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A comprehensive overview of plant genus: *Lindernia*

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Abstract

Objective: Generally *Lindernia* species were considered as weeds, but now only their therapeutic value was identified and investigated last few decades. *Lindernia* species occupy a most important place in the traditional medicine used worldwide especially in China. Many species under *Lindernia* genus were yet to be explored phytochemically and pharmacologically. So our current investigation was to generate a comprehensive overview for *Lindernia* genus.

Key findings: This review enlightens the geographical distribution of *Lindernia* species. A comparison study was done to identify the different *Lindernia* species through their morphological characteristics, Traditional medicinal uses and their usages in modern medicine were tabulated along with their phytochemical profiles and reported biological activities of plant species under *Lindernia* genus.

Summary: Reported ethano medicinal usage and secondary metabolite proforma concludes the importance and renowned usage of *Lindernia* species for centuries in various countries. Further scientific exploration was needed to prove efficacy of *Lindernia* species as potential source for drug discovery.

Keywords: *Lindernia*, ethano medicinal, morphology, phytochemical and biological activities

Introduction

One of the plant genus with a high traditional medical summary with less pharmacognostical, the phytochemical and biological profile is *Lindernia*. *Lindernia* species are one of the major sources herbal preparations in several traditional medicines practiced in various nations including China and India. Plant species under the genus *Lindernia* belongs to the family Linderniaceae. Linderniaceae is a family of flowering plants in the order Lamiales, which comprises of around 13 genera and 195 species from around the world, commonly in the neotropics [1]. In other classifications, it used to be included within the family, Scrophulariaceae sensu lato or more recently in Plantaginaceae sensu lato, but several authors have demonstrated that this taxon should be segregated from those families, as Linderniaceae a separate family [2, 3]. Now the Linderniaceae family contains 12 or more different genera: *Lindernia* All., *Vandellia* L., *Bonnaya* Link and Otto, and *Ilysanthus* Rafin are most commonly used [4, 5].

Among all the genera of Linderniaceae family, *Lindernia* scores a great importance owing to its reported ethnomedicinal uses, reported pharmacological activities and easy availability. *Lindernia* All., genus named after F. B. von Lindern who first portrayed and represented this species. Traditionally *Lindernia* All. Genus belongs to the Scrophulariaceae later segregated as a member of the new family Linderniaceae which was accepted by APG III in the year 2009.

Methodology

The literatures related to *Lindernia* species were retrieve from online databases includes Google Scholar, Pubmed, Web of science and Science Direct Navigators. There were more than 250 articles collected and a comprehensive review was generated for the plant genus *Lindernia*. Data were organized and tabulated by using Microsoft Word. The geographical distribution and habitat of *Lindernia* species were mentioned in Table 1. The morphological characteristics of various *Lindernia* species were compared in Table 2. The medicinal uses of *Lindernia* species in traditional and modern era, phytochemical and biological activities of *Lindernia* species performed till date were mentioned in Table 3.

Lindernia: Global distribution and general morphology

This genus contains around 160 species all through the vast majority of the old and new world tropics. They fall in 3 fundamental geographical groups, the largest occurring in Asia followed by those in Africa and America [5]. There are 22 species were identified in India, in that 18 species of *Lindernia* were recorded in the checklist of angiosperms of Kerala itself [6].

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Plants are annuals or perennials. Stem are erect to prostrate, generally quadrangular. Leaves are opposite, simple, pinnately or palmately nerved, entire or serrate. Lower in terminal or axillary racemes or in subumbellate clusters. Calyx is deeply to shallowly 5-lobed, 5-nerved, each nerve with an obscure or distinct rib. Corolla is tubular, bilabiate; posterior lip 2-lobed, entire or emarginated; anterior lip 3-lobed. Stamens are 2 or 4; posterior pair fertile; anterior pair fertile, sterile or reduced to simple staminodes; anterior filaments usually ach with a distinct appendage or geniculum arising near base; anthers touching in pairs under posterior lip; another cell divaricate. Style is filiform; stigma 2-parted.

