

PLANT & FOREST

# An updated taxonomy of the family Linderniaceae in Korea

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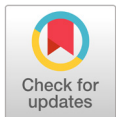
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## Abstract

In the present study, according to morphological observations followed by recent circumscriptions, we have classified the Korean taxa of the family Linderniaceae into Scrophulariaceae sensu lato has been considered in several works, though the taxa have remained undefined because identification work was mostly done according to vegetative morphological features, such as the leaf shape, leaf margins, and leaf venation. The taxa of Linderniaceae are mostly considered to be weeds and, for correct identification, it is necessary to clarify their taxonomic characteristics. Morphological studies were carried out using samples collected in the field. Micro-morphological observations of the vegetative and floral parts were also performed using light microscopy (LM) and scanning electron microscopy (SEM). We concluded that important characteristics are reproductive morphologies viz. calyx, stamen structure, capsule shape, calyx ratio with capsule, inflorescence morphology, and seed morphology. As a result, we formulated taxa descriptions and provided a key of the genera of Linderniaceae in Korea. *Lindernia crustacea* (L.) F. Muell. is transferred to *Torenia crustacea* (L.) Cham. & Schtdl. *Lindernia micrantha* D. Don and *L. angustifolia* (Benth.) Wettstein are a synonym of *Vandellia micrantha* (D. Don) Eb. Fisch., Schäferh. & Kai Müll. *Lindernia attenuata* Muhl. and *L. dubia* var. *major* (Pursh) Pennell are a synonym of *Lindernia dubia* (L.). *Lindernia verbenifolia* (Colsm.) Pennell is a synonym of *Bonnaya antipoda* Druce. Our study reports the presence of four genera: *Bonnaya*, *Lindernia*, *Torenia*, and *Vandellia*, comprising six taxa under the family Linderniaceae in Korea.



## OPEN ACCESS

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**Keywords:** exotic weeds, identification, Linderniaceae, morphology, SEM

## Introduction

Linderniaceae is a recently established family segregated from Scrophulariaceae as a result of recent circumscription (APG, 2009; Fischer et al., 2013). Based on molecular and morphological evidence, these studies made new combinations, confirming relationships within Linderniaceae. Some monotypic genera, namely *Bryodes* and *Psammetes*, having cleistogamous flowers, were included in *Lindernia*. Further, a group of species earlier circumscribed under section *Torenioides* were transferred to *Torenia*.

Some species having abaxial staminodes, pinnate leaf venation, and bothrospermous seeds were shifted to *Bonnaya*. On the other hand, species having pinnate leaf venation, serrate leaf margin, 1-celled chalazal haustorium, and alveolate endosperm were shifted to *Vandellia*. The type genus *Lindernia* is characterized by the presence of palmate leaf venation, entire or only slightly dentate leaf margin, a 2-celled chalazal haustorium, and smooth endosperm (Fischer et al., 2013). Further, Liang and Wang (2014) established section *Bonnaya* under the genus *Bonnaya*; section is characterized by the presence of pinnate leaf venation, a deeply five-lobed calyx, two fertile stamens, clavate staminodes without appendages, and linear cylindrical capsule.

In Korea, Lee (2003) identified 4 species of *Lindernia* (*L. procumbens* Borb., *L. micrantha* D. Don, *L. crustacea* (L.) F. Muell., *L. attenuata* Muhl.), whereas Lee (2006) recognised 3 species within the genus, viz. *L. angustifolia* (Benth.) Wettstein, *L. crustacea* (L.) F.V.Mueller and *L. procumbens* (Krock.) Philcox. Kim et al. (2009) identified 7 taxa within the genus namely *L. crustacea* (L.) F.V.Mueller, *L. procumbens* (Krock.) Philcox, *L. micrantha* D. Don, *L. verbenaefolia* (Colsm.) Pennell, *L. dubia* (L.) Pennell, *L. dubia* var. *major* (Pursh) Pennell, and *L. dubia* var. *anagallidea* (Michaux) Cooperrider based on the vegetative characters like leaf shape, base, margin, and venation. The present study is an attempt to provide a synopsis of the family Linderniaceae in light of the recent circumscriptions. Our study reports the occurrence of four genera and six species under family Linderniaceae in Korea. To understand the taxonomy and population variation in detail, we have further carried out morphometric studies on Linderniaceae members in Korea. Photomicrography was also performed using a Scanning Electron Microscope to understand the taxonomic details of the seeds.

## Materials and Methods

A total of 31 accessions of Linderniaceae species from 17 populations were collected from different parts of Korea, some of which were planted in the nursery. The vegetative and floral morphology was studied using microscopes (HT003 Gas World, Truro, United Kingdom; SWF-9W, Sam Won, Seoul, Korea). Further, 21 characteristics comprising leaf petiole, blade, apex and base shape, margin, venations, blade length, width, ratio length and width (L/W); pedicel length, shorter or longer than subtending leaf, hairy or glabrous; capsule shape, length, width, equally or longer than persistent calyx; seed shape, color, length, width, and ratio L/W characteristics were measured for 31 accessions. Mean maximum, mean minimum, average, and standard deviation were calculated (Table 1 and 2).

