Traditional antidiabetic plants from Indonesia

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Abstract

Background: Indonesia with its widely varied geographical features is rich with knowledge and practice in the utilization of plants for maintaining health and treating diseases, including for diabetes mellitus. This review summarizes the result of ethnopharmacological studies mentioning the application of plants to treat diabetes mellitus conducted in Indonesia.

Methods: The online literature search using Google Scholar (https://scholar.google.com/) was carried out to collect data on the use of plants for traditional treatment of diabetes mellitus from ethnobotanical studies in Indonesia published in 2014-2018.

Results: The traditional medicinal plants listed in this article are compiled from 67 studies conducted in 18 provinces and 37 defined ethnicities. There are 132 species of antidiabetic plants from 53 families reported. The most popular plants with multiple uses in different places include *Orthosiphon aristatus* (Blume) Miq., *Persea americana* Mill., and *Syzygium polyanthum* (Wight) Walp. Leaves, decoction, and oral were found to be the most frequently used plant parts, preparation method, and administration route of those antidiabetic plants, respectively.

Conclusions: Indonesia has a large number of traditional antidiabetic plants that are potentially developed further into standardized herbal medicines to enable their uses in formal healthcare systems.

Keywords: Ethnopharmacology, Indonesia, medicinal plants, antidiabetic activities, antidiabetic compounds.

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Background

Traditional medicines have a long history of use in maintenance of health as well as prevention and treatment, particularly for chronic diseases (WHO 2013). *Jamu* is the Indonesian traditional herbal medicine and the prominent representative of Indonesian traditional medicines. Although conventional medicine is essential in the Indonesian healthcare system, the use of *jamu* is still popular in rural areas. A survey demonstrated that 49.53% of the Indonesian citizens used *jamu* and 95.6% of them reported the benefits of their *jamu* intake (Balitbangkes 2010; Elfahmi *et al.* 2014).

One of the goals of traditional medicine is to be included as an integral aspect of a national health system. To be in such a role, it requires a strong evidence base that will assure safety and efficacy for patients (Cordell 2011). The government of Indonesia had established a Science Based *Jamu* Development program in 2010 to achieve *jamu* status as an excellent Indonesian brand and specific traditional medicine practice. At the first stage of the Science Based *Jamu* Development,

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ethnopharmacological studies shall obtain baseline data of the traditional utilization of medicinal plants (Aditama 2015; Purwadianto 2015). Such studies were systematically conducted by National Research on Medicinal Plants and *Jamu* (*Riset Nasional Tanaman Obat dan Jamu*, *RISTOJA*) program in 2012, 2015 and 2017. Other than *RISTOJAs*, the ethnobotanical and ethnopharmacological studies were also simultaneously conducted elsewhere in Indonesia.

Those studies resulted in a profile of medicinal plants used by people from almost entire ethnicities nationwide. The government had set a priority system for the medicinal plants that would be developed further in a Science Based *Jamu* Development program, which allowed plants traditionally used for treating diseases with high prevalence to be prioritized (Dewoto 2007). In Indonesia, diabetes mellitus is among the top three causes of death with the prevalence in adults of 6.7% (WHO 2012; IDF 2017). This article reviews the ethnopharmacological use of Indonesian plants indicated for treating diabetes mellitus, covering studies published 2004-2018. It includes the geographical, botanical, and practical aspects of the utilization of plants for the aforementioned purpose. This article also describes the antidiabetic-related activities and the antidiabetic compounds of the most cited plants.

Materials and Methods

The online literature search using Google Scholar (https://scholar.google.com/) was carried out with the search terms of ethnobotany AND medicinal plants AND diabetes AND Indonesia, both in English and Indonesian. Time of publication was customized to 2014-2018. This review was limited to 67 articles that mentioned the use of plants for treating diabetes mellitus. The information of the province where the respective study took place and the ethnicity of the surveyed respondents is listed in the geographical aspect. The botanical aspect lists the taxa (species, genus, and family) of each plant that is used for treating diabetes mellitus. The names are written according to the accepted name at The Plant List (http://www.theplantlist.org/), along with the common English name. In the case of the English name is not available, the local name of the plant is used. The ethnopharmacological aspect describes the parts of plants used, method of preparation, and route of administration of each plant. The indices used and the most important antidiabetic plants, if data is available, are described in the quantitative aspect of this study.

Geographical aspects

The ethnopharmacological surveys mentioning the use of plants for treating diabetes mellitus have been conducted in the major islands of Sumatra, Java, Bali, Kalimantan, Sulawesi, and Maluku (Figure 1, Table 1).

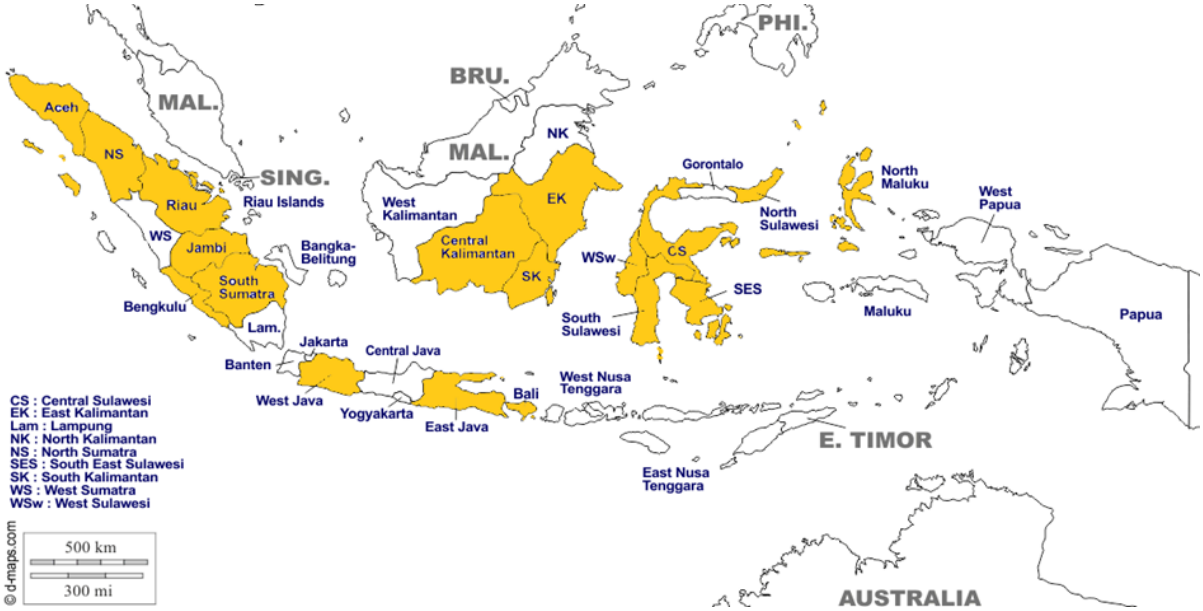

Figure 1. Location of the surveyed provinces (yellow), modified from d-map.com (d-maps 2020)

Table 1. The plants traditionally used for treating diabetes mellitus in Indonesia

Family and scientific name	Vernacular name	Province/people	Plant part used/preparation method/administration route/dose	Reference
ACANTHACEAE				
Acanthus ilicifolius L.	Holy mangrove	West Kalimantan/-	Leaves and roots/decocted/oral/twice a day	(Ernianingsih *et al.* 2014)
Andrographis paniculata (Burm.f.) Nees	King of bitter	Central Sulawesi/Bungkudi	Leaves/decocted/oral/three times a day	(Hermin *et al.* 2016)
		Riau/-	Leaves/decocted/oral/-	(Safitri *et al.* 2015)
		West Java/-	Leaves/decocted/oral/-	(Emilda *et al.* 2017)
		Central Sulawesi/Seko	-/-/-/-	(Tapundu *et al.* 2015)
Ruellia tuberosa L.	Fever root	Southeast Sulawesi/Wolia	Leaves/decocted/oral/-	(Slamet & Andarias 2018)
Sericocalyx crispus (L.) Bremek.	*Keje beling*	Central Sulawesi/Taa Wana	Leaves/decocted/oral/-	(Akhsa *et al.* 2015)
Strobilanthes crispa Blume	*Keji beling*	North Maluku/-	Leaves/-/-/-	(Pitra *et al.* 2017)
		Central Sulawesi/Mori	Leaves/decocted/oral/three times a day	(Idris *et al.* 2018)
		North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
ACTINIDIACEAE				
Saurauia vulcani Korth.	*Pirdot*	North Sumatra/Karo	Leaves/decocted/oral/two-three times a day	(Situmorang *et al.* 2015)
AMARANTHACEAE				
Amaranthus spinosus L.	Spiny amaranth	Central Sulawesi/Taa Wana	Stems/decocted/oral/-	(Akhsa *et al.* 2015)
AMARYLLIDACEAE				
Allium cepa L.	Onion	North Sumatra/Karo	Bulbs/prepared into a concoction/oral and topical/-	(Nasution *et al.* 2018)
		North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
Allium chinense G.Don	Chinese onion	North Sumatra/Batak Simalungun	Bulbs/-/-/-	(Silalahi *et al.* 2015)
Allium sativum L.	Garlic	North Sumatra/Karo	Bulbs/prepared into a concoction/oral and topical/-	(Nasution *et al.* 2018)
ANACARDIACEAE				
Lannea coromandelica (Houtt.) Merr.	Indian ash tree	Central Sulawesi/Kaili Ledo	Barks/-/-/-	(Dianto *et al.* 2015)
Mangifera indica L.	Mango	Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
ANNONACEAE				
Annona muricata L.	Soursop	West Java/-	Leaves/decocted/oral/-	(Emilda *et al.* 2017)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
Annona squamosa L.	Sugar apple	Southeast Sulawesi/Wolia	Leaves/decocted/oral/-	(Slamet & Andarias 2018)
APIACEAE				
Centella asiatica (L.) Urb.	Asiatic pennywort	North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
Eryngium foetidum L.	Long coriander	East Java/-	Whole plants/-/-/-	(Batoro & Siswanto 2017)
Pimpinella pruatjan Molk.	*Purwoceng*	East Java/-	Whole plants/-/-/-	(Batoro & Siswanto 2017)

APOCYNACEAE				
Alstonia pneumatophora Baker ex Den Berger	Marsh pulai	North Sumatra/Batak Simalungun	Barks/-/-/-	(Silalahi *et al.* 2015)
Alstonia scholaris (L.) R. Br.	Blackboard tree	Central Sulawesi/Kaili Ledo	Barks/-/-/-	(Dianto *et al.* 2015)
		Southeast Sulawesi/Buton	Barks/decocted/oral/-	(Indrayangingsih *et al.* 2015)
		North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
Catharanthus roseus (L.) G.Don	Madagascar periwinkle	East Java/-	Flowers, leaves and stems/-/-/-	(Batoro & Siswanto 2017)
		Central Sulawesi/Tialo	Leaves and roots/decocted/oral/-	(Anggraini *et al.* 2016)
		North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
		Riau/-	Whole plants/decocted/oral/-	(Safitri *et al.* 2015)
ARECACEAE				
Areca catechu L.	Betel nut	Central Sulawesi/Mori	Fruits/-/-/-	(Idris *et al.* 2018)
		Central Sulawesi/Topo Uma	Fruits/brewed/oral/twice a day	(Yulia *et al.* 2017)
		Central Sulawesi/Dondo	Seeds/-/-/-	(Fajrin *et al.* 2015)
Arenga pinnata (Wurmb) Merr.	Sugar palm	South Sulawesi/-	Exudates/-/-/-	(Ariandi & Khaerati 2016)
		North Sumatra/Batak Simalungun	Roots/-/-/-	(Silalahi *et al.* 2015)
Cocos nucifera L.	Coconut	North Sumatra/Batak Simalungun	Fruits and roots/-/-/-	(Silalahi *et al.* 2015)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
Nypa fruticans Wurmb	Mangrove palm	North Sumatra/Karo	Leaves/-/-/-	(Nasution *et al.* 2018)
		North Sumatra/Batak Simalungun	Roots/-/-/-	(Silalahi *et al.* 2015)
ASPARAGACEAE				
Sansevieria trifasciata Prain	Snake plant	South Sumatra/-	Exudates and roots/-/-/-	(Kartika 2014)
BASELLACEAE				
Anredera cordifolia (Ten.) Steenis	Mignonette vine	Central Sulawesi/-	Leaves/decocted and mixed with honey/oral/-	(Ifandi *et al.* 2016)
BORAGINACEAE				
Cordia subcordata Lam.	Kerosene wood	Central Sulawesi/Kaili Ledo	Leaves/-/-/-	(Dianto *et al.* 2015)
CARICACEAE				
Carica papaya L.	Papaya	South Sulawesi/-	Leaves/-/-/-	(Ariandi & Khaerati 2016)
		South Sulawesi/-	Leaves/decocted/oral/-	(Wahidah 2013)
		West Java/-	Leaves/decocted/oral/-	(Gunarti & Nurlina 2018)
		North Sumatra/Batak Karo	Leaves/cooked/oral/-	(Silalahi & Nisyawati 2018)
		North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)

