of *Dalbergia* in Myanmar.

The present study assessed the taxonomic status for all Myanmar *Dalbergia* species, taxonomic treatment for each species with illustration and comparison with traditional classification and molecular classification. It confirmed the species level of Myanmar *Dalbergia* species and has a closed relationship to each species. It provides the fundamental information for genetic and conservation studies of *Dalbergia* species in Myanmar. The following recommendations are applied for the better understanding the plant diversity of Myanmar and contributing the conservation priority settings:

- (1) Much more botanical collections and explorations are needed to better understandg the genus *Dalbergia* of Myanmar and distribution pattern that are the base line information for the conservation planning.
- (2) International cooperation of biodiversity research, taxonomists training and conservation should be accelerated so as to better understand the biodiversity of Myanmar.
- (3) Genus *Dalbergia* is consist of valuable timber species, thus the proection of illegal logging is crucial, therefore the implementation of DNA barcoding is urgently needed.
- (4) Species composition and genetic diversity of the political units in Myanmar is critical for the biodiversity assessment in Myanmar.

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