Photomicrography was performed on the seed surface of the collected samples using a Scanning Electron Microscope (SEM). Prior to the SEM study, the specimens were washed with distilled water and placed on a specimen stub and dried at 25°C. After that, samples were directly sputtered with gold palladium in a Sputter Coater (Hitachi E-1010, Hitachi, Hitachi city, Japan) and examined using a scanning electron microscope, S-3400N (manufactured by Hitachi, Japan). Seed morphological characteristics such as size, shape, color, and surface structures are presented in Table 3.

**Table 1.** Morphological characters of the taxa of Linderniaceae in Korea.

Taxa	Leaf		Pedicel	Capsule		Seed		Seed ratio (L/W)
	Length (mm)	Width (mm)	Length (mm)	Length (mm)	Width (mm)	Length (mm)	Width (mm)	
<i>L. procumbens</i>								
Minimum	6.0	3.2	3.8	2.2	1.1	0.32	0.18	1.52
Mean	10.3	5.5	7.5	2.8	1.9	0.36	0.20	1.83
Maximum	21.7	10.3	13.3	3.3	3.1	0.39	0.23	2.11
<i>L. dubia</i>								
Minimum	12.8	6.4	2.8	4.1	1.6	0.30	0.10	2.00
Mean	23.8	9.0	4.6	5.3	2.1	0.37	0.14	2.68
Maximum	29.3	12.1	7.7	6.3	2.4	0.42	0.19	4.10
<i>L. dubia</i> var. <i>anagallidea</i>								
Minimum	5.8	3.0	3.5	3.9	1.4	0.29	0.12	1.68
Mean	9.3	5.5	7.9	4.4	1.8	0.32	0.16	2.03
Maximum	15.1	8.4	9.2	5.9	2.1	0.38	0.22	2.83
<i>Torenia crustacea</i>								
Minimum	7.8	3.0	9.4	4.5	2.9	0.30	0.25	1.10
Mean	10.5	5.3	14.7	5.2	3.4	0.38	0.29	1.28
Maximum	15.4	8.2	20.9	6.0	3.9	0.41	0.33	1.43
<i>Vandellia micrantha</i>								
Minimum	10.9	2.2	6.3	8.6	1.8	0.36	0.20	1.19
Mean	19.3	3.8	10.9	10.8	2.2	0.40	0.23	1.76
Maximum	31.6	6.9	16.5	14.2	2.6	0.42	0.32	2.05
<i>Bonnaya antipoda</i>								
Minimum	14.0	5.4	3.5	6.5	1.9	0.38	0.18	1.65
Mean	26.8	8.9	5.7	7.5	2.2	0.41	0.20	2.02
Maximum	39.7	13.8	9.3	8.9	2.6	0.42	0.23	2.22

L/W, ratio length and width.

**Table 2.** Morphological characters of the Linderniaceae taxa in Korea.

Taxa	Petiole	Blade shape/ apex/base	Leaf margin	Leaf venation	Inflorescence	Stamens	Ovary	Calyx	Capsule	Pedicele
<i>Lindernia procumbens</i>	Absent	Oblong/ obtuse/ attenuate	Weakly obtusely toothed	3 palmate	Flowers pair axillary, solitary axillary or branching in standing leaf	Stamens 4, all fertile, anterior filaments with small clavate glandiflorum appendage	Ovary ellipsoid to 2 mm, style very short	Calyx lobed to base, lobes lanceolate	Capsule globose to ovoid- globose, as long as or slightly longer than persistent calyx	Pedicele glabrous, longer than subtending leaf
<i>L. dubia</i> var. <i>dubia</i>	Present	Elliptic/obtuse/ cuneate	Conspicuous serrate	3 - 5 palmate	Flowers pair axillary, solitary axillary or branching in standing leaf	Posterior pair fertile, anterior pair stamenoides linear, glandular with spur- like 2 appendages at middle part	Ellipsoid, style shorter or equal than ovary	Calyx lobes free to base, lobes lanceolate, hispidulous above	Capsule potbellied oblong ovoid, equally or little longer than persistent calyx	Pedicele glabrous, shorter than subtending leaf
<i>L. dubia</i> var. <i>anagallidea</i>	Absent	Triangular- ovate/acute/ truncate or slightly sub cordate	Slightly serrate	3 - 5 palmate	Flowers pair axillary, solitary axillary or branching in standing leaf	Posterior pair fertile, anterior pair stamenoides linear, glandular, with spur- like 2 appendage near apex	Ovary ellipsoid, to 1 mm. Style shorter or equal than ovary, almost 0.5 mm	Calyx actinomorphic, lobes lanceolate, linear, surface aspirate or gibbous	Capsule potbellied oblong ovoid, apex acute, shorter than persistent calyx	Pedicele glabrous trichomes in bottom part, longer than subtending leaf
<i>Torenia crustacea</i>	Present	Triangular- ovate/ rounded/ attenuate	Shallow serrate	3 - 5 pinnate	Terminal racemes, pair axillary flowers below the terminal raceme	Stamens 4, all fertile, standing upright short glandular knob like appendages in the base of posterior filaments	Ovary ellipsoid, style fugacious	Calyx urn- like, shallowly lobed, lobes triangular-ovate, outside sparsely pubescent	Capsule broadly obovate, almost as long as persistent calyx	Pedicele slender, subglabrous, longer than subtending leaf
<i>Vandellia micrantha</i>	Present	Linear to linear lanceolate/ obtuse/ attenuate	Obscurely serrate	Midvein visible	Flowers pair axillary, solitary axillary or branching in standing leaf	Fertile stamens 4, anterior filaments with spur like appendage; posterior anthers with connective of lower locule produced into a long tail equalling locule	Ovary ellipsoid, to 2 mm. Style longer or than ovary, almost 3 mm	Calyx lobed to base, lobes narrowly lanceolate, glabrous	Capsule linear cylindric, to 1.4 cm, more than 2-3 as long as persistent calyx	Pedicele ascending, spreading, shorter than subtending leaf
<i>Bonnaya antipoda</i>	Present	Oblong- Lanceolate/ acute/cuneate	Sharply serrate	Pinnate	Terminal racemes, pair axillary flowers below the terminal raceme	Anterior 2 stamens reduced, filaments slightly curved, glandular. Posterior pair stamens fertile	Ovary ellipsoid, to 2.5 mm. Style longer or than ovary, 3 mm	Calyx lobed to base, lobes lanceolate, hispidulous along midrib and edges	Capsule cylindric, 2 times or more as long as persistent calyx	Pedicele to 1.5 cm, ascending, spreading, to deflexed in fruit