CLUSIACEAE				
Garcinia × *mangostana* L.	Purple mangosteen	Central Sulawesi/Kulawi	Fruits/-/-/-	(Arham *et al.* 2016)
		Riau/Mandailing	Fruits/-/-/-	(Nilawati *et al.* 2017)
		Riau/-	Fruits/decocted/oral/two-three times a day	(Safitri *et al.* 2015)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
COMBRETACEAE				
Terminalia catappa L.	Indian almond	Southeast Sulawesi/Moronene	Barks/decocted/oral/twice a day	(Indrawati *et al.* 2014)
COMPOSITAE				
Ageratum conyzoides (L.) L.	Goat weed	West Sulawesi/-	Leaves/decocted/oral/twice a day	(Syamsiah 2014)
		West Sulawesi/Mamuju	Leaves/-/-/-	(Syamsiah *et al.* 2016)
		North Sumatra/Batak Simalungun	Leaves/-/-/-	(Silalahi *et al.* 2015)
Blumea balsamifera (L.) DC.	Nagi camphor	West Java/-	Leaves/decocted/oral/-	(Emilda *et al.* 2017)
		North Sumatra/Karo	Leaves/juiced/oral /-	(Nasution *et al.* 2018)
Chromolaena odorata (L.) R.M.King & H.Rob.	Siam weed	South Sulawesi/-	Leaves/-/-/-	(Tambaru 2017)
Clibadium surinamense L.	Jackass breadnut	North Sumatra/Batak Simalungun	Leaves/-/-/-	(Silalahi *et al.* 2015)
Eupatorium inulifolium Kunth	*Komba komba*	North Sumatra/Batak Simalungun	Leaves/-/-/-	(Silalahi *et al.* 2015)
		Southeast Sulawesi/Moronene	Leaves/prepared into a concoction/oral/-	(Siharis & Fidrianny 2016)
Gynura procumbens (Lour.) Merr.	*Sambung nyawa*	West Sulawesi/Mandar	Leaves/decocted/oral/-	(Rusmina *et al.* 2015)
Helianthus annuus L.	Sunflower	Central Sulawesi/Taa Wana	Roots/decocted/oral/-	(Akhsa *et al.* 2015)
Taraxacum campylodes G.E.Haglund	Puffball	North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
Tithonia diversifolia (Hemsl.) A.Gray.	Mexican sunflower	West Java/-	Barks, flowers, and leaves/decocted/oral/-	(Kodir *et al.* 2017)
		South Sulawesi/-	Leaves/-/-/-	(Tambaru 2017)
Vernonia amygdalina Delile	Bitterleaf	East Kalimantan/Kutai	Leaves/decocted/oral/-	(Hadijah *et al.* 2016)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
COSTACEAE				
Cheilocostus speciosus (J.Koenig) C.D.Specht	Crepe ginger	Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
CUCURBITACEAE				
Cucurbita moschata Duchesne	Pumpkin	Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
Momordica charantia L.	Bittermelon	Central Sulawesi/-	Fruits and seeds/cooked/oral/-	(Susila *et al.* 2017)
		West Java/-	Fruits and seeds/cooked/oral/-	(Emilda *et al.* 2017)
		West Java/-	Leaves/-/-/-	(Malini *et al.* 2017)
		North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)

DIPTEROCARPACEAE				
Cotylelobium melanoxylon (Hook.f.) Pierre	*Raru*	North Sumatra/Karo	Barks/decocted/oral/twice a day	(Situmorang *et al.* 2015)
Shorea balangeran Burck	Red balau	South Kalimantan/-	Barks/-/-/-	(Kissinger *et al.* 2015)
Shorea balanocarpoides Symington	White meranti	North Sumatra/Karo	Barks/decocted/oral/twice a day	(Situmorang *et al.* 2015)
EBENACEAE				
Diospyros celebica Bahk	Black ebony	Central Sulawesi/Kaili Ija	Leaves/decocted/oral/-	(Megawati *et al.* 2016)
HYPERICACEAE				
Cratoxylum arborescens (Vahl) Blume	*Gerunggang*	Central Kalimantan/-	Barks/-/-/-	(Kissinger *et al.* 2015)
IRIDACEAE				
Eleutherine bulbosa (Mill.) Urb.	Tears of the Virgin	North Sumatra/Karo	Whole plants/decocted/oral/-	(Nasution *et al.* 2018)
LAMIACEAE				
Hyptis capitata Jacq.	Knobweed	Central Sulawesi/Banggai	Whole plants/decocted/oral/three times a day	(Khairiyah *et al.* 2016)
Ocimum tenuiflorum L.	Holy basil	Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
Orthosiphon aristatus (Blume) Miq.	Java tea	West Java/-	Leaves/-/-/-	(Mariani *et al.* 2015)
		West Java/-	Leaves/-/-/-	(Malini *et al.* 2017)
		West Java/-	Leaves/decocted/oral/-	(Mulyani *et al.* 2018)
		Central Sulawesi/-	Leaves/juiced/oral/-	(Arnold *et al.* 2017)
		Central Sulawesi/Banggai	Whole plants/-/-/-	(Khairiyah *et al.* 2016)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
		West Kalimantan/-	Roots/-/-/-	(Aminah *et al.* 2016)
		North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
Plectranthus scutellarioides (L.) R.Br.	Coleus	North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
Plectranthus sp.	*Bunga bebek*	Central Sulawesi/Mori	Leaves/-/-/-	(Idris *et al.* 2018)
LAURACEAE				
Cinnamomum burmanni (Nees & T.Nees) Blume	Cinnamon	North Sumatra/Karo	Barks/decocted/oral/one-two times a day	(Situmorang *et al.* 2015)
		North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
Persea americana Mill.	Avocado	North Sumatra/Simalungun	Leaves/-/-/-	(Situmorang & Sihombing 2018)
		North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
		South Sumatra/-	Fruits, leaves, and seeds/-/-/-	(Kartika 2014)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
		Southeast Sulawesi/Wolia	Leaves/decocted/oral/-	(Slamet & Andarias 2018)
		Central Sulawesi/Kaili Ija	Leaves/decocted/oral/-	(Bana *et al.* 2016)
		West Java/-	Leaves/decocted/oral/-	(Mutaqin *et al.* 2016)
LEGUMINOSAE				
Archidendron pauciflorum (Benth.) I.C.Nielsen	*Jengkol*	West Java/-	Fruits/-/-/-	(Malini *et al.* 2017)
		West Kalimantan/Dayak	-/-/-/-	(Efremila *et al.* 2015)

Leucaena leucocephala (Lam.) de Wit	River tamarind	Southeast Sulawesi/Wolia	Fruits/brewed (after dry-fried)/oral/-	(Slamet & Andarias 2018)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
		West Java/-	Seeds/-/-/-	(Malini *et al.* 2017)
		Bali/-	Seeds/juiced/oral/-	(Oktavia *et al.* 2017)
Parkia speciosa Hassk.	*Petai*	West Kalimantan/Dayak Ahe	-/-/-/-	(Sari *et al.* 2014)
		West Kalimantan/-	Roots/-/-/-	(Aminah *et al.* 2016)
Phaseolus vulgaris L.	Common bean	North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
Vigna unguiculata (L.) Walp.	Cowpea	Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
LOGANIACEAE				
Strychnos nux-vomica L.	Poison nut	North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
MALVACEAE				
Durio zibethinus L.	*Durian*	Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
Guazuma ulmifolia Lam.	West Indian elm	North Sumatra/Karo	Leaves/decocted/oral/twice a day	(Situmorang *et al.* 2015)
Hibiscus sabdariffa L.	Roselle	Central Sulawesi/Banggai	Flowers/-/-/-	(Khairiyah *et al.* 2016)
		South Sumatra/-	Flowers and leaves/-/-/-	(Kartika 2014)
Kleinhovia hospita L.	Guest tree	Central Sulawesi/Dondo	Leaves/-/-/-	(Fajrin *et al.* 2015)
Pterospermum celebicum Miq.	*Bayur*	Central Sulawesi/Kulawi	Roots/-/-/-	(Arham *et al.* 2016)
		Central Sulawesi/-	Roots/boiled in coconut sap/oral/-	(Arnold *et al.* 2017)
Theobroma cacao L.	Cocoa tree	North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
MELIACEAE				
Azadirachta indica A.Juss.	Neem	Central Sulawesi/-	Leaves/decocted/oral/-	(Ifandi *et al.* 2016)
		Central Sulawesi/Seko	-/-/-/-	(Tapundu *et al.* 2015)
		East Java/-	Leaves/decocted/oral/-	(Sodirun *et al.* 2016)
Lansium parasiticum (Osbeck) K.C.Sahni & Benne	*Langsat*	Central Sulawesi/Taa Wana	Leaves/decocted/oral/-	(Akhsa *et al.* 2015)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
Swietenia mahagoni (L.) Jacq.	West Indian mahogany	West Java/-	Seeds/-/-/-	(Malini *et al.* 2017)
		North Sumatra/Karo	Seeds/decocted/oral/one-two times a day	(Situmorang *et al.* 2015)
MENISPERMACEAE				
Arcangelisia flava (L.) Merr.	Yellow root	West Kalimantan/-	Leaves, roots, and stems/-/-/-	(Mulyadi *et al.* 2014)
		Southeast Sulawesi/Moronene	Stems/decocted/oral/three times a day	(Setiawan & Qiptiyah 2014)
Tinospora crispa (L.) Hook. f. & Thomson	Bitter grape	Central Sulawesi/-	Leaves and stems/-/-/-	(Tudjuka *et al.* 2014)
		Southeast Sulawesi/Wolia	Stems/decocted/oral/-	(Slamet & Andarias 2018)
		North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
		North Sumatra/Batak Simalungun	Stems/-/-/-	(Silalahi *et al.* 2015)
MORACEAE				
Artocarpus altilis (Parkinson ex F.A.Zorn) Fosberg	Breadfruit	Southeast Sulawesi/Wolia	Leaves/decocted/oral/-	(Slamet & Andarias 2018)
		South Sulawesi/-	Leaves/-/-/-	(Ariandi & Khaerati 2016)
		West Kalimantan/Dayak Iban	Leaves/-/-/-	(Pradityo *et al.* 2016)
		North Sumatra/Karo	Leaves/decocted/oral/twice a day	(Situmorang *et al.* 2015)

Artocarpus elasticus Reinw. ex Blume	*Terap*	North Sumatra/Batak Simalungun	Barks/-/-/-	(Silalahi *et al.* 2015)
Artocarpus heterophyllus Lam.	Jackfruit	Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
Ficus septica Burm.f.	Septic fig	North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
		North Sulawesi/Minahasa	-/-/-/-	(Arini 2017)
Morus alba L.	White mulberry	North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
MORINGACEAE				
Moringa oleifera Lam.	Drumstick tree	Bengkulu/-	-/-/-/-	(Kasrina & Veriana 2014)
MUNTINGIACEAE				
Muntingia calabura L.	Jamaica cherry	Southeast Sulawesi/Wolia	Leaves/decocted/oral/-	(Slamet & Andarias 2018)
		West Java/-	Leaves/decocted/oral/-	(Gunarti & Nurlina 2018)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
MUSACEAE				
Musa × *paradisiaca* L.	Banana	South Sumatra/-	Fruits/-/-/-	(Kartika 2014)
MYRTACEAE				
Baeckea frutescens L.	*Rambuhatap*	Central Kalimantan/-	Leaves/-/-/-	(Kissinger *et al.* 2015)
Psidium guajava L.	Guava	South Sumatra/-	fruits, seeds and leaves/-/-/-	(Kartika 2014)
		North Sumatra/Batak Simalungun	Leaves/-/-/-	(Silalahi *et al.* 2015)
		North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
		Central Sulawesi/Kaili Moma	Seeds/-/-/-	(Islami *et al.* 2017)
		Central Sulawesi/Kulawi	Fruits/-/-/-	(Arham *et al.* 2016)
Syzygium aqueum (Burm.f.) Alston	Watery rose apple	South Sumatra/-	Flowers, fruits, and seeds/-/-/-	(Kartika 2014)
Syzygium cumini (L.) Skeels	Java plum	Southeast Sulawesi/Wolia	Barks/decocted/oral/- or Fruits/unprocessed/oral/-	(Slamet & Andarias 2018)
		Southeast Sulawesi/Moronene	Barks/decocted/oral/twice a day	(Indrawati *et al.* 2014)
		North Sulawesi/Bolaang Mongondow	-/-/-/-	(Arini 2017)
		North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
Syzygium malaccense (L.) Merr. & L.M.Perry	Malay apple	Central Sulawesi/Kaili Ledo	Barks/-/-/-	(Dianto *et al.* 2015)
Syzygium polyanthum (Wight) Walp	Indonesian bayleaf	North Sumatra/Batak Simalungun	Leaves/-/-/-	(Silalahi *et al.* 2015)
		North Sumatra/Karo	Leaves/decocted/oral/-	(Nasution *et al.* 2018)
		North Sumatra/Karo	Leaves/decocted/oral/twice a day	(Situmorang *et al.* 2015)
		North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
		South Sumatra/-	Leaves/-/-/-	(Kartika 2014)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
		Aceh/-	Leaves/decocted/oral/-	(Ernilasari *et al.* 2018)