Ovary is obliquely or symmetrically ovate, oblong or cylindrical, glabrous. Capsule is septicidally 2-valved, valves separated from the placenterous septum. Seeds are small, numerous, ellipsoid, shortly cylindrical or triangle-like to polygonal, reticulate or scrobiculate [7-12].

A list of Indian *Lindernia* species with its habitat and distribution throughout the world was given in Table 1. The morphological characters of *Lindernia madayiparensis* was compared with the other species in the same genera. The details were given in Table 2. The medicinal uses, phytochemicals, and biological activities carried out yet were reported in the Table 3.

Table 1: List of some important *Lindernia* species with its habitat and geographical Distribution

<i>Lindernia</i> species	Habitat	Distribution
<i>Lindernia anagallis</i> (Burm.f.) Pennell [13]	Edge of forests, along streams, rice fields, wet places; ca. 1500 m	Bhutan, Cambodia, India, Japan, Laos, Malaysia, Myanmar, Philippines, Sikkim, Thailand, Vietnam; Australia
<i>Lindernia antipoda</i> (L.) Alston [14]	Rice fields, wet grassland; below 1700 m.	Bhutan, Cambodia, India, Japan (Ryukyu Islands), Laos, Malaysia, Myanmar, Nepal, Philippines
<i>Lindernia caespitosa</i> (Blume) Panigrahi [15]		
<i>Lindernia ciliata</i> (Colsm.) Pennell [16]	Moist places, rice fields, grassland, wastelands, trailsides; ca. 1300 m.	Cambodia, India, Japan (Ryukyu Islands), Laos, Malaysia, Myanmar, Philippines, Vietnam; North Australia
<i>Lindernia crustacea</i> (L.) F.v. Muell. [17]	Moist areas, rice fields, grassland, trailsides; below 1300 m.	widely distributed in tropics and subtropics- Asia, Africa America
<i>Lindernia diffusa</i> (L.) Wettst [18]	Moist places	America, West tropical Africa
<i>Lindernia hyssopoides</i> (L.) Haines [19]	Dry fields, wet areas; ca 1200 m	India, Indonesia, Sri Lanka, Vietnam
<i>Lindernia madayiparensis</i> [20]	Beside and in pond	Madayipara, Kerala, India
<i>Lindernia manilaliana</i> V.V. Sivarajan [21]	moist grounds, swampy lowlands, wet lands	Southern west ghats, India
<i>Lindernia minima</i> (Benth.) Mukerjee is (synonym of <i>Lindernia fugax</i> R.G.N. young) [22]	Rice fields, along rivers, wet areas; ca. 1500 m	Cambodia, India, Indonesia (Java), Japan, S Korea, Laos, Myanmar, Nepal, Sri Lanka, Thailand, Vietnam
<i>Lindernia oppositifolia</i> (Retz.) Mukerjee [23]	Fields, scrub on sunny mountain slopes, forest edges, along streams; 900–1400 m. F	Cambodia, India, Indonesia, Laos, Malaysia, Myanmar, Pakistan, Vietnam
<i>Lindernia parviflora</i> (Roxb.) Haines [24]	Humid sandy places, rice fields, perennially moist areas and along river banks	Bangladesh; Botswana; China (Yunnan); Ethiopia; India (Assam, Bihar, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Tamil Nadu, Uttar Pradesh, West Bengal); Lao People's Democratic Republic; Madagascar; Malawi; Mozambique; Myanmar (Myanmar (mainland)); Namibia; Nepal; South Sudan; Sri Lanka; Sudan; Thailand; Viet Nam; Zimbabwe
<i>Lindernia procumbens</i> (Krock.) Philcox [25]	Next to water, wet areas; below 1200 m.	Afghanistan, India, Indonesia (Java), Japan, Kashmir, Kazakstan, Laos, Nepal, Pakistan, Russia, Tajikistan, Thailand, Vietnam; S Europe
<i>Lindernia rotundifolia</i> (L.) Alston [26]	Marshy areas	Paleotropics
<i>Lindernia ruellioides</i> (Colsm.) Pennell [27]	River side, Stream side, Fresh water, Grassland, plains, mountain valleys, forests; below 1500 m.	Cambodia, India, Indonesia, Japan (Ryukyu Islands), Malaysia, Myanmar, New Guinea, Philippines, Vietnam