**Table 3.** Seed morphology of the taxa of Linderniaceae in Korea.

Taxa	Seed shape	Seed color	Surface	Apex/base	Surface ornamentation
<i>Lindernia procumbens</i>	Oblong ellipsoid	Pale yellow	Rough, fuzzy	Apex short beaked, base obtuse	Surface ribbed, longitudinal papillate, pusticulate
<i>L. dubia</i> var. <i>dubia</i>	Unequally tetra to pentagonal ellipsoid,	Pale yellow	Rough, lustrous, glabrous	Apex short reclinate beaked, base obtuse	Surface ribbed, pusticulate, actinomorphic nerves
<i>L. dubia</i> var. <i>anagallidea</i>	Unequally tetra to pentagonal ellipsoid	Gold yellow	Rough, lustrous, glabrous	Apex short beaked, base obtuse	Surface ribbed, pusticulate, reticulated nerves
<i>Torenia crustacea</i>	Subglobose	Yellow	Rough, lustrous, Rlabrous	Apex and base rounded	Surface rounded pits, promiscuous nerves in protuberant, sparsely pusticulate
<i>Vandellia micrantha</i>	Ovoid	Reddish yellow	Wrinkled, glabrous	Apex obtuse, base obtuse	Surface irregular wrinkles, pusticulate
<i>Bonnaya antipoda</i>	Triangular to polygonal ellipsoid	Brown yellow with spotty	Rough, glabrous	Apex beaked, base obtuse	Surface reticulate, stellate projections, sparsely pusticulate

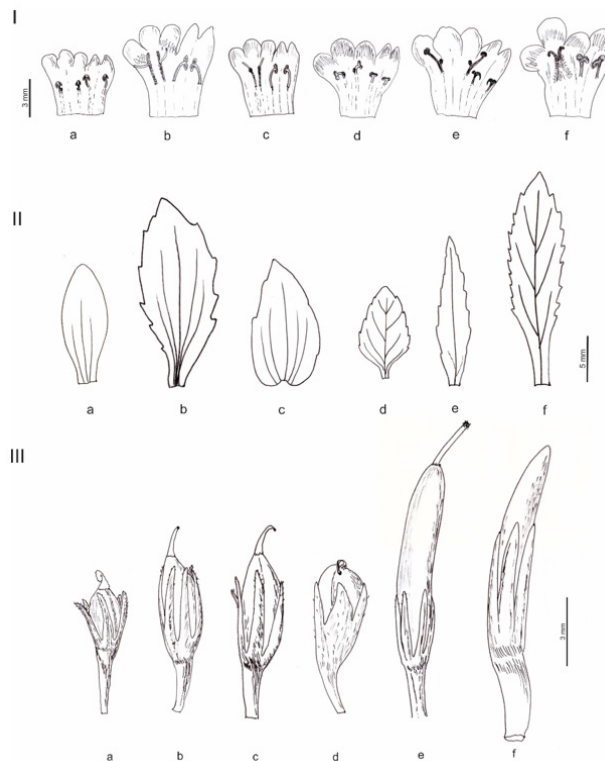
## Results

### Leaf morphology

The leaves could be divided, two groups:

Group A: consisting of the species having palmate venation, petiole absent, blade with 1 - 2 pairs of impalpable serration (Fig. 1-II a, b, c);

Group B: having pinnate venation, petiole present, blade with 5 - 11 pairs of conspicuous serration (Fig. 1-II d, e, f).



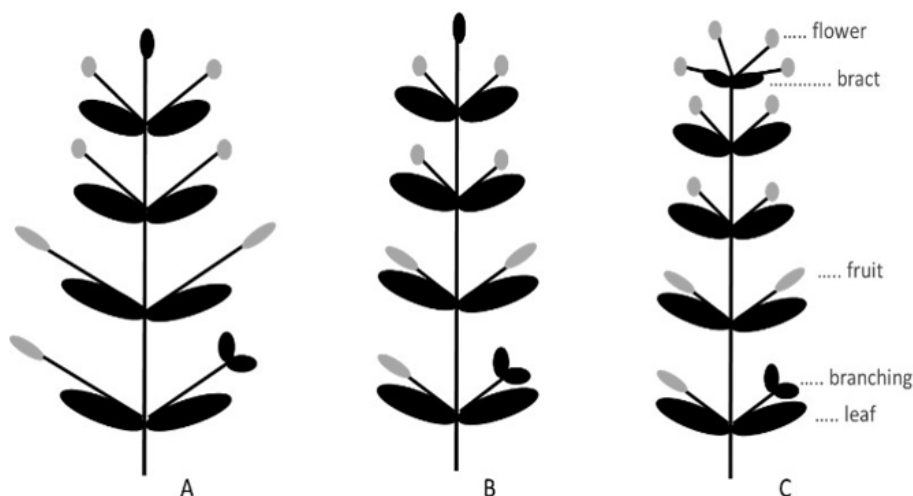
**Fig. 1.** (I) Floral morphology (Scale bars: 3 mm), (II) Leaves (Scale bars: 5 mm), (III) Calyx and capsules (Scale bars: 3 mm) (a, *Lindernia procumbens*; b, *L. dubia*; c, *L. dubia* var. *anagallidea*; c, *Torenia crustacea*; d, *Vandellia micrantha*; f, *Bonnaya antipoda*).