Syzygium sp.	-/-/-/-	North Sulawesi/Sangir	-/-/-/-	(Arini 2017)
ORCHIDACEAE				
Goodyera rubicunda (Blume) Lindl.	*Gadong harangan*	North Sumatra/Batak	Seeds/-/-/-	(Silalahi & Nisyawati 2015)
Phaius callosus (Blume) Lindl.	Callousy phaius	North Sumatra/Batak	Seeds/-/-/-	(Silalahi & Nisyawati 2015)
OXALIDACEAE				
Averrhoa bilimbi L.	Cucumber tree	South Sumatra/-	Fruits and leaves/-/-/-	(Kartika 2014)
Averrhoa carambola L.	Star fruit	North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
PASSIFLORACEAE				
Passiflora foetida L.	Stinking passionflower	Southeast Sulawesi/Buton	Leaves/-/-/-	(Indrayangingsih *et al.* 2015)
PHYLLANTACEAE				
Phyllanthus amarus Schumach. & Thonn.	Hurricane weed	West Kalimantan/-	Roots/-/-/-	(Aminah *et al.* 2016)
Bischofia javanica Blume	Java cedar	North Sumatra/Batak Simalungun	Barks and roots/-/-/-	(Silalahi *et al.* 2015)
		North Sumatra/Karo	Barks/fermented or boiled in mangrove palm vinegar/oral/-	(Nasution *et al.* 2018)
Phyllanthus sp.	*Sampa-sampalu*	Southeast Sulawesi/Buton	Leaves/-/-/-	(Indrayangingsih *et al.* 2015)
Phyllanthus niruri L.	Gale of the wind	South Sulawesi/-	Leaves/-/-/-	(Ariandi & Khaerati 2016)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
		Bengkulu/-	-/-/-/-	(Kasrina & Veriana 2014)
		Bengkulu/Mukomuko	-/-/-/-	(Kasrina *et al.* 2015)
		North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
PIPERACEAE				
Piper betle L.	Betel leaf	North Sumatra/Karo	Leaves/prepared into a concoction/oral and topical/-	(Nasution *et al.* 2018)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
Piper crocatum Ruiz et Pav	Celebes peper	Riau/-	Leaves/decocted/oral/-	(Safitri *et al.* 2015)
Piper nigrum L.	Black pepper	North Sumatra/Karo	Fruits/prepared into a concoction/oral and topical	(Nasution *et al.* 2018)
Piper ornatum N.E.Br.	Red betel	Central Sulawesi/Kulawi	Leaves/decocted/oral/-	(Arham *et al.* 2016)
		Southeast Sulawesi/Wolia	Leaves/decocted/oral/-	(Slamet & Andarias 2018)
		West Java/-	Leaves/decocted/oral/-	(Emilda *et al.* 2017)
PLANTAGINACEAE				
Plantago major L.	Broadleaf plantain	East Java/-	Whole plants/-/-/-	(Batoro & Siswanto 2017)
POACEAE				
Axonopus compressus (Sw.) P.Beauv.	Broadleaf carpetgrass	Jambi/-	-/-/-/-	(Novinovrita 2016)
Bambusa horsfieldii Munro	*Bulu bolon*	North Sumatra/Batak	Roots/-/-/-	(Silalahi *et al.* 2015)
Bambusa vulgaris Schrad.	Common bamboo	North Sumatra/Karo	Shoots/boiled in coconut sap/oral/twice a day	(Situmorang *et al.* 2015)

Imperata cylindrica (L.) Raeusch.	Cogon grass	Aceh/-	-/-/-/-	(Safryadi *et al.* 2017)
		East Java/Osing	Roots/-/-/-	(Khotimah *et al.* 2018)
Oryza sativa L. var *glutinosa*	Sticky rice	Southeast Sulawesi/Moronene	Fruits/soaked/topical/-	(Indrawati *et al.* 2014)
Saccharum officinarum L.	Sugarcane	Southeast Sulawesi/Wolia	Leaves/decocted/oral/-	(Slamet & Andarias 2018)
		East Java/-	Stems/-/-/-	(Batoro & Siswanto 2017)
		South Sumatra/-	Stems/-/-/-	(Kartika 2014)
Saccharum spontaneum L.	Wild sugarcane	Central Kalimantan/Dayak Ot Danum	Stems/-/-/-	(Herianto *et al.* 2018)
Schizostachyum blumei Nees	*Bulu hayan*	North Sumatra/Batak Simalungun	Roots/-/-/-	(Silalahi *et al.* 2015)
Schizostachyum sp.1	*Bulu laga*	North Sumatra/Batak Simalungun	Roots/-/-/-	(Silalahi *et al.* 2015)
POLYPODIACEAE				
Drynaria sparsisora (Desv.) T. Moore	Oakleaf fern	Southeast Sulawesi/Wolia	Stems/decocted/oral/-	(Slamet & Andarias 2018)
RANUNCULACEAE				
Nigella sativa L.	Black caraway	East Java/Osing	Fruits/-/-/-	(Khotimah *et al.* 2018)
RHAMNACEAE				
Maesopsis eminii Engl.	Umbrella tree	North Sumatra/Karo	Leaves/decocted/oral/two-three times a day	(Situmorang *et al.* 2015)
ROSACEAE				
Prunus maritima Marshall	Beach plum	North Sumatra/Karo	Leaves/decocted/oral/twice a day	(Situmorang *et al.* 2015)
RUBIACEAE				
Morinda citrifolia L.	Noni	West Java/-	Flowers/decocted/oral/-	(Emilda *et al.* 2017)
		East Java/-	Fruits/-/-/-	(Batoro & Siswanto 2017)
		North Sumatra/Simalungun	Fruits/-/-/-	(Situmorang & Sihombing 2018)
		North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
		Aceh/-	-/-/-/-	(Safryadi *et al.* 2017)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
Myrmecodia tuberosa Jack	Ant plant	West Kalimantan/-	-/-/-/-	(I'ismi *et al.* 2018)
Psychotria sp.	*Loning*	North Sumatra/Karo	Leaves/decocted/oral/twice a day	(Situmorang *et al.* 2015)
RUTACEAE				
Aegle marmelos (L.) Corrêa	Bael	Southeast Sulawesi/Moronene	Fruits/prepared into a concoction/oral/-	(Siharis & Fidrianny 2016)
Citrus aurantiifolia (Christm.) Swingle	Lime	North Sumatra/Karo	Fruits/prepared into a concoction/oral and topical	(Nasution *et al.* 2018)
Citrus medica L.	Citron	East Java/-	Fruits/juiced/oral/-	(Handayani *et al.* 2018)
SAPINDACEAE				
Nephelium lappaceum L.	Rambutan	Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)

SOLANACEAE				
Physalis angulata L.	*Cecendet*	West Java/-	Roots/-/-/-	(Malini *et al.* 2017)
		West Java/-	Roots/decocted/oral/-	(Kodir *et al.* 2017)
	Ciplukan	Southeast Sulawesi/Wolia	Stems/decocted/oral/-	(Slamet & Andarias 2018)
Physalis minima L.	*Ceplukan*	North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
		East Java/-	Whole plants/-/-/-	(Batoro & Siswanto 2017)
Physalis peruviana L.	Cape gooseberry	Central Sulawesi/Kaili Ledo	Whole plants/-/-/-	(Dianto *et al.* 2015)
Solanum lycopersicum L.	Tomato	South Sumatra/-	Fruits and seeds/-/-/-	(Kartika 2014)
THEACEAE				
Eurya sp.1	*Raru*	North Sumatra/Batak Simalungun	Barks/-/-/-	(Silalahi *et al.* 2015)
THYMELAEACEAE				
Phaleria macrocarpa (Scheff.) Boerl.	King of drug	West Java/-	Flowers/decocted/oral/-	(Gunarti & Nurlina 2018)
		Central Sulawesi/Kaili Ledo	Fruits and leaves/-/-/-	(Dianto *et al.* 2015)
		Central Sulawesi/Mori	Fruits/-/-/-	(Idris *et al.* 2018)
		South Sumatra/-	Fruits and leaves/-/-/-	(Kartika 2014)
VITACEAE				
Leea indica (Burm. f.) Merr.	Bandicoot berry	Central Kalimantan/Dayak Ot Danum	Leaves, roots, and stems/-/-/-	(Herianto *et al.* 2018)
XANTHORRHOEACEAE				
Aloe vera (L.) Burm.f.	Aloe vera	North Sumatra/Simalungun	-/-/-/-	(Simanjuntak 2018)
		Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
ZINGIBERACEAE				
Amomum maximum Roxb.	*Hangasa*	West Java/-	Stems/-/-/-	(Malini *et al.* 2017)
Boesenbergia rotunda (L.) Mansf.	Fingerroot	North Sumatra/Karo	Rhizomes/prepared into a concoction/oral and topical/-	(Nasution *et al.* 2018)
Curcuma longa L.	Turmeric	Aceh/-	-/-/-/-	(Hasanuddin & Kusyanti 2016)
		North Sumatra/Karo	Rhizomes/prepared into a concoction/oral and topical/-	(Nasution *et al.* 2018)
		Southeast Sulawesi/Moronene	Rhizomes/decocted/oral/-	(Efremila *et al.* 2015)
		West Kalimantan/Dayak	-/-/-/-	(Hasanuddin & Kusyanti 2016)
Curcuma zanthorrhiza Roxb.	Javenese turmeric	North Sumatra/Batak Simalungun	Rhizomes/-/-/-	(Silalahi *et al.* 2015)
Kaempferia galanga L.	Aromatic ginger	North Sumatra/Karo	Rhizomes/prepared into a concoction/oral and topical/-	(Nasution *et al.* 2018)
Zingiber montanum (J.Koenig) Link ex A.Dietr.	Cassumunar ginger	North Sumatra/Karo	Rhizomes/prepared into a concoction/oral and topical/-	(Nasution *et al.* 2018)
Zingiber officinale Roscoe	Ginger	North Sumatra/Karo	Rhizomes/prepared into a concoction/oral and topical/-	(Nasution *et al.* 2018)

"-":indicates that the data is not available

In total, there were 18 surveyed provinces with Aceh, Bengkulu, Riau, West Java, East Java, Central Kalimantan, West Sulawesi, Central Sulawesi, Southeast Sulawesi, and South Sulawesi were surveyed in multiple times. About 46% of the studies cited in this article do not indicate the ethnicity of surveyed respondents. Of those studies with defined ethnicities, Moronene, Batak, Karo, and Simalungun were found to be surveyed multiple times (Figure 2).

The other ethnicities that were surveyed for one time included Banggai, Batak Karo, Batak Simalungun, Bolaang Mongondow, Minahasa, Sangir, Bungkudi, Buton, Dayak, Dayak Ahe, Dayak Iban, Dayak Ot Danum, Dondo, Kaili Ija, Kaili Ledo, Kaili Moma, Kaili Rai, Kulawi, Kutai, Mamuju, Mandailing, Mandar, Mori, Mukomuko, Osing, Seko, Taa Wana, Tialo, Topo Uma, and Wolia.