Table 2: A Comparative Morphological Chart of *Lindernia* species [13- 20, 23-30]

Plant name	Leaves	Stems	Pedicels	Corolla	Staminodes	Capsule	Seeds
<i>Lindernia anagallis</i>	Leaves 0.8-2 x 0.5-1 cm, ovate to elliptic, base truncate, margin crenate-serrate, apex subacute, penninerved, glabrous, sessile	Stems creeping, often branched, striate, glabrous, rooting from nodes.	pedicel 1-1.5 cm long	Corolla tube 6-8 mm long; limb 2-lipped, upper lip entire, lower lip 3-lobed	staminodes 2-lobed	Capsule to 1.3 mm long, linear, glabrous, much exceeding the calyx.	Seeds c. 0.5 mm long, ellipsoid.
<i>Lindernia antipoda</i>	opposite leaves are oblong to lanceolate, measuring 1-4 cm long	slender, branching at the base	Pedicel to 1.5 cm, ascending, spreading, to deflexed in fruit	Corolla bluish with a yellow mouth, 6-8 mm long, internally short pilose between the staminodes	staminodes 2, hooked	Capsule 1-1.4 cm long, linear-lanceolate	Seeds yellow, ridged.
<i>Lindernia caespitosa</i> (Blume) Panigrahi	Ovate, orbicular ovate, truncate at base, obtuse at	Prostrate, with long internodes,	Pedicels 3-20mm long, slender, glandular-	3mm long, 2 lobes at apex, pale brown with		Globose 3-4mm in diameter, glab	