### Inflorescence

The inflorescence could be divided, two groups:

Group A: consisting of the species having axillary flower pairs, solitary axillary or branching in standing, pedicel longer than leaf (*L. procumbens*, *L. dubia* var. *anagallidea*, *Vandellia micrantha*) or shorter (*L. dubia*) than subtending leaf (Fig. 2 a, b);

Group B: having terminal racemes, axillary flower pairs below the terminal raceme, pedicel shorter than subtending leaf (*Torenia crustacea*, *Bonnaya antipoda*) (Fig. 2 c).



**Fig. 2.** Inflorescence types. A, B. Flowers axillary, solitary axillary or branching in subtending leaf (A, *Lindernia procumbens*, *L. dubia* var. *anagallidea*, *Vandellia micrantha*; B, *L. dubia*); C, Inflorescence terminal racemes, axillary flowers below the terminal raceme (*Torenia crustacea*, *Bonnaya antipoda*).

### Reproductive morphology

The reproductive morphologies could be divided, two groups:

Group A: consisting of the species having cleistogamous flowers with all fertile stamens 4 or fertile stamens 2, staminodes 2 (Fig. 1-I a, b, c);

Group B: consisting of the species having chasmogamous flowers with fertile stamens 4 or fertile stamens 2, reduced stamens 2 (Fig. 1-I d, e, f).

### Calyx and capsule

Calyx and capsules could be divided, two groups:

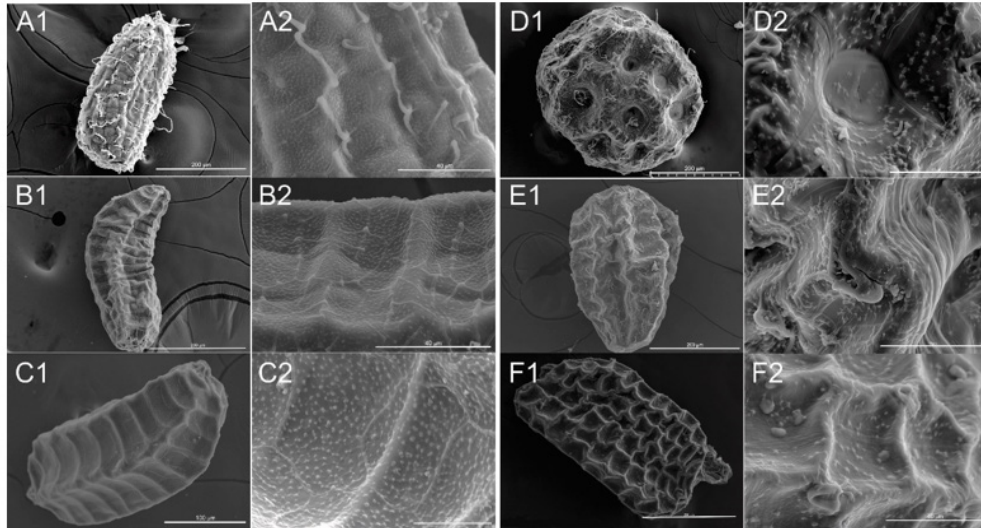
Group A: consisting of the species having 5-lobed to base, lobes linear-lanceolate, or lanceolate, with lobes equally and slightly shorter than capsules, capsules ovoid or potbellied oblong-ovoid in shape (*L. procumbens*, *L. dubia*, *L. dubia* var. *anagallidea*) or lobes 2 - 3 times shorter than capsules, capsules cylindrical linear (*Vandellia micrantha* and *Bonnaya antipoda*) (Fig. 1-III a, b, c, e, f);

Group B: consisting of the species having calyx 5-lobed to the middle, lobes triangular-ovate, slightly shorter than a capsule, capsule obovate in shape (*Torenia crustacea*) (Fig. 1-III d).

### Seed morphology

The seed morphology of the collected species exhibited the following characters:

Seeds oblong ellipsoid or unequally tetra to pentagonal ellipsoid, pale or golden yellow in color, surface ribbed in genus *Lindernia* (Fig. 3-A, B, C). Subglobose shaped, yellow colored, rounded pits surfaced seed in genus *Torenia* (*T. crustacea*, Fig. 3-D). Seed ovoid, reddish-yellow, surface irregular wrinkles in *Vandellia observation* (Fig. 3-E); triangular to polygonal ellipsoid, brown with yellow spotty, surface reticulate in *Bonnaya antipoda* (Fig. 3-F, Table 3).