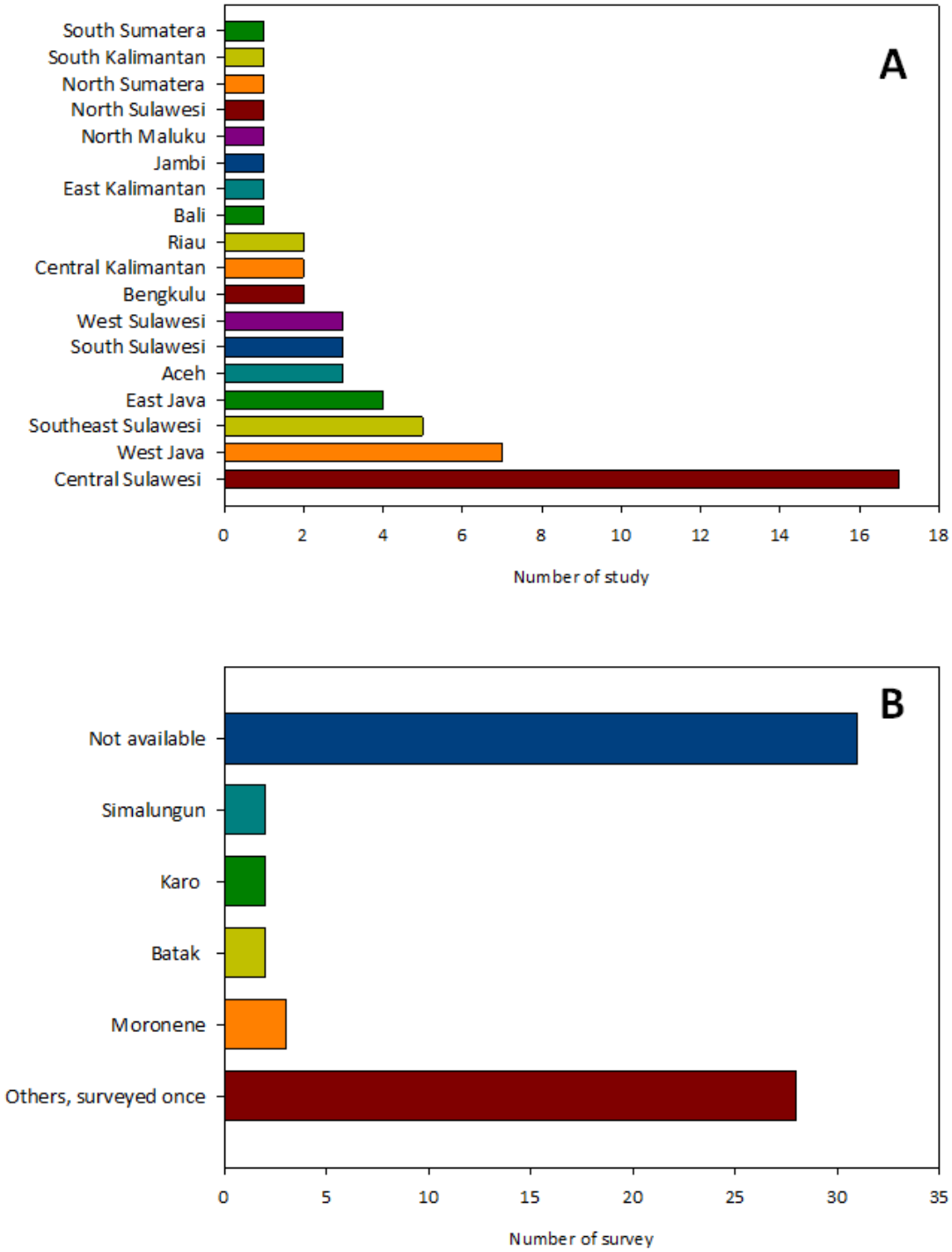

Figure 2. The geographical aspects of the ethnopharmacological studies mentioning the use of plants for treatment of diabetes mellitus in Indonesia; (A) number of surveys in each province, (B) the ethnicity of surveyed people

Botanical aspects

There were 132 plant species from 53 families reported for treating diabetes mellitus in Indonesia. Compositae, Poaceae, Zingiberaceae, Malvaceae, Myrtaceae, and Acanthaceae were the families with the highest number of species used. The most frequently used antidiabetic plants included *Orthosiphon aristatus* (Blume) Miq., *Persea americana* Mill., *Syzygium polyanthum* (Wight) Walp, *Psidium guajava* L., and *Morinda citrifolia* L. (Table 1, Figure 3). *Orthosiphon aristatus* was used for treating diabetes mellitus by people West Java (3 places), Central Sulawesi (3 places), West Kalimantan, and Aceh, while *Psidium guajava* was employed for the said purpose in Central Sulawesi (3 places), Aceh, Jambi, North Sumatra, South Sumatra, and Riau. The traditional antidiabetic utilization of *Morinda citrifolia* was reported in Aceh (2 places), North Sumatra, East Java, West Java, and Central Sulawesi. The other popular medicinal plants for traditional treatment of diabetes mellitus included *Areca catechu* L., *Catharanthus roseus* (L.) G.Don, *Curcuma longa* L., *Andrographis paniculata* (Burm.f.) Nees, *Garcinia x mangostana* L., and *Phyllanthus niruri* L.

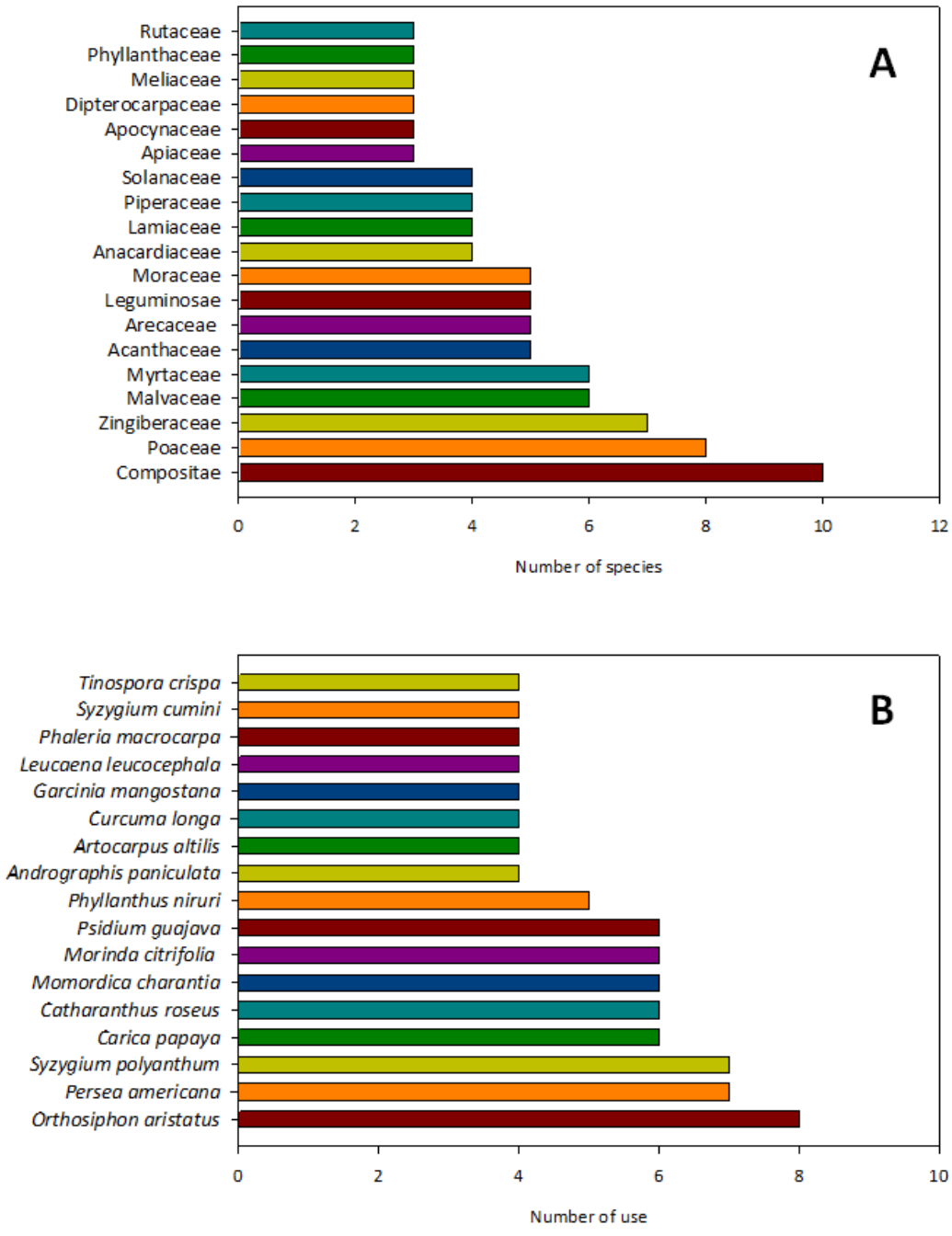

Figure 3. The most frequently used taxon for treating diabetes mellitus in Indonesia; (A) by family and (B) by species

Ethnopharmacological aspect

About 25% of the total entries did not describe the part of plants that were used for treatment of diabetes mellitus. The most frequently used part was leaves and subsequently followed by fruits, roots, barks, seeds, stems, and whole plants (Table 1, Figure 4). Some rarely used plant parts were also mentioned, including shoots, bulbs, and exudates. Shoots are particularly obtained from *Bambusa* spp. while bulbs are from *Allium* spp. (Silalahi & Nisyawati 2015; Situmorang *et al.* 2015; Nasution *et al.* 2018; Simanjuntak 2018). The use of exudates of *Arenga pinnata* (Wurmb) Merr. and *Sansevieria trifasciata* Prain were described in South Sulawesi and South Sumatra, respectively (Kartika 2014; Ariandi & Khaerati 2016).

About 46% of the total entries cited in this article do not describe the methods of medicine preparation. From the available descriptions, the most often method used was by preparing decoction in water and subsequently taking the water extract orally. The preparation of plant materials before decoction, the ratio of water and plant materials, time of boiling, and also the posology of water extract varied widely. Some plant materials, including *Gynura procumbens* (Lour.) Merr. and *Annona muricata* L., were boiled freshly (Rusmina *et al.* 2015; Emilda *et al.* 2017). Other plant materials, for example, *Saurauia vulcani* Korth. and *Acanthus ilicifolius* L., were dried first (Ernianingsih *et al.* 2014; Situmorang *et al.* 2015). The hard plant materials, including *Areca catechu* fruits, *Alstonia scholaris* (L.) R. Br. barks, and *Swietenia mahagoni* (L.) Jacq. seeds were comminuted by grinding, pounding, or chopping into appropriate size before boiling (Dianto *et al.* 2015; Malini *et al.* 2017; Idris *et al.* 2018).

The ratio of plant material to water in decoction also varied widely. Ten leaves of *Andrographis paniculata* in 900 ml of water (Hermin *et al.* 2016), 15 leaves of *Strobilanthes crispa* Blume in 6 glasses of water (Idris *et al.* 2018), and 3-4 cm barks of *Cinnamomum burmanni* (Nees & T.Nees) Blume in 1 l of water (Situmorang *et al.* 2015) were the examples of this variation. The unstandardized measurements, for example, handful and *jengkal*, were also described (Indrawati *et al.* 2014; Situmorang *et al.* 2015; Mutaqin *et al.* 2016). Some reports specified the final volume of the water extracts, for example, boiled until a third, a half, or two-thirds of the initial volume, while others did not mention it (Indrayangingsih *et al.* 2015; Situmorang *et al.* 2015; Mutaqin *et al.* 2016). Sometimes, honey or palm sap were added to the water extract in order to improve the taste (Ifandi *et al.* 2016; Arnold *et al.* 2017). The posology of water extract was also varied, some mentioned twice, two-three, or three times in a day, with one or two glasses each (Ernianingsih *et al.* 2014; Situmorang *et al.* 2015; Hermin *et al.* 2016).

The grains of *Oryza sativa* L. were soaked in water and topically used for treating diabetic wounds in Southeast Sulawesi (Indrawati *et al.* 2014). The example of an antidiabetic plant that was simply cooked and eaten was *Momordica charantia* L. fruits (Emilda *et al.* 2017). The use of fermented barks of *Bischofia javanica* Blume in mangrove palm vinegar was described in North Sumatra (Nasution *et al.* 2018). Juice preparation was also reported from *Blumea balsamifera* (L.) DC. leaves (Emilda *et al.* 2017), *Leucaena leucocephala* (Lam.) de Wit seeds (Oktavia *et al.* 2017), and *Citrus medica* L. fruits (Handayani *et al.* 2018).

The medicinal plants mentioned in the studies cited in this article were mostly used as a single plant preparation. There were only two formulas of plant combination reported, they were used by Ethnic of Karo (North Sumatra) and Moronene (Southeast Sulawesi). The first formula consisted of nine plants and was used both topical and orally for treating diabetic wounds. The second one was in a form of decoction prepared from *Eupatorium inulifolium* Kunth leaves and *Aegle marmelos* (L.) Corrêa fruits (Siharis and Fidrianny 2016; Nasution *et al.* 2018).

