An updated taxonomy of the family Linderniaceae in Korea

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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. & Schldtl. Lindernia micrantha D. Don and L. angustifolia (Benth.) Wettstein are a synonym of Vandella 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.

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 Psamnetes, 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 chalazar 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 chalazar 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 pallidum 