**Fig. 3.** Scanning electron microscope (SEM) micrographs of seeds of six taxa in the family Linderniaceae: 1, dorsal or ventral view (Scale bars: A, B, D, E, F 200  $\mu$ m; C 100  $\mu$ m); 2, detail of seed surface (Scale bars: A, B, D, E, F 40  $\mu$ m; C 20  $\mu$ m). A, *Lindernia procumbens*; B, *L. dubia*; C, *L. dubia* var. *anagallidea*; D, *Torenia crustacea*; E, *Vandellia micrantha*; F, *Bonnaya antipoda*.

#### *Lindernia procumbens* (Krock.) Philcox

Seed oblong ellipsoid; pale yellow; length 0.32 (0.36) 0.39 mm, width 0.18 (0.20) 0.23 mm, L/W ratio 1.52 (1.83) 2.11; rough, fuzzy, apex short beaked, base obtuse; surface ribbed, longitudinal papillate, pusticulate.

#### *L. dubia* (L.) Pennell

Seed unequally tetra to pentagonal ellipsoid; pale yellow; length 0.30 (0.37) 0.42 mm, width 0.10 (0.14) 0.19 mm, L/W ratio 2.00 (2.68) 4.10; rough, lustrous, glabrous; apex short reclinate beaked, base obtuse; surface ribbed, pusticulate, actinomorphic nerves.

#### *L. dubia* var. *anagallidea* (Michaux) Cooperrider

Seed unequally tetra to pentagonal ellipsoid; gold yellow; length 0.29 (0.32) 0.38 mm, width 0.12 (0.16) 0.22 mm, L/W ratio 1.68 (2.03) 2.83; rough, lustrous, glabrous; apex short beaked, base obtuse; surface ribbed, pusticulate, reticulated nerves.

#### *Torenia crustacea* (L.) Cham. & Schltdl.

Seed subglobose; yellow; length 0.30 (0.38) 0.41 mm, width 0.25 (0.29) 0.33 mm, L/W ratio 1.10 (1.28) 1.43; rough, lustrous, glabrous; apex and base rounded; surface rounded pits, promiscuous nerves in protuberant, sparsely pusticulate.

#### *Vandellia micrantha* (D. Don) Eb.Fisch., Schäferh. & Kai Müll.

Seed ovoid; reddish yellow; length 0.36 (0.40) 0.42 mm, width 0.20 (0.23) 0.32 mm, L/W ratio 1.19 (1.76) 2.05; wrinkled, glabrous; apex and base obtuse, surface irregular wrinkles, pustulate.

*Bonnaya antipoda* Druce

Seed triangular to polygonal ellipsoid; brown with yellow spotty; length 0.38 (0.41) 0.42 mm, width 0.18 (0.20) 0.23 mm, L/W ratio 1.65 (2.02) 2.22; rough, glabrous; apex beaked, base obtuse, surface reticulate, stellate projections, sparsely pustulate.

**Taxonomic treatment:**

Key to the genera of Linderniaceae in Korea

1a. Cleistogamous flowers present; leaf venation palmate; calyx equal or slightly shorter than capsule; 4 stamens all fertile or 2 stamens fertile, staminodes 2 with appendage; capsule ovoid or potbellied oblong; seed surface ribbed, endosperm weakly polygonal or undulate in transverse ..... *Lindernia*

1b. Cleistogamous flowers absent; leaf venation pinnate; calyx 2 - 3 times shorter than capsule; 4 stamens fertile or 2 stamens fertile and 2 reduced; capsule obovoid or cylindrical linear, seed surface with rounded pits, wrinkles or reticulations, endosperm subglobose, ovoid or polygonal ellipsoid

2a. Leaf triangular-ovate, petiolate; calyx shallowly 5-lobed, lobes triangular-ovate, outside sparsely pubescent; capsule obovoid; seed surface with rounded pits, endosperm subglobose ..... *Torenia*

2b. Leaf oblong or linear-lanceolate, sessile; calyx deeply 5-lobed, lobes lanceolate, glabrous; capsule cylindrical-linear; seed surface with reticulations or irregular wrinkles, endosperm ovoid or polygonal ellipsoid

3a. Leaf oblong, pinnate; inflorescence terminal racemes, pair axillary flowers below the terminal raceme; fertile stamens 2, clavate staminodes without appendage ..... *Bonnaya*

3b. Leaf linear-lanceolate; inflorescence pairs axillary subtending leaves; fertile stamens 4, anterior filaments with spur-like an appendage, posterior anthers with appendage ..... *Vandellia*

**Taxonomic treatment of the species of Linderniaceae in Korea**

*Bonnaya* Link & Otto, *Icon. Pl. Select.*, 25, 4 t. 11

*Lindernia* sect. *Bonnaya* (Link & Otto) Philcox. *Kew Bull.* 22: 51 (1967). Type: *Bonnaya brachiata* Link & Otto, *Icon, Pl. Select.* 25, t. 11 (1820) (= *Bonnaya ciliata* (Colsm.) Spreng.).

Annual herbs. Leaves opposite, simple, sessile or petiolate, pinnately veined. Inflorescence terminal racemose or axillary. Calyx deeply 5-lobed, lobes linear-lanceolate, equal. Stamens 2 fertile, staminodes 2, simple without appendage, clavate. Fruits septicial 2-valved capsules, capsule cylindric, apex acute, longer than persistent calyx. Seeds numerous, angular, surface reticulate.