Quantitative ethnobotanical studies

There were only 10 studies using a quantitative approach. The different indices were utilized in the various research efforts, including familiarity index (Fi), index of cultural significance (ICS), relative importance (RI), relative frequency of citation (RFC), and use value (UV) (Table 2).

Discussion

Comparison to *RISTOJA* 2015

The ethnopharmacological data presented in this article were collected from surveys on 37 defined ethnicities and 18 provinces. Hence, its coverage is considered narrower than that of *RISTOJA* 2015, which covered 24 provinces and 96 different ethnicities. However, both this article and *RISTOJA* 2015 recorded the similar most popular antidiabetic plants. Five out of 11 most frequently used antidiabetic plants in this article were also in the top ten list of those surveyed by *RISTOJA* 2015, they were *Andographis paniculata, Areca catechu, Curcuma longa, Orthosiphon aristatus,* and *Syzygium polyanthum*. In addition, the other five plants in top ten antidiabetic plants of *RISTOJA* 2015 (*Curcuma zanthorrhiza* Roxb., *Tinospora crispa* (L.) Hook. f. & Thomson, *Physalis peruviana* L., *Centella asiatica* (L.) Urb., and *Cocos nucifera* L.) were also cited for having traditional antidiabetic uses in this article.

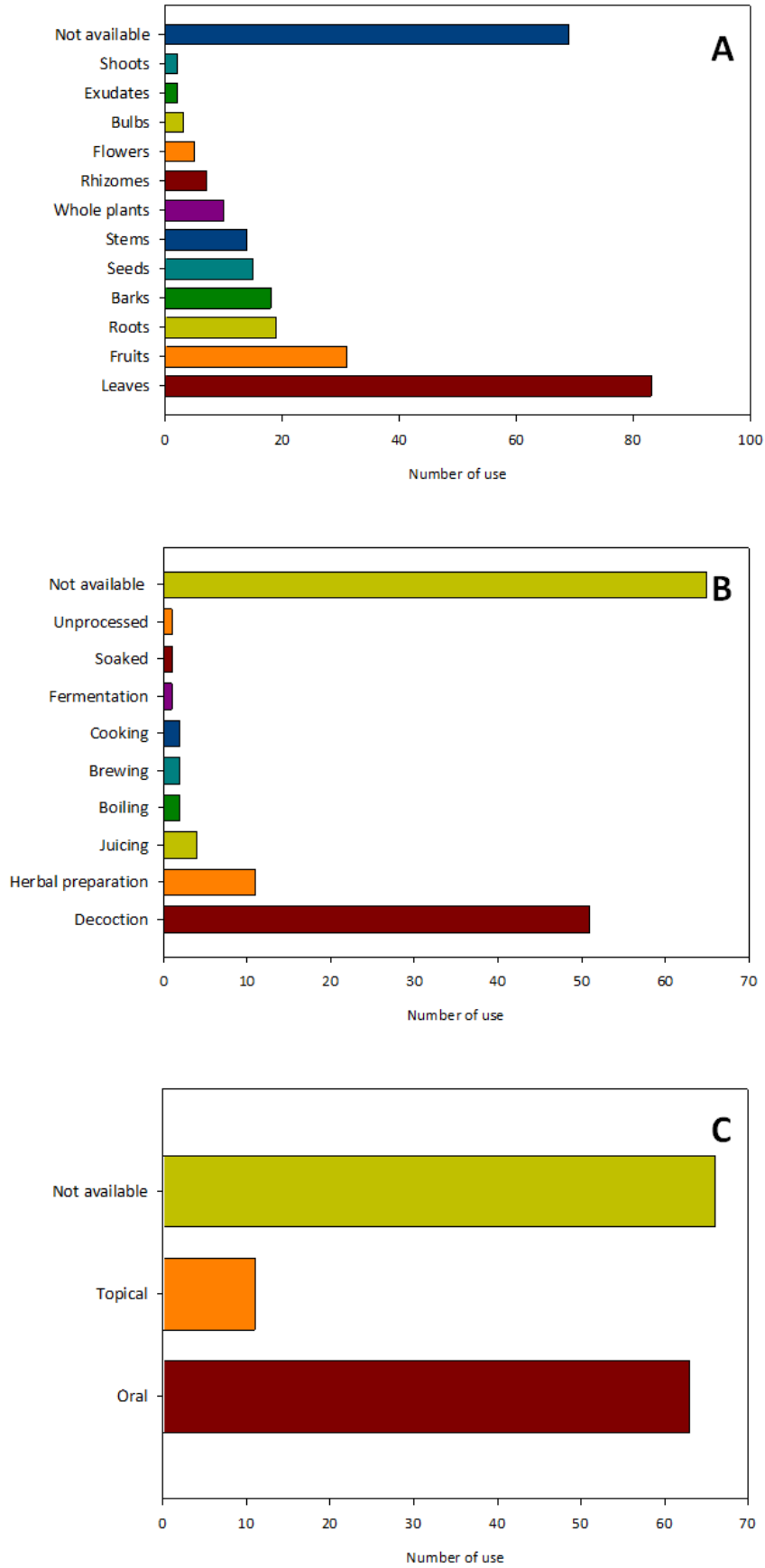

Figure 4. The utilization of medicinal plants for treatment of diabetes in Indonesia; (A) plant parts used, (B) preparation method, and (C) administration route

Table 2. Quantitative ethnobotanical surveys mentioning the use of plant for treating diabetes mellitus in Indonesia (2014-2018)

Location/people	Indices used	Interesting finding	Reference
North Sumatra/Karo	Fi	Fi value of all plants was equal 0.25	(Nasution *et al.* 2018)
North Sumatra/Karo	ICS	The plants in the high ICS category (100-199) were *Psychotria* sp., *Maesopsis eminii*, and *Guazuma ulmifolia*	(Situmorang *et al.* 2015)
North Sumatra/Batak Simalungun	UV, ICS	The plants in the high ICS category were *Guazuma ulmifolia* and *Bischofia javanica*, while that with the highest UV value was *Allium chinense*	(Silalahi *et al.* 2015)
West Java/-	UV, RFC, and RI	The most important antidiabetic plant was *Physalis angulata* with UV, RI, and RFC values were 0.33, 0.32, and 0.22, respectively	(Kodir *et al.* 2017)
Bali/-	UV	The UV of *Leucaena leucocephala* was 0.2	(Oktavia *et al.* 2017)
Central Sulawesi/Taa Wana	UV	The plants with the UV >0.5 were *Sericocalyx crispus* and *Lansium parasiticum*	(Akhsa *et al.* 2015)
Central Sulawesi/Kulawi	UV	The plants with the UV >0.5 were *Garcinia × mangostana* and *Pterospermum celebicum*	(Arham *et al.* 2016)
Central Sulawesi/Kaili Ija	UV	The UV of *Diospyros celebica* was in the category of 0.2-0.5	(Megawati *et al.* 2016)
Central Sulawesi/Seko	UV	The UV of *Azadirachta indica* and *Andrographis paniculata* were equally 0.48	(Tapundu *et al.* 2015)
West Sulawesi/Mandar	UV	The UV of *Gynura procumbens* was in the category of <0.2	(Rusmina *et al.* 2015)

RISTOJA 2015 also reported the use of the formula or the combination of antidiabetic plants in Bali. The Balinese used water extract of a formula consisted of *Alstonia scholaris* barks, *Zingiber zerumbet* (L.) Roscoe ex Sm. rhizomes, *Azadirachta indica* stems, *Andrographis paniculata* leaves, and *Vitex trifolia* L. leaves to treat diabetes mellitus (Kemenkes 2015).

The confirmed antidiabetic activity of the most cited plants

Interestingly, most of the plants traditionally used for treating diabetes mellitus in Indonesia have been proven to have anti-hyperglycemic activities. In some plants, the active compounds that are responsible for anti-diabetic properties have been successfully isolated and characterized (Figure 5). The extracts, fractions, and isolated compounds of *Orthosiphon aristatus* have shown the anti-hyperglycemic effects through the mechanisms such as an increased release of insulin, prevention of glucotoxicity, as well as inhibition of carbohydrate metabolizing enzymes (Mohamed *et al.* 2013; Lee *et al.* 2015). The antidiabetic compounds from *Orthosiphon aristatus* were salvigenin, sinensetin, 3,7,4'-tri-*O*-methylkaempferol, tetramethylscutellarein, and orthosiphol A (Mohamed *et al.* 2012; Damsud *et al.* 2014). Extract of *Carica papaya* L. was capable of decreasing the glucose blood levels as well as lipid, triglycerides, and transaminases in the diabetic rat serum. It also enhanced regeneration of the cells, reduced fatty changes and pyknotic nucleus of the liver tissues, and recovered the cuboidal kidney tissue. It positively affected the integrity and function of both liver and pancreas, as well as improved the basal insulin secretion (Juárez-Rojop *et al.* 2012; Maniyar and Bhixavatimath 2012; Miranda-Osorio *et al.* 2016).

The juice of fresh leaves of *Catharanthus roseus* decreased the blood glucose level in diabetic rats (Al-Shaqha *et al.* 2015). Vindolidine, vindoline, vindolinine, vindolicine, ursonic acid, ursolic acid, kaurenoic acid, 3-hydroxy-11-ursen-28,13-olide, and spatozoate were considered as the antidiabetic compounds (Tiong *et al.* 2013; Tam *et al.* 2016). Treatment with the juice of *Morinda citrifolia* fruits was proven to significantly decrease the morning blood glucose level and glycosylated hemoglobin (HbA1c) value of patients with type 2 diabetes mellitus (Algenstaedt *et al.* 2018). A similar outcome was also shown in the high-fat diet rats, which was mediated by the improved glucose metabolism (Nerurkar *et al.* 2012). The identified compounds of

Morinda citrifolia were episesamin 2,6-dicatechol, lirioresinol B, lirioresinol B dimethyl ether, ursolic acid, damnacanthol-3-O-β-D-primeveroside, and lucidin 3-O-β-D-primeveroside (Nguyen *et al.* 2013).

The potential antidiabetic activities of *Psidium guajava* have been demonstrated in Caco-2 cells and diabetic rats models (Hedayathullah-Khan *et al.* 2013; Muller *et al.* 2018). Psidiumlanostenoic acid, 12β-hydroxypsidiumlanostenoic acid, trihydroxypsidiumlanostenoic acid, psidiumlanostenoic acid glucoside, quercetin, isoquercetin, and rutin were considered as the compounds responsible for the antidiabetic activity of this plant (Bagri *et al.* 2016). The antidiabetic related activities of various extracts and fractions of *Andrograrphis paniculata* have been proved in in-vivo and in-vitro studies (Wibudi *et al.* 2008; Chaurasia *et al.* 2012). Andrographolide was found to be the active constituents of this plant, the effects of which on the diabetes mellitus-related conditions were comparable or even better than that of *Andrograrphis paniculata* extract (Thakur *et al.* 2016). Several mechanisms of andrographolide effects that might be beneficial for treating diabetes mellitus had been reported (Xu *et al.* 2012; Zhang *et al.* 2013; Yu *et al.* 2015). Another hypoglycemic compound of *Andrograrphis paniculata* was deoxyandrographolide (Arha *et al.* 2015).