	apex, Petioles 1-3mm long	hispidulous	pubsectant. longer	purpleish linease			
<i>Lindernia cilita</i>	0.8-1.5 x 0.4-0.6 cm, elliptic-oblong, base rounded, margin aristate-dentate, apex obtuse or acute, penninerved, sessile.		Flowers in lax terminal racemes pedicels 1-2 mm long. Bracts leafy, 2-3 mm long. Calyx-lobes 5, c. 5 mm long, linear	. Corolla pink or bluish-pink, c. 8 mm long, tube curved, 2-lipped. Ovary 2 -3 mm long, elongate.	Stamens 2; anthers unequal; staminodes with divergent hooks.	Capsule 1-1.5 cm long, linear, septum winged, exceeding the fruiting calyx.	Seeds black.
<i>Lindernia crustacea</i>	Leaves 0.8-1.5 x 0.7-1.2 cm, ovate, base truncate, margin serrate, apex subacute, penninerved;	stem 4-angled, slightly winged on angles	pedicel 1-1.2 cm long	Corolla rose to purple, tube c. 5 mm long.	Staminoids 2-fid, obtuse, with a linear, hairy, basal appendage.	Capsule c. 5 mm long, 2-3 mm across, ovoid.	Seeds minute, many.
<i>Lindernia Diffusa</i> [29]	ovate to subcircular, 12-19 (-25) mm long, 9-15(-19) mm wide, rounded to broadly cuneate at base, apex obtuse, margins finely crenate-serrate, glabrous above	Stems up to 20 cm long, quarter angular	Solitary in axils, pedicels 2-3.5 mm long Calyx prominently 5-ribbed, 3.5-4.5 mm long	Corolla white or cream 5-6 mm long, tube ± 4.5 mm long; upper lip shallowly emarginate or minutely irregularly toothed	4 fertile stamens	Capsule oblong-ellipsoid, 7-7.5(-12) mm long, 2-3.5 mm broad	
<i>Lindernia hyssopioides</i>	Leaves 1-2 x 0.2-0.4 cm, linear-lanceolate, basal ones elliptic-ovate, base cuneate or truncate, apex acute	stem 4-angled, simple or diffusely branched	Glabrous	Corolla pale lilac or bluish	staminodes usually 2-fid, obtuse with a linear, hairy, basal appendage	Capsule 4-5 mm long, ovoid-ellipsoid, twice as long as the fruiting calyx	Seeds yellow, oblong
<i>Lindernia madayiparense</i> [30]	Leaves dimorphic, submerged in whorls, linear, aerial decussate, oblong-linear; margins of aerial leaves sharply 1-3 dentate, densely punctuate	Submerged stem terete and spongy, aerial stem 4-angled, not spongy	Glandular-puberulent	Corolla throat devoid of yellow spots, upper lip sharply 2- fid with acute lobes	staminodes simple, ca. 1 mm long, linear to club-shaped, white, glandular-hairy at base	Young capsules densely punctuate, mature capsules sub-equalling or slightly longer than the persistent sepals	narrowly ellipsoidal, slightly curved, longitudinally ridged, ridges rugose
<i>Lindernia oppositifolia</i>	Leaves 4 x 0.5 cm, linear-oblong, acute, distantly serrate, sessile. Racemes to 13 cm long, terminal;	Stem Glabrous	pedicels opposite, 2 cm long, slender, perpendicular to the axis	Flowers paired; sepals 7 mm long, linear lanceolate, free to the base corolla 12 mm long; upper lip entire or emarginate, lower lip equally 3-lobed; anthers divaricate	staminodes linear, bulged at apex	Capsule 17 x 1.5 mm, terete	Seeds 0.3 mm long, obovoid, minutely muriculate.
<i>Lindernia parviflora</i>	Leaves to 1.5 x 0.7 cm, ovate, acute, entire, sessile	Stem 4-angled and solid	Pedicels not glandular-puberulent	Corolla throat provided with two yellow dots, upper lip notched	staminodes with lateral vermiform appendages.	Young capsules do not densely punctuate, mature capsules two times as long as the persistent sepals	Seeds 0.3 mm long, obovoid, yellow, glabrous.
<i>Lindernia procumbens</i>	Leaves 1-2.5 x 0.5-1 cm, elliptic to ovate -elliptic, margins entire or sub-crentae, scabrid, 3-5-nerved from base, sessile.	Stem 2-15 cm high, ascending or erect, 4-sulcate	Pedicles to 1.5 cm long, slender.	Corolla 3-6 mm long, white, upper lip almost circular.	-	Capsule ellipsoid, equal to or slightly longer than calyx.	Seeds yellow, compressed-cylindric.
<i>Lindernia rotundifolia</i>	Leaves 0.8-1.3 x 0.5-1 cm, ovate to orbicular, base and apex rounded, margin crenate to subentire, basally 3-nerved, sessile	Erect, prostate and 4 angled	pedicle 0.5-1 cm long, slender	Corolla c. 1 cm long, white with blue blotches at mouth and lobes; lobes orbicular.	staminodes 2, glandular-scabrid at the base.	Capsule c. 3 mm long, subglobose, equal to or slightly shorter than calyx.	Seeds c. 0.5 mm long, oblong, pale brown.

<i>Lindernia ruellioides</i> (Colsm.) Pennell	Leaves to 5 x 1.8 cm, elliptic-oblong, obtuse at apex, coarsely dentate-serrate; nerves 3-5 pairs;	Quarter angled, erect	opposite; pedicels 1 cm long, slender, perpendicular to axis; sepals 6 mm long, lanceolate, basely connate, glabrous;	Corolla blue, 2-lipped, lobes round.	Capsule 1.7 cm long, linear, acuminate	Seeds trigonous, 0.5 mm long, rugose, brown.
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Table 3: Reported Medicinal uses, Phytochemicals and Biological activities of *Lindernia* species