*Bonnaya antipoda* Druce in Bot. Exch. Club Brit. Isles Rep. 3(5): 415. 1914 = *Lindernia antipoda* (L.) Alston in Trimen, *Handb. Fl. Ceylon* 6: 214. 1931; Kim et al., 2009: 273 – *Lindernia verbenifolia* (Colsm.) Pennell

Annuals to 30 cm tall. Roots fibrous, fascicled. Stems suberect or prostrate basally and rooting from lower nodes then ascending, many-branched, channelled, glabrous. Petiole broad shorter; leaf blade oblong, oblong-lanceolate, oblong-ob lanceolate, or linear-lanceolate, 14.0 (- 26.8) 39.7 mm length, 5.4 (- 8.9) 13.8 mm width, glabrous, base cuneate and decurrent, margin obscurely to sharply serrate or subentire, apex acute to rounded. Racemes terminal, to 15 cm, 2-20-flowered; bracts subulate. Pedicel 3.5 (- 5.7) 9.3 mm, ascending, spreading, to deflexed in fruit. Calyx 5-lobed to base; lobes lanceolate, hispidulous along midrib and edges. Corolla purple to purplish-white, or white, up to 1 cm; tube up to 7 mm; lower lip 3-lobed, lobes subequal; upper lip 2-lobed. Fertile stamens 2; filaments without appendage, anterior filaments reduced stamens 2 curved,



glandular. Ovary cylindrical, stigma lamellate. Capsule cylindrical, 2 times or more as long as persistent calyx. Capsules 6.5 (- 7.5) 8.9 mm length, 1.9 (- 2.2) 2.6 mm width, cylindrical linear, 2 times or more as long as persistent calyx. Seed triangular to polygonal ellipsoid, brown with yellow spotty. Flowering May-September and fruiting September-October.

Distribution: South-East Asia: Bhutan, Cambodia, India, Japan (Ryukyu Islands), Laos, Malaysia, Myanmar, Nepal, Philippines, Sri Lanka, Thailand, Vietnam, Australia, Pacific Islands, Indochina, Polynesia, South and Central China, Taiwan, Korea.

*Lindernia* All. in Melanges Philos. Math. Soc. Roy. Turin 3(1):178.

Annual herbs. Leaves opposite, simple, sessile, 3 - 5 palmately veined. Inflorescence solitary or axillary, cleistogamous flowers. Calyx deeply 5-lobed, lobes linear-lanceolate, zygomorphic or actinomorphic. Stamens 2 or 4, all fertile, didynamous; anterior stamens with an appendage or 2 staminodes. Fruits septicidal 2-valved capsules, capsule ovoid or potbellied ovoid, apex acute, equal or slightly longer than persistent calyx. Seeds numerous, tetra to pentagonal ellipsoid, surface ribbed, pustulate.

*Lindernia procumbens* (Krock.) Philcox in Taxon 14(1): 30. 1965; Tchang Bok Lee, 2003: II-171; Lee Yong No, 2006. II: 191; Kim et al., 2009: 272

Annual 5 - 20 cm tall. Stem erect, suberect or decumbent, quadrangular, basally much-branched, glabrous. Roots slender, rooting from lower nodes. Leaves sessile, elliptic to oblong, 6.0 (- 10.3) 21.7 mm length, 3.2 (- 5.5) 10.3 mm width, glabrous, margin entire or weakly obtusely toothed, apex obtuse to rounded; 3 - 5 palmately nerved, parallel from the base. Flower axillary, solitary, cleistogamous flowers. Pedicel slender, 3.8 (- 7.5) 13.3 mm, longer than subtending leaf, glabrous. Calyx lobed almost to base; lobes linear-lanceolate, slightly zygomorphic, outside sparsely pubescent, apex obtuse, hispidulous above. Corolla pink to purple, 5 - 7 mm; lower lip 3-lobed, middle lobe rounded and larger than other lobes, lateral lobes elliptic; upper lip 2-lobed. Stamens 4, all fertile; filaments of anterior stamens with a small clavate glandular appendage. Ovary ovoid, style shorter than ovary, stigma 2-lobed. Capsules 2.2 (- 2.8) 3.3 mm length, 1.1 (- 1.9) 3.1 mm width, ovoid to ovoid-globose, as long as or slightly longer than persistent calyx. Seed oblong ellipsoid, pale yellow. Flowering July-October, fruiting September to November.

Distribution: Widely distributed over tropical to warm-temperate regions Eastern Europe and East Asia to South East Asia. Afghanistan, China, India, Indonesia (Java), Japan, Kashmir, Kazakhstan, Laos, Nepal, Pakistan, Russia, Tajikistan, Thailand, Vietnam; South Europe: Slovakia (Hrivnák et al., 2016), Russia: (West Siberia, Far East), Kazakhstan (Alt.) (Kosachev, 2017).