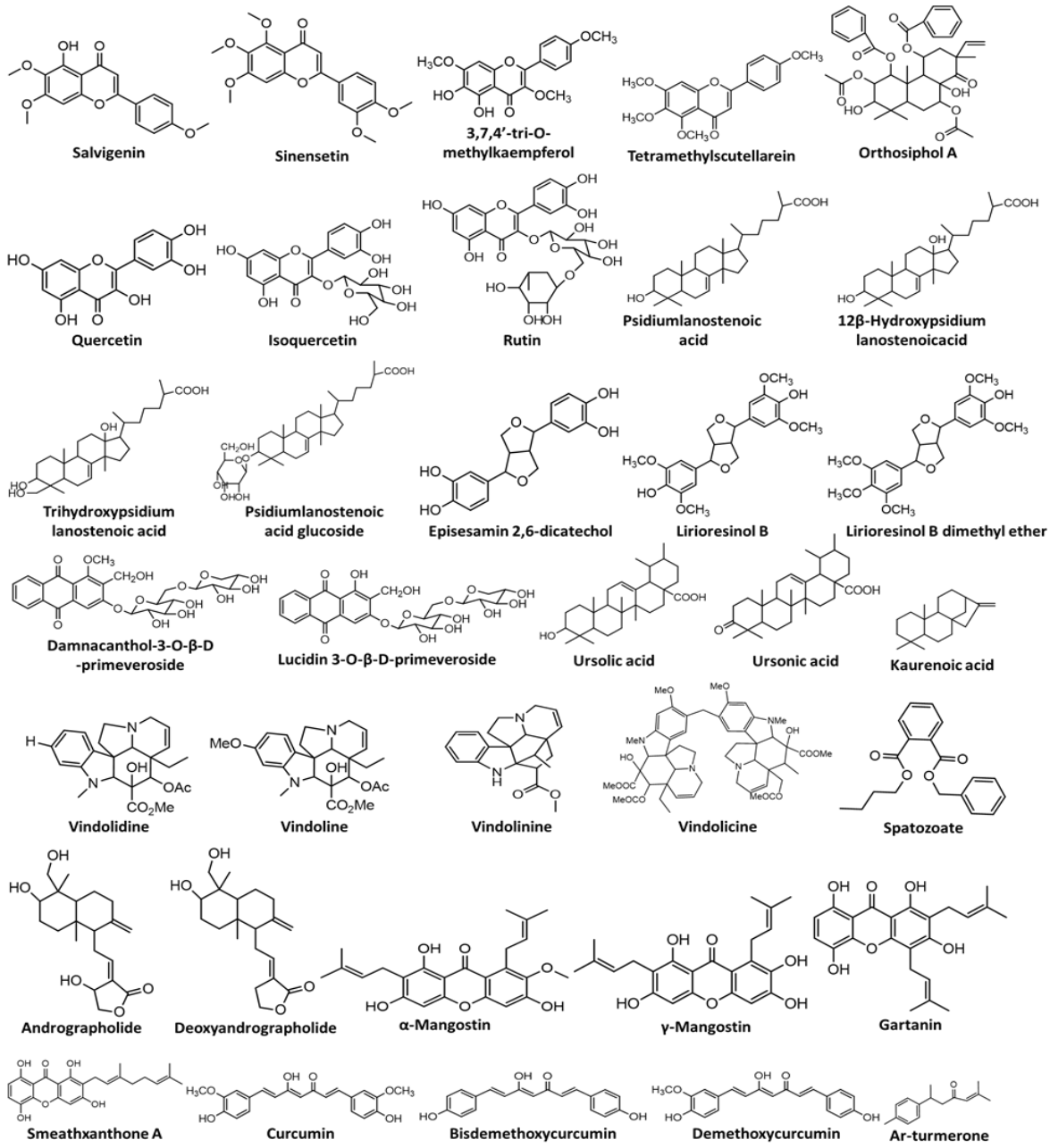

Figure 5. The antidiabetic compounds of the most popular plants traditionally used for treating diabetes mellitus in Indonesia

Curcumin, bisdemethoxycurcumin, and demethoxycurcumin from *Curcuma longa* showed a high inhibitory effect on α-glucosidase (Kalaycioglu *et al.* 2017). Curcumin was found to be more potent as an anti-hyperglycemic agent than the extract (Arun and Nalini 2002). In addition, *ar*-turmerone demonstrated highly potent α-glucosidase and α-amylase inhibitory activities (Lekshmi *et al.* 2012). The combination of behavioral therapy and *Garcinia x mangostana* supplement demonstrated a significant amelioration in insulin sensitivity in obese female patients with insulin resistance (Watanabe *et al.* 2018). A similar potential outcome was also shown in diabetic rats (Taher *et al.* 2016). Xanthones, including α-mangostin, γ-mangostin, gartanin, and smeathxanthone A, have been proven to be the antidiabetic compounds of this plant (Ryu *et al.* 2011; Ratwita *et al.* 2017; Lee *et al.* 2018).

The in-vitro studies suggested that the antihyperglycemic effect of *Tinospora crispa* was due to the inhibitory of α-glucosidase and α-amylase (Hamid *et al.* 2015). Borapetoside C, borapetoside A, borapetoside E, and borapetol B were identified as the hypoglycemic constituents of *Tinospora crispa*, which acted by mechanisms of increasing glucose utilization, delaying the development of insulin resistance and enhancing insulin sensitivity, reducing the hepatic gluconeogenesis, activating the insulin signaling pathway, as well as improving insulin resistance, hepatic steatosis, and hyperlipidemia (Ruan *et al.* 2012; Lokman *et al.* 2013; Ruan *et al.* 2013; Xu *et al.* 2017).

The quantitative ethnobotanical study

Indices in ethnobotanical study are important to quantitatively rank the plants that are most useful to a given culture (Zenderland *et al.* 2019). Result of this study can be used as the rationale for selection of the antidiabetic plants for further development as phytopharmaceuticals, in addition to the pharmacological activity as described in the previous section. As only 15% of the cited ethnopharmacological studies in this article were the quantitative ones, more well-designed studies are needed.

Conclusive remarks

This review compiles the medicinal plants traditionally used for treating diabetes mellitus in Indonesia. Data is retrieved from 67 ethnopharmacological research published in 2014-2018. Those studies were conducted in 18 provinces which cover 37 defined ethnicities. There are 132 species of medicinal plants from 53 families, with Compositae, Poaceae, Zingiberaceae, Malvaceae, and Myrtaceae as the families with the highest number of species used for the said purpose. The most popular plants with multiple uses in different places include *Orthosiphon aristatus, Persea americana,* and *Syzygium polyanthum*. The parts of the plant used and the methods of preparation of those antidiabetic plants vary widely across the nation. However, most of the cited studies in this article were descriptive ones, only 15% of those used quantitative approach.

The safety and efficacy of the selected antidiabetic plants should be evaluated. Preclinical as well as clinical studies on the standardized materials should be conducted. Scientific Based *Jamu* Development enables enhancement of their status so they eventually can be used in formal healthcare systems. Development of those plants into the standardized herbal medicines is another strategy to take to reach the same goal.

Declarations

List of abbreviations: Fi: familiarity index**;** HbA1c: Glycosylated hemoglobin**;** ICS: index of cultural significance**;** RFC: relative frequency of citation; RI: relative importance; *RISTOJA*: *Riset Nasional Tanaman Obat dan Jamu* (National Research on Medicinal Plants and Jamu); UV: use value

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Literature cited

Aditama TY. 2015. Jamu & Kesehatan. Lembaga Penerbit Badan Penelitian dan Pengembangan Kesehatan (LPB), Jakarta, Indonesia.

Akhsa M. Pitopang R, Anam S. 2015. Studi etnobiologi bahan obat-obatan pada masyarakat Suku Taa Wana di Desa Mire Kecamatan Ulubongka Kabupaten Tojo Una Una Sulawesi Tengah. Biocelebes 9(1):58-72.

Al-Shaqha WM, Khan M, Salam N, Azzi A, Chaudhary AA. 2015. Anti-diabetic potential of Catharanthus roseus Linn. and its effect on the glucose transport gene (GLUT-2 and GLUT-4) in streptozotocin induced diabetic wistar rats. BMC

Complementary and Alternative Medicine 15:article 379.

Algenstaedt P, Stumpenhagen A, Westendorf J. 2018. The effect of Morinda citrifolia L. fruit juice on the blood sugar level and other serum parameters in patients with diabetes type 2. Evidence-Based Complementary and Alternative Medicine 2018:article 3565427.

Aminah S, Wardenaar E, Muflihati. 2016. Tumbuhan obat yang dimanfaatkan oleh Battra di Desa Sejahtera Kecamatan Sukadana Kabupaten Kayong Utara. Jurnal Hutan Lestari 4(3):299-305.

Anggraini S, Miswan, Pitopang R. 2016. Kajian etnobotani tumbuhan berkhasiat obat Suku Tialo di Desa Taopa Kecamatan Taopa Kabupaten Parigi Moutong. Biocelebes 10(1):45-55.

Arha D, Pandeti S, Mishra A, Srivastava SP, Srivastava AK, Narender T, Tamrakar AK. 2015. Deoxyandrographolide promotes glucose uptake through glucose transporter-4 translocation to plasma membrane in L6 myotubes and exerts antihyperglycemic effect in vivo. European Journal of Pharmacology 768:207-216.

Arham S, Khumaidi A, Pitopang R. 2016. Keanekaragaman jenis tumbuhan obat tradisional dan pemanfaatannya pada Suku Kulawi di Desa Mataue Kawasan Taman Nasional Lore Lindu. Biocelebes 10(2):01-16.

Ariandi, Khaerati. 2016. Identifikasi indeks keanekaragaman tanaman obat-obatan di kawasan hutan Kelurahan Battang dan Battang Barat. In Prosiding Seminar Nasional Universitas Cokroaminoto Palopo. Edited by Sainudin S, Ikram M, Hartono N, Nirsal, Basir F. Universitas Cokroaminoto, Palopo, Indonesia, Pp. 729-737.

Arini DID. 2017. Pengetahuan lokal Masyarakat Sulawesi Utara dalam pemanfaatan pohon hutan sebagai bahan obat tradisional. Jurnal Masyarakat & Budaya 19(2):161-174.

Arnold, Harijanto H, Sustri. 2017. Keanekaragaman jenis dan pemanfaatan tumbuhan obat di kawasan Taman Nasional Lore Lindu (TNLL) di Desa Mataue Kecamatan Kulawi Kabupaten Sigi. Warta Rimba 5(1):71-79.

Arun N, Nalini N. 2002. Efficacy on tumeric on blood sugar and polyol pathway in diabetic albino rats. Plant Foods for Human Nutrition 57(1):41-52.

Bagri P, Ali M, Aeri V, Bhowmik M. 2016. Isolation and antidiabetic activity of new lanostenoids from the leaves of Psidium guajava L. International Journal of Pharmacy and Pharmaceutical Sciences 8(9):14-18.

Balitbangkes. 2010. Laporan Hasil Riset Kesehatan Dasar tahun 2010. Kementrian Kesehatan Republik Indonesia, Jakarta, Indonesia.

Bana SWA, Khumaidi A, Pitopang R. 2016. Studi etnobotani tumbuhan obat pada mayarakat Kaili Rai di Desa Taripa Kecamatan Sindue Kabupaten Donggala Sulawesi Tengah. Biocelebes 10(2):68-81.

Batoro J, Siswanto D. 2017. Ethnomedicinal survey of plants used by local society in Poncokusumo District, Malang, East Java Province, Indonesia. Asian Journal of Medical and Biological Research 3(2):158-167.

Chaurasia A, Kharya MD, Sharma B, Roy P. 2012. Glucose metabolism and diabetogenic gene expression analysis of chloroform fraction of Andrographis paniculata (Nees) whole herb in diabetic albino mice. Journal of Complementary and Integrative Medicine 9(1):article 21

Cordell GA. 2011. Phytochemistry and traditional medicine - A revolution in process. Phytochemistry Letters 4:391-398.

d-maps 2020. Map Indonesia. Available at:https://d-maps.com/carte.php?num_car=15293&lang=en.

Damsud T, Grace MH, Adisakwattana S, Phuwapraisirisan P. 2014. Orthosiphol A from the aerial parts of Orthosiphon aristatus is putatively responsible for hypoglycemic effect via alpha-glucosidase inhibition. Natural Product Communications 9(5):639-641.

Dewoto HR. 2007. Pengembangan obat tradisional Indonesia menjadi fitofarmaka. Majalah Kedokteran Indonesia 57(7):205-211.

Dianto I, Anam S, Khumaidi A. 2015. Studi etnofarmasi tumbuhan berkhasiat obat pada Suku Kaili Ledo di Kabupaten Sigi Provinsi Sulawesi Tengah. GALENIKA Journal of Pharmacy 1(2):85-91.

Efremila, Wardenaar E, Sisillia L. 2015. Studi etnobotani tumbuhan obat oleh Etnis Suku Dayak di Desa Kayu Tanam Kecamatan Mandor Kabupaten Landak. Jurnal Hutan Lestari 3(2):234 - 246.

Elfahmi, Woerdenbag HJ, Kayser O. 2014. Jamu:Indonesian traditional herbal medicine towards rational phytopharmacological use. Journal of Herbal Medicine 4:51-73.

Emilda, Hidayah M, Heriyati. 2017. Analisis pengetahuan masyarakat tentang pemanfaatan tanaman obat keluarga (Studi kasus Kelurahan Situgede, Kecamatan Bogor Barat). Sainmatika 14(1):11-21.

Ernianingsih SW, Mukarlina, Linda R. 2014.