Species name	Medicinal Uses (in combination / alone)		Phytochemicals reported yet	Biological activities carried out	Citations
	Traditional era	Modern era			
<i>Lindernia anagallis</i>	-clear heat and toxic substance, -eliminate phlegm, -relieve a cough, -for swelling and pain, -nourish yin To treat gonorrhoea	To treat pharyngitis		-antimicrobial activity -antioxidant activity -anti-inflammatory activity -antioxidant property	Xurui and Jianfeng, 2008 ^[31] Swapna <i>et al.</i> , 2011 ^[32] Tsai <i>et al.</i> , 2011 ^[33] Shyura <i>et al.</i> , 2005 ^[34]
<i>Lindernia antipoda</i>	-eliminate dampness and relieve pain	-relieve rigidity of muscles -activate collaterals, -promote blood circulation -remove blood stasis -dispell pathogenic wind -remove dampness -treat rheumatism -cold rheumatism -joint pain -limb numbness caused by rheumatism, chronic joint pain, bone and muscle pain -rheumatism pain -traumatic injury -treat prostatic hyperplasia	Flavonoid and flavonol		Lan and Zihua, 2006 ^[35] Ho <i>et al.</i> , 2012 ^[36]
<i>Lindernia pusilla</i> / <i>Lindernia caespitosa</i> (Blume) Panigrahi	-after childbirth to promote lactation -to cure the infected fingernails -to induce emesis				Gunatilaka <i>et al.</i> , 2015 ^[37]
<i>Lindernia ciliate</i> or <i>Lindernia bracheata</i>	-anti-diabetic purposes -Gonorrhoea -jaundice, -urinary disturbances, -headache, -liver complaints, -spleen diseases, -constipation, -fever, -loss of appetite, -cough, -worms and skin diseases	-for hypertension, -diabetes, -anaemia, -gonorrhoea, -jaundice, -bronchitis, -asthma,	β -sitosterol, stigmasterol and lup-20(29)en-3 β -ol Flavonoids and phenolic compounds	Hepatoprotective activity	Barukial and Sarmah, 2011 ^[38] Swapna <i>et al.</i> , 2011 ^[32] Gupta and Pandey, 2014 ^[39] Devi <i>et al.</i> , 2013 ^[40] Praneetha <i>et al.</i> , 2014 ^[41]
<i>Lindernia crustaceae</i>	-to cure the skin disease. -to treat high fever -diabetes -abdominal ailments. -to cure throat irritation -to cure excess bile secretion -To remove dampness, -relax and activate tendons, -promote blood circulation to remove blood stasis, -eliminate slough and promote granulation, -benefit qi and nourish blood, -soften the bone spur, -subside swelling and relieve pain. -To remove heat and toxic substances, -eliminate dampness and relieve dysentery. -For gynaecological disease Used in postpartum women. -to cure the skin disease. -resist cancer and inflammation, -inhibit tumor,	-asthma, rheumatism -to heal wounds -treatment of tonsil -for cervical syndrome, -lumbar vertebra diseases, Scapulo humeral peri-arthritis, -lumbar disk herniation, -rheumatoid arthritis, -hyperostosis, -bone tuberculosis, -osteomyelitis, -bone necrosis, -lymphoid tuberculosis, -ischialgia, -hyperplasia of mammary glands, and intractable dermatologic disease -to treat bacillary dysentery -to treat sallow complexion due to blood deficiency, -giddiness, -cardiopalmus, -insomnia, -cool blood, -asthenia, -menoxenia,	Linderside A (Cucurbitane glycoside) and Lindersin B (Cucurbitane triterpenoid)	-induces neuritogenesis -anti- and pro-lipase activity -inhibits H22 tumor and EL_4 lymphoma	Madhu and Rajesh, 2011 ^[42] Tiwari and Rana, 2015 ^[43] Meenu <i>et al.</i> , 2016 ^[44] Swapna <i>et al.</i> , 2011 ^[32] Roshan and Apruba, 2016 ^[45] Lihong <i>et al.</i> , 2017 ^[46] Abubakar <i>et al.</i> , 2013 ^[47] Xie <i>et al.</i> , 2012 ^[48] Qu <i>et al.</i> , 2009 ^[49] Hu <i>et al.</i> , 2008 ^[50] Minh <i>et al.</i> , 2014 ^[51] Sivaranjani and Ramakrishnan, 2012 ^[52] Xie <i>et al.</i> , 2012 ^[53] Zhu <i>et al.</i> , 2013 ^[54] Wang and Haikuo, 2007 ^[55] Wang <i>et al.</i> , 2012 ^[56]