*Lindernia dubia* (L.) Pennell in Monogr. Acad. Nat. Sci. Philadelphia 1: 141. 1935; Tchang Bok Lee, 2003: II-172. *Lindernia attenuata* Mull.; Kim et al., 2009: 273. *Lindernia dubia* subsp. *major* (Pursh) Pennell

Annual glabrous herb to 35 cm tall. Stem erect to diffuse, quadrangular, rooting at lower nodes, much-branched. Leaves sessile, elliptic, 12.8 (- 23.8) 29.3 mm length, 6.4 (- 9.0) 12.1 mm width, decreasing in size upward, base cuneate, apex acute; 3 - 5 palmately nerved. Flowers axillary, solitary, cleistogamous flowers. Pedicel slender, 2.8 (- 4.6) 7.7 mm, shorter than subtending leaf, glabrous. Calyx lobes free to base, actinomorphic, hispidulous above, apex acuminate, obscurely 3-veined, equal or slightly shorter than capsules. Corolla white or pale blue, 6.5 mm; lower lip 3-lobed; upper lip galeate, shallowly 2-lobed, lobes sharply pointed. Posterior pair stamens fertile, anterior pair staminodes linear, glandular with spur-like 2 appendages at the middle part. Ovary ovoid, style longer than ovary, stigma 2 lobed. Capsules 4.1 (- 5.3) 6.3 mm length, 1.6 (- 2.1) 2.4 mm width, potbellied ovoid oblong in shape. Seed unequally tetra to pentagonal ellipsoid, pale yellow. Flowering May-October, fruiting August to November.

Distribution: Native to the Americas, introduced in Europe and East Asia. Argentina, Belize, Bolivia, Brazil, Canada, Chile, Colombia, Cuba, Dominican Republic, Ecuador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto

Rico, USA, Venezuela (Prasad and Sunojkumar, 2014), Slovakia (Hrivnák et al., 2016), Taiwan (Liang et al., 2012), Korea.

*Lindernia dubia* var. *anagallidea* (Michaux) Cooperrider in *Castanea* 41: 224. 1976;

Annual herb to 25 cm tall. Stem erect to diffuse, slender, quadrangular, rooting at lower nodes, much-branched near base. Leaves sessile, triangular-ovate, 5.8 (- 9.3) 15.1 mm length, 3.0 (- 5.5) 8.4 mm width, base truncate or slightly subcordate, apex obtuse; margin deaffly 2 - 3 serrate, 3 - 5 palmately nerved. Flowers axillary, solitary, cleistogamous flowers. Pedicel slender, 3.5 (- 7.9) 9.2 mm, longer than subtending leaf, glandular-pubescent. Calyx lobes free to base, hispidulous above, apex acuminate, equal or slightly shorter than capsules. Corolla white or pale blue, 6.5 mm; lower lip 3-lobed; upper lip galeate, shallowly 2-lobed, lobes sharply pointed. Posterior pair stamens fertile, anterior pair staminodes linear, glandular, with spur-like 2 appendages near the apex. Ovary ovoid, style longer than ovary, stigma 2 lobed. Capsules 3.9 (-4.4) 5.9 mm length, 1.4 (- 1.8) 2.1 mm width, potbellied ovoid oblong in shape. Seed unequally tetra to pentagonal ellipsoid, gold yellow. Flowering May-October, fruiting August to November.

Distribution: Native to the Americas. Taiwan (Liang et al., 2012), Korea.

Notes: Here we have treated *Lidernia dubia* var. *anagallidea* as a distinct taxon here despite its recent treatment (Hassler, 2019) as a synonym of *Lindernia dubia* (L.) Pennell. Our morphological observations revealed the presence of two striking characters which make this taxon distinct which are pubescent pedicel (vs glabrous pedicel), and gold yellow (vs pale yellow) colored seeds. Some earlier works also support this treatment (Liang et al., 2012, Fischer et al., 2013, Hrivnák et al., 2016).

*Torenia* L., Sp. Pl. 2:619. 1753.- Type: *T. asiatica* L.

Annual herbs. Leaves opposite, simple, petiolate, pinnately veined. Inflorescence terminal racemose or axillary. Calyx 5-lobed to mid, lobes triangular, actinomorphic. Stamens 4, all fertile, posterior stamens with glandular appendage. Fruits septicidal 2-valved capsules, capsule obovoid, apex rounded, slightly longer than persistent calyx. Seeds numerous, subglobose, surface rounded pits.

*Torenia crustacea* (L.) Cham. & Schltld. in *Linnaea* 2:570. 1827; = *Lindernia crustacea* (L.) F.Muell. *Syst. Census Austral. Pl.* 97. 1882-1883.; Tchang Bok Lee, 2003: II-172 – *Lindernia crustacea* (L.) F. Muell.; Lee Yong No, 2006. II: 191. = *Lindernia crustacea* (L.) F. V. Mueller

Annuals, 10 - 20 cm tall. Stem erect or creeping and rooting at the nodes, much-branched. Branches widely spreading, sub quadrangular, glabrous or hispid on the angles. Leaves petiolate, petiole 1.5 (- 2.6) 5 mm long; leaf blade triangular-ovate to broadly ovate, 7.8 (- 10.5) 15.4 mm length, 3.0 (- 5.3) 8.2 mm width, apex obtuse, base rounded, margin shallowly serrate, abaxially pilose along veins to subglabrous, adaxially subglabrous, pinnately nerved. Flowers axillary and solitary or in short apical racemes, chasmogamous flowers. Pedicel slender, 9.4 (- 14.7) 20.9 mm long, longer than subtending leaf, subglabrous. Calyx shallowly 5-lobed to the middle; lobes triangular-ovate, outside sparsely pubescent. Corolla purple, 5 - 8 mm; lilac to purple, tube slightly longer than calyx; lower lip 3-lobed, middle lobe larger and slightly longer than upper lip; upper lip ovate, sometimes shallowly 2-lobed. Stamens didynamous, 4, all fertile, standing upright short glandular spur-like appendages in the base of posterior filaments. Ovary ovoid oblong, style fugacious, almost equally than ovary, stigma 2 lobed. Capsule 4.5 (- 5.2) 6.0 mm length, 2.9 (- 3.4) 3.9 mm width, broadly ellipsoid or obovoid, slightly as longer than persistent calyx. Seed subglobose, yellow. Flowering May-August and fruiting August-September.

Distribution: India, Nepal, Sri Lanka, Malaysia, Indochina, China, Japan, Philippines, Australia, New Guinea, Polynesia, Madagascar, Taiwan, Korea (Jeju Islands).

*Vandellia* L., *Syst. Nat.*, ed. 12, 2:384, 422; *Mant.Pl.* 1:12. 1767. – Type: *V. diffusa* L.

Annual herbs. Leaves pinnately veined or mid vein visible. Inflorescence solitary or axillary. Calyx 5-lobed to basal, lobes linear-lanceolate, actinomorphic. Stamens 4, all fertile, didynamous, posterior stamens with spur-like an appendage, anterior anthers with an appendage. Fruits septicidal 2-valved capsules, capsule cylindrical, apex acute, longer than persistent calyx. Seeds numerous, ovoid, surface irregular wrinkles, pustulate.

*Vandellia micrantha* (D. Don) Eb. Fisch., Schäferh. & Kai Müll. in *Vandellia micrantha* (D. Don) Eb. Fisch., Schäferh. & Kai Müll. comb. nov. = *Lindernia micrantha* D. Don, Prodr. Fl. Nepal. 85. 1825.; Tchang Bok Lee, 2003. II: 171. *Lindernia angustifolia* (Benth.) Wettstein

Annuals, to 40 cm tall. Roots fibrous, abundant. Stems usually erect or suberect, quadrangular striate, glabrous; branches few to numerous, ascending. Leaves sessile, linear to linear-lanceolate, 10.9 (- 19.3) 31.6 mm length, 2.2 (- 3.8) 6.9 mm width, glabrous, margin entire or somewhat irregularly serrate; main veins 3 - 5, parallel or mid veins visible. Flowers axillary, solitary. Pedicel 6.3 (- 10.9) 16.5 mm long, to elongated in fruit, striate, glabrous. Calyx 2.5 mm long, elongated to 4 mm in fruit, 5-lobed to base; lobes narrowly lanceolate, glabrous. Corolla purple, blue-purple, or white, ca. 6.5 mm; lower lip slightly longer than upper, spreading flat, 3-lobed; upper lip 2-lobed. Fertile stamens 4, anterior filaments with a short appendage, posterior anthers with connective of lower locule produced into a long tail equalling locule. Ovary ovoid, style persistent, almost equally than ovary, stigma 2 lobed. Capsule 8.6 (- 10.8) 14.2 mm length, 1.8 (- 2.2) 2.6 mm width, cylindrical linear, more than 2 times as long as persistent calyx. Seed ovoid, reddish-yellow. Flowering June-September and fruiting August-September.

Distribution: Cambodia, China, India, Japan, Laos, Myanmar, Nepal, Sri Lanka, Vietnam, Korea.

## Discussion and Conclusion

In the present study, we classified taxa of family Linderniaceae in Korea according to our own morphological observation and following the circumscriptions of new combinations made by Fischer et al. (2013).

Consequently, *Lindernia crustacea* (L.) F. Muell. (Lee, 2003; Lee, 2006; Kim et al., 2009) is transferred to *Torenia crustacea* (L.) Cham. & Schltldl.; *Lindernia micrantha* D. Don (Lee, 2003; Kim et al., 2009) and *L. angustifolia* (Benth.) Wettstein (Lee, 2006) are a synonym of *Vandellia micrantha* (D. Don) Eb. Fisch., Schäferh. & Kai Müll.; *Lindernia attenuata* Muhl. (Lee, 2003), *L. dubia* var. *major* (Pursh) Pennell (Kim et al., 2009) are a synonym of *Lindernia dubia* (L.) Pennell according to Fischer et al. (2013) and Hassler (2019). Also, Kim et al. (2009) identified that *Lindernia verbenifolia* (Colsm.) Pennell is a synonym of *Bonnaya antipoda* Druce (Fischer et al., 2013; Hassler, 2019).

Kim et al. (2009) performed identification based on morphological characteristics of leaf shape, base, margin, and venation, but we concluded that important characteristics are reproductive morphologies, calyx, stamen structure, capsule shape, calyx ratio with capsule, inflorescence morphology, and seed morphology with vegetative characteristics, leaf venation, leaf shape. Our study reports the presence of four genera viz. *Bonnaya*, *Lindernia*, *Torenia*, and *Vandellia*, comprising 6 taxa under family Linderniaceae in Korea.

We have treated *Lindernia dubia* var. *anagallidea* as a distinct taxon despite its recent treatment as a synonym of *L. dubia*. However, our observation results were that *L. dubia* var. *anagallidea* has longer pedicel than subtending leaves, a pubescent pedicel, gold yellow color seed, and staminodes with spur-like 2 appendages near the apex. However, we have insufficient specimens to analogize morphological variations to worldwide distribution. We need to sufficient study materials for comparable characteristics of distinct taxa and it is imperative for the future to consider these things in detail, especially stamen structure.

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