Etnofarmakologi tumbuhan mangrove Achantus ilicifolius L., Acrostichum speciosum L. dan Xylocarpus rumphii Mabb. di Desa Sungai Tekong Kecamatan Sungai Kakap Kabupaten Kubu Raya. Protobiont 3(2):252- 258.

Ernilasari, Saudah, Suzanni MA, Diana, Irhamni, Viena V. 2018. Kajian etnobotani tumbuhan obat pada masyarakat Blang Bungong Kecamatan Tangse Kabupaten Pidie Aceh. Talenta Conference Series:Tropical Medicine 1(3):34-37.

Fajrin M, Ibrahim N, Nugrahani AW. 2015. Studi etnofarmasi Suku Dondo Kecamatan Dondo Kabupaten Tolitoli Sulawesi Tengah. GALENIKA Journal of Pharmacy 1(2):92-98.

Gunarti NS, Nurlina E. 2018. Studi etnobotani & etnofarmakologi tumbuhan obat di Desa Cigunungsari Kecamatan Tegalwaru Kabupaten Karawang Jawa Barat. Pharma Xplore:Jurnal Sains dan Ilmu Farmasi 4(1):260-267.

Hadijah S, Hendra M, Hariani N. 2016. Etnobotani obat tradisional oleh Masyarakat Kutai di Kec. Muara Bengkal Kab. Kutai Timur. Bioprospek 11(2):19-24.

Hamid HA, Yusoff MM, Liu M, Karim MR. 2015. α-Glucosidase and α-amylase inhibitory constituents of Tinospora crispa:Isolation and chemical profile confirmation by ultra-high performance liquid chromatography-quadrupole time-of-flight/mass spectrometry. Jornal of Functional Food 16:74-80.

Handayani S, Lukitasari M, Widiyanto J. 2018. Studi etnobotani tumbuhan berkhasiat obat (Ordo Rutales, Myrtales dan Euforbiales) di Kecamatan Plaosan. In Prosiding Seminar Nasional SIMBIOSIS III. Edited by Pujiati. Universitas PGRI Madiun, Madiun, Indonesia, Pp. 95-107.

Hasanuddin, Kusyanti. 2016. Jenis tumbuhan sebagai obat penyakit Diabetes Mellitus pada Masyarakat Rundeng Kota Subulussalam. In Prosiding Seminar Nasional Biotik 2016. Edited by Kamal S, Tsabirin M, Falah N, Razi F, Fastawa, Arhas FR, Mulyadi, Ahadi R. Universitas Islam Negeri Ar-Raniry, Banda Aceh, Indonesia, Pp. 95-100.

Hedayathullah-Khan HB, Shanmugavalli R, Rajendran D, Bai MR, Sorimuthu S. 2013. Protective effect of Psidium guajava leaf extract on altered carbohydrate metabolism in Streptozotocin-induced diabetic rats. Journal of Dietary Supplements 10(4):335-344.

Herianto, Kusuma Z, Nihayati E, Prayogo C. 2018. The plant wisdom of Dayak Ot Danum, Central Kalimantan. The Journal of Tropical Life Science 8(2):130 - 143.

Hermin, Nugraheni AW. 2016. Kajian etnofarmasi Etnik Bungkudi Kecamatan Bungku Tengah Kabupaten Morowali Provinsi Sulawesi Tengah. GALENIKA Journal of Pharmacy 2(2):76-82.

l'ismi B, Herawatiningsih R, Muflihati. 2018. Pemanfaatan tumbuhan obat oleh masyarakat di sekitar areal IUPHHK-HTI PT. Bhatara Alam Lestari di Kabupaten Mempawah. Jurnal Hutan Lestari 6(1):16-24.

IDF 2017. Indonesia. Available at:https://idf.org/our-network/regions-members/western-pacific/members/104-indonesia.html

Idris, Ibrahim N, Nugrahani AW. 2018. Studi tanaman berkhasiat obat Suku Mori di Kecamatan Petasia, Petasia Barat, dan Petasia Timur Kabupaten Morowali Utara Sulawesi Tengah. Biocelebes 12(1):23-31.

Ifandi S, Jumari, Suedy SWA. 2016. Knowledge understanding and utilization of medicinal plants by local community Tompu District of Kaili, Sigi Biromaru, Central Sulawesi. Biosaintifika 8(1):1-11.

Indrawati Sabilu Y, Ompo A. 2014. Pengetahuan dan pemanfaat tumbuhan obat tradisional masyarakat Suku Moronene di Desa Rau-Rau Sulawesi Tenggara. Biowallacea 1(1):39-48.

Indrayangingsih WOI, Ibrahim N, Anam S. 2015. Studi etnofarmasi tumbuhan berkhasiat obat pada Suku Buton di Kecamatan Binongko, Kabupaten Wakatobi, Sulawesi Tenggara. GALENIKA Journal of Pharmacy 1(2):79-84.

Islami MY, Ibrahim N, Nugrahani AW. 2017. Studi etnofarmasi Suku Kaili Moma di Kecamatan Kulawi, Kabupaten Sigi, Provinsi Sulawesi Tengah. GALENIKA Journal of Pharmacy 3(1):27-33.

Juárez-Rojop IE, Díaz-Zagoya JC, Ble-Castillo JL, Miranda-Osorio PH, Castell-Rodríguez AE, Tovilla-Zárate CA, Rodríguez-Hernández A, Aguilar-Mariscal H, Ramón-Frías T, Bermúdez-Ocaña DY. 2012. Hypoglycemic effect of Carica papaya leaves in streptozotocin-induced diabetic rats. BMC Complementary and Alternative Medicine 12:article 236.

Kalaycioglu Z, Gazioğlu I, Erim FB. 2017. Comparison of antioxidant, anticholinesterase, and antidiabetic activities of three curcuminoids isolated from Curcuma longa L. Natural Product Research 31(24):2914-2917.

Kartika T. 2014. Inventarisasi jenis-jenis tumbuhan berkhasiat obat di Desa Tanjung Baru Petai Kecamatan Tanjung Batu Kabupaten Ogan Ilir (OI) Provinsi Sumatera Selatan. Sainmatika 12(1):32-41.

Kasrina, Winarni EW, Karyadi B, Ruyani A. 2015.

Ethnobotanical study of medicinal plants by people of Mukomuko Ethnic in Bengkulu. In Proceeding of International Seminar on Promoting Local Resources for Food and Health. Edited by Danim S, Sasongko RN, Somantri M, Risdianto E, Lida H. Badan Penerbitan Fakultas Pertanian Universitas Bengkulu, BengkuluIndonesia, Pp. 127-132.

Kasrina, Veriana T. 2014. Studi etnobotani tumbuhan obat yang dimanfaatkan oleh masyarakat di Kecamatan Sindang Kelingi Kabupaten Rejang Lebong Bengkulu. In Prosiding Seminar Nasional XI Pendidikan Biologi FKIP UNS. Edited by Karyanto P, Saputra A. Program Studi Pendidikan Biologi FKIP UNS, Surakarta, Indonesia, Pp. 354-359.

Kemenkes. 2015. Laporan Nasional Riset Khusus Eksplorasi Pengetahuan Lokal Etnomedisin dan Tumbuhan Obat Berbasis Komunitas di Indonesia. Kementrian Kesehatan Republik Indonesia, Jakarta, Indonesia.

Khairiyah N, Anam S, Khumaidi A. 2016. Studi etnofarmasi tumbuhan berkhasiat obat pada Suku Banggai di Kabupaten Banggai Laut, Provinsi Sulawesi Tengah. GALENIKA Journal of Pharmacy 2(1): 1-7.

Khotimah K, Nurchayati, Ridho R. 2018. Studi etnobotani tanaman berkhasiat obat berbasis pengetahuan lokal masyarakat Suku Osing di Kecamatan Licin Banyuwangi. Biosense 1(1):36-50.

Kissinger, Yamani A, Thamrin GAR, Muhayah RNP, Zuhud EAM. 2015. Bioaktivitas antidiabetes beberapa jenis pohon lokal dari Hutan Kerangas. Jurnal Tumbuhan Obat Indonesia 8(1):1-8.

Kodir RA, Moektiwardoyo M, Iskandar Y. 2017. Etnofarmasi dan ulasan bioprospektif tumbuhan obat liar dalam pengobatan tradisional Kampung Adat Cikondang, Kecamatan Pangalengan, Kabupaten Bandung, Jawa Barat. Farmaka 15(1):26-44.

Lee D, Kim YM, Jung K, Chin YW, Kang KS. 2018. Alpha-mangostin improves insulin secretion and protects INS-1 cells from Streptozotocin-induced damage. International Journal of Molecular Sciences 19:article 1484.

Lee HJ, Choi YJ, Park SY, Kim JY, Won KC, Son JK, Kim YW. 2015. Hexane extract of Orthosiphon stamineus induces insulin expression and prevents glucotoxicity in INS-1 cells. Diabetes and Metabolism Journal 39:51-58.

Lekshmi PC, Arimboor R, Indulekha PS, Menon AN. 2012. Turmeric (Curcuma longa L.) volatile oil inhibits key enzymes linked to type 2 diabetes. International Journal of Food Sciences and Nutrition 63(7):832-834.

Lokman FE, Gu HF, Mohamud WNW, Yusoff MM, Chia KL, Ostenson CG. 2013. Antidiabetic effect of oral Borapetol B compound, isolated from the plant Tinospora crispa, by stimulating insulin release. Evidence-Based Complementary and Alternative Medicine 2013:article 727602.

Malini DM, Madihah, Kusmoro J, Kamilawati F, Iskandar J. 2017. Ethnobotanical study of medicinal plants in Karangwangi, District of Cianjur, West Java. Biosaintifika 9(2):345-356.

Maniyar Y, Bhixavatimath P. 2012. Antihyperglycemic and hypolipidemic activities of aqueous extract of Carica papaya Linn. leaves in alloxan-induced diabetic rats. Journal of Ayurveda & Integrative Medicine 3(2):70-74.

Mariani R, Qowiyyah A, Fitriyanti I. 2015. Studi etnofarmakognosi- etnofarmakologi tumbuhan sebagai obat di Kampung Naga Kecamatan Salawu Kabupaten Tasikmalaya. Jurnal Farmasi Galenika 2(1):30-35.

Megawati, Anam S, Pitopang R. 2016. Studi etnobotani tumbuhan obat pada masyarakat Suku Kaili Ija di Desa Bora Kecamatan Sigi Biromaru Kabupaten Sigi Sulawesi Tengah. Biocelebes 10(1):76-90.

Miranda-Osorio PH, Castell-Rodríguez AE, Vargas-Mancilla J, Tovilla-Zárate CA, Ble-Castillo JL, Aguilar-Domínguez DE, Juárez-Rojop IE, Díaz-Zagoya JC. 2016. Protective action of Carica papaya on β-cells in streptozotocin-induced diabetic rats. International Journal of Environmental Research and Public Health 2013:article 446.

Mohamed AA, Ali SI, El-Baz FK. 2013. Antioxidant and antibacterial activities of crude extracts and essential oils of Syzygium cumini Leaves. PLOS ONE 8(4):article e60269.

Mohamed EAH, Siddiqui MJA, Ang LF, Sadikun A, Chan SH, Tan SC, Asmawi MZ, Yam MF. 2012. Potent α-glucosidase and α-amylase inhibitory activities of standardized 50% ethanolic extracts and sinensetin from Orthosiphon stamineus Benth as anti-diabetic mechanism. BMC Complementary and Alternative Medicine 12(176):article 176.

Muller U, Stübl F, Schwarzinger B, Sandner G, Iken M, Himmelsbach M, Schwarzinger C, Ollinger N, Stadlbauer V, Höglinger O, Kühne T, Lanzerstorfer P, Weghuber J. 2018. In vitro and in vivo inhibition of intestinal glucose transport by guava (Psidium guajava) extracts. Molecular Nutrition and Food Research 62(11):article e1701012.

Mulyadi, Tavita GE, Yusro F. 2014. Kajian etnobotani tumbuhan obat di Desa Panding Jaya Kecamatan Ketungau Tengah Kabupaten Sintang.

Jurnal Hutan Lestari 2(1):134-141.

Mulyani Y, MunandarA, Nuraeni E. 2018. Local wisdom of Cikondang village community in the utilization of medicinal plants. IOP Conference Series:Journal of Physics 1013:article 012006.

Mutaqin AZ, Noviani E, Partasasmita R, Iskandar J. 2016. Studi etnobotani pemanfaatan jenis-jenis tumbuhan yang digunakan sebagai obat oleh masyarakat Desa Pangandaran Kecamatan Pangandaran Kabupaten Pangandaran. In Prosiding Seminar Nasional MIPA 2016. Fakultas Matematika dan Ilmu Pengetahuan Alam Universitas Padjajaran. Bandung, Indonesia, Pp. 55-61.

Nasution BR, Aththorick TA, Rahayu S. 2018. Medicinal plants used in the treatment of diabetes in Karo Ethnic, North Sumatra, Indonesia. IOP Conference Series:Earth and Environmental Science 130:article 012038.

Nerurkar PV, Nishioka A, Eck PO, Johns LM, Volper E, Nerurkar VR. 2012. Regulation of glucose metabolism via hepatic forkhead transcription factor 1 (FoxO1) by Morinda citrifolia (noni) in high-fat diet-induced obese mice. British Journal of Nutrition 108(2):218-228.

Nguyen PH, Yang JL, Uddin MN, Park SL, Lim SL, Jung DW, Williams DR, Oh WK. 2013. Protein tyrosine phosphatase 1B (PTP1B) inhibitors from Morinda citrifolia (Noni) and their insulin mimetic activity. Journal of Natural Products 76:2080−2087.

Nilawati, Mubarrak J, Brahmana EM. 2017. Studi etnobotani tumbuhan obat di Kecamatan Bangun Purba Kabupaten Rokan Hulu Provinsi Riau. e-Journal Mahasiswa Prodi Biologi 3(1):1-6.

Novinovrita M. 2016. Diversitas tumbuhan yang dimanfaatkan sebagai obat tradisional oleh masyarakat Desa Koto Dua Lama. Tarbawi:Jurnal Ilmu - Ilmu Pendidikan 1(1)" 1-11.

Oktavia GAE, Darma IDP, Sujarwo W. 2017. Studi etnobotani tumbuhan obat di kawasan sekitar Danau Buyan-Tamblingan, Bali. Buletin Kebun Raya 20(1):1-16.

Pitra H, Haerullah A, Papuangan N. 2017. Studi pengetahuan lokal Masyarakat Moya tentang pemanfaatan tumbuhan sebagai obat tradisional. Jurnal Saintifika MIPA 1(1):45-49.

Pradityo T, Santoso N, Zuhud EAM. 2016. Etnobotani di Kebun Tembawang Suku Dayak Iban, Desa Sungai Mawang, Kalimantan Barat. Media Konservasi 21(2):183-198.

Purwadianto A. 2015. Bioethics implementation on jamu's scientification. In Proceeding of Bioethic Seminar. Faculty of Medicine Universitas Islam Indonesia, Yogyakarta, Indonesia.

Ratwita W, Sukandar EY, Adnyana IK, Kurniati NF. 2017. Alpha mangostin and xanthone from Mangosteen (Garcinia mangostana L.) role on glucose tolerance and glucose transporter-4 in diabetes mellitus. International Journal of Pharmacognosy and Phytochemical Research 9(9):1206-1212.

Ruan CT, Lam SH, Chi TC, Lee SS, Su MJ. 2012. Borapetoside C from Tinospora crispa improves insulin sensitivity in diabetic mice. Phytomedicine 19(8-9):719-724.

Ruan CT, Lam SL, Lee SS, Su MJ. 2013. Hypoglycemic action of borapetoside A from the plant Tinospora crispa in mice. Phytomedicine 20:667- 675.

Rusmina HZ, Miswan, Pitopang R. 2015. Studi etnobotani tumbuhan obat pada masyarakat Suku Mandar di Desa Sarude Sarjo Kabupaten Mamuju Utara Sulawesi Barat. Biocelebes 9(1):73-87.

Ryu HW, Cho JK, Curtis-Long MJ, Yuk HJ, Kim YS, Jung S, Kim YS, Lee BW, Park KH. 2011. α-Glucosidase inhibition and antihyperglycemic activity of prenylated xanthones from Garcinia mangostana. Phytochemistry 72:2148-2154.

Safitri S, Yolanda R, Brahmana EM. 2015. Studi etnobotani tumbuhan obat di Kecamatan Rambah Samo Kabupaten Rokan Hulu. e-Journal Mahasiswa Prodi Biologi 1(1):1-4.

Safryadi A, Nasution AR, Mahdalena. 2017. Kajian etnobotani melalui pemanfaatan tanaman obat di Desa Rema Kecamatan Bukit Tusam Kabupaten Aceh Tenggara. In Prosiding Seminar Nasional Biotik 2017. Edited by Kamal S, Tsabirin M, Falah N, Razi F, Fastawa, Arhas FR, Mulyadi, Ahadi R. Universitas Islam Negeri Ar-Raniry, Banda Aceh, Indonesia, Pp. 367-380.

Sari RY, Wardenaar E, Muflihati. 2014. Etnobotani tumbuhan obat di Dusun Serambai Kecamatan Kembayan Kabupaten Sanggau Kalimantan Barat. Jurnal Hutan Lestari 2(3):379-387.

Setiawan H, Qiptiyah M. 2014. Kajian etnobotani masyarakat adat Suku Moronene Di Taman Nasional Rawa Aopawatumohai. Jurnal Penelitian Kehutanan Wallacea 3(2):107-117.

Siharis FS, Fidrianny I. 2016. Ethnopharmacology and activity determination of a plant in Moronene Ethnic at Tobu Hukaea-Laea Bombana - South East Sulawesi. Indonesia Natural Research Pharmaceutical Journal 1(1):36-42.

Silalahi M, Supriatna J, Walujo EB, Nisyawati. et al. 2015. Local knowledge of medicinal plants in sub-

ethnic Batak Simalungun of North Sumatra, Indonesia. Biodiversitas 16(1):44-54.

Silalahi M, Nisyawati. 2015. Pemanfaatan Anggrek sebagai bahan obat tradisional pada Etnis Batak Sumatera Utara. Berita Biologi 14(2):187-193.

Silalahi M, Nisyawati. 2018. The ethnobotanical study of edible and medicinal plants in the home garden of Batak Karo sub-ethnic in North Sumatra, Indonesia. Biodiversitas 19(1):229-238.

Simanjuntak HA. 2018. Pemanfaatan tumbuhan obat diabetes mellitus di masyarakat Etnis Simalungun Kabupaten Simalungun Provinsi Sumatera Utara. BioLink 5(1):59-71.

Situmorang ROP, Harianja AH, Silalahi J. 2015. Karo's local wisdom:The use of woody plants for traditional diabetic medicines. Indonesian Journal of Forestry Research 2(2):121-131.

Situmorang TS, Sihombing ESR. 2018. Kajian pemanfaatan tumbuhan obat pada masyarakat Suku Simalungun di Kecamatan Raya Desa Raya Bayu dan Raya Huluan Kabupaten Simalungun. BioLink - Jurnal Biologi Lingkungan, Industri, Kesehatan 4(2):112-121.

Slamet A, Andarias SH. 2018. Studi etnobotani dan identifikasi tumbuhan berkhasiat obat masyarakat Sub Etnis Wolio Kota Baubau Sulawesi Tenggara. In Proceeding Biology Education Conference. Edited by Saputra A. Fakultas MIPA Universitas Sebelas Maret Surakarta, Surakarta, Indonesia, Pp. 721-732.

Sodirun F, Hayati A, Zayad H. 2016. Persepsi masyarakat tradisional Pulau Mandangin Kabupaten Sampang terhadap Tanaman Mimba (Azadirachta indica Juss). e-Jurnal Ilmiah Biosaintropis 2(1):11-18.

Susila KA, Tellu AT, Tangge L. 2017. Jenis dan pemanfaatan tanaman obat di Desa Tinading dan pengembangannya sebagai media pembelajaran. e-Jurnal Ilmiah Pendidikan Biologi 5(2):60-70.

Syamsiah. 2014. Eksplorasi tumbuhan obat tradisional di Kecamatan Pamboang Kabupaten Majene Sulawesi Barat. Bionature 15(2):127-136.

Syamsiah, Hiola SF, Mu'nisa A, Jumadi O. 2016. Study on medicinal plants used by the Ethnic Mamuju in West Sulawesi, Indonesia. Journal of Tropical Crop Science 3(2):42-48.

Taher M, Zakaria TMFST, Susanti D, Zakaria ZA. 2016. Hypoglycaemic activity of ethanolic extract of Garcinia mangostana Linn. in normoglycaemic and streptozotocin-induced diabetic rats. BMC Complementary and Alternative medicine 16:article 135.

Tam NT, Thien DC, Sung TV, Anh NTH, Thuy TT, Trung KH, Xuan TD, Khanh TD. 2016. Evaluation of ursolic acid as the main component isolated from Catharanthus roseus against hyperglycemia. International Letters of Natural Sciences 50:7-17.

Tambaru E. 2017. Keragaman jenis tumbuhan obat indigenous di Sulawesi Selatan. Jurnal Ilmu Alam dan Lingkungan 8(15):7-3.

Tapundu AS, Anam S, Pitopang R. 2015. Studi etnobotani tumbuhan obat pada Suku Seko di Desa Tanah Harapan, Kabupaten Sigi, Sulawesi Tengah. Biocelebes 9(2):66-86.

Thakur AK, Rai G, Chatterjee SS, Kumar V. 2016. Beneficial effects of an Andrographis paniculata extract and andrographolide on cognitive functions in streptozotocin-induced diabetic rats. Pharmaceutical Biology 54(9):1528-1538.

Tiong SH, Looi CY, Hazni H, Arya A, Paydar M, Wong WF, S Cheah SC, Mustafa MR, Awang K. 2013. Antidiabetic and antioxidant properties of alkaloids from Catharanthus roseus (L.) G. Don. Molecules 18(8):9770-9784.

Tudjuka K, Ningsih S, Toknok B. 2014. Keanekaragaman jenis tumbuhan obat pada kawasan hutan lindung di Desa Tindoli Kecamatan Pamona Tenggara Kabupaten Poso. Warta Rimba 2(1):120-128.

Wahidah BF, Husain F. 2018. Etnobotani tumbuhan obat yang dimanfaatkan oleh masyarakat Kecamatan Tompobulu Kabupaten Gowa Sulawesi Selatan. Life Sciences Journal of Biology 7(2):56-65.

Watanabe M, Gangitano E, Francomano D, Addessi E, Toscano R, Costantini D, Tuccinardi D, Mariani S, Basciani S, Spera G, Gnessi L, Lubrano C. 2018. Mangosteen extract shows a potent insulin sensitizing effect in obese female patients:A prospective randomized controlled pilot study. Nutrients 10:article 586.

WHO 2012. Indonesia:WHO statistical profile. Available at:https://www.who.int/gho/countries/idn.pdf?ua=1

WHO 2013. WHO Traditional Medicine Strategy:2014-2023. World Health Organization, Hong Kong, Hong Kong.

Wibudi A, Kiranadi B, Manalu W, Winarto A, Suyono S. 2008. The traditional plant, Andrographis paniculata (Sambiloto), exhibits insulin-releasing actions in vitro. Acta Medica Indonesia Indonesian Journal of Internal Medicine 40(2):63-68.

Xu J, Li Z, Cao M, Zhang H, Sun J, Zhao J, Zhou Q, Wu Z, Yang L. 2012. Synergetic effect of

Andrographis paniculata polysaccharide on diabetic nephropathy with andrographolide. International Journal of Biological Macromolecules 51:738-742.

Xu Y, Niu Y, Gao Y, Wang F, Qin W, Lu Y, Hu L, Peng L, Liu J, Xiong W. 2017. Borapetoside E, a clerodane diterpenoid extracted from Tinospora crispa, improves hyperglycemia and hyperlipidemia in high-fat-diet-induced type 2 diabetes mice. Journal of Natural Products 80:2319−2327.

Yu Z, Lu B, Sheng Y, Zhou L, Ji L, Wang Z. 2015. Andrographolide ameliorates diabetic retinopathy by inhibiting retinal angiogenesis and inflammation. Biochimica et Biophysica Acta 1840:824-831.

Yulia C, Fahri, Pitopang R. 2017. Studi etnobotani tumbuhan obat Suku “Topo Uma” di Desa Oo Parese Kecamatan Kulawi Selatan Kabupaten Sigi Sulawesi Tengah. Biocelebes 12(2):1-22.

Zenderland J, Hart R, Bussmann RW, Zambrana NYP, Sikharulidze S, Kikvidze Z, Kikodze D, Tchelidze D, Khutsishvili M, Batsatsashvili K. 2019. The use of ‘Use Value’:Quantifying importance in ethnobotany. Economic Botany 3(3):293-303.

Zhang C, Gui L, Xu Y, Wu T, Liu D. 2013. Preventive effects of andrographolide on the development of diabetes in autoimmune diabetic NOD mice by inducing immune tolerance. International Immunopharmacology 16:451-456.