	<ul style="list-style-type: none"> -expel heat evil and toxins -improve sleep, -resist senility -improve immunity. -to treat leprosy 	<ul style="list-style-type: none"> -metrorrhagia, -waist soreness, -leg weakness, -lumbodynia due to spleen deficiency, -limb numbness, -amnesia, -night sweat, -qi deficiency, -susceptibility to common cold, -irascibility, -malnutrition, -infertility and recurrent abortion due to asthenia. -to treat nose furuncle in early stage -for regulating blood lipid and blood pressure, -increasing coronary and cerebral blood flow, -removing heat and relieving inflammation, - inhibiting carcinogenesis cell, -preventing arteriosclerosis -to eliminating toxins and inflammation, -stopping bleeding, - removing stasis and swelling, -promoting secretion and treating haemorrhoid 			
<i>Lindernia diffusa</i>	-to treat of fever intermittent fevers, bilious fevers, dysentery and liver ailments, antiemetic, laxative, oxytocic, vermifuge				Melina <i>et al.</i> , 2010 ^[57]
<i>Lindernia hyssopioides</i>	-to dysentery, Intestinal problems and liver problems				Tropical plant database ^[58] T Pullaiah 1253 ^[59]
<i>Lindernia madayiparensis</i>	Treat fever			Antioxidant activity Cytotoxicity against HepG-2 cell lines Anthelmintic activity	Umakrithika <i>et al.</i> , 2016 ^[20] Umakrithika <i>et al.</i> , 2017 ^[60] U Chiranjeevi <i>et al.</i> , 2017 ^[61] Chiranjeevi U <i>et al.</i> , 2018 ^[62]
<i>Lindernia montana</i>	<ul style="list-style-type: none"> -clearing heat and toxic materials in the body, -invigorating the circulation of blood, -eliminating swelling 				Swapna <i>et al.</i> , 2011 ^[32]
<i>Lindernia oppositifolia</i>	-to treat fevers				Swapna <i>et al.</i> , 2011 ^[32] Abhijit and Jitendra, 2012 ^[63]
<i>Lindernia Parviflora</i>	- Blood dysentery, ephemeral fever of livestock				Gupta and Pandey, 2014 ^[39]
<i>Lindernia procumbens</i>	<ul style="list-style-type: none"> -To treat dysentery -heat-clearing -detoxicating, -anti-inflammatory, -pain relieving, -blood cooling, -hemostasis, -dampness eliminating, -toxic substances removing, -hard mass resolving, - bowels relaxing -anti-tumor, -immunity enhancing effects 	<ul style="list-style-type: none"> -cancer, -benign tumor such as esophageal cancer, hepatocarcinoma, liver cirrhosis, leukemia, uterus myoma; -inflammation such as cholecystitis, tonsillitis, pharyngolaryngitis, appendicitis, pid, gynecol. inflammation; -tuberculosis such as lymphoid tuberculosis, tuberculosis testis, tuberculosis of galactophore; - intestinal obstruction -hypertension, -drug dependence, -sexually transmitted diseases, -prostatitis, -hemorrhage, -obesity. -As aerosol for treating simple 	Linderniosides A and B, oleanane saponins	-anti-tumor(Lewis lung cancer, H22 ascite tumor)	Swapna <i>et al.</i> , 2011 ^[32, 66] Toshio <i>et al.</i> , 1995 ^[64] Pan <i>et al.</i> , 2009 ^[65] Liu <i>et al.</i> , 2013 ^[66] Xie and Yu, 2006 ^[67] Rao and Xinge, 2012 ^[68]

		gingivitis and treat gingival swelling and pain		
<i>Lindernia rotundifolia</i>		-for treating chalosma and boils		Chen and Wenzhong, 2013 ^[69] Uddin, 2019 ^[70]

Summary

The current review mostly focused on the geographical distribution, morphological description, phytochemistry, medicinal uses and biological activities reported so far.

The review emphasized the following points:

1. *Lindernia* species are widely distributed in moist tropical lands mainly in Asia and African continents.
2. Plant identification guidelines were on account of morphological features and anatomical characteristics of plant species.
3. The reported ethano medicinal uses give valuable clues to assess the efficacy of plant species.
4. The isolated and identified phytochemicals were biomarkers to recognize the corresponding plant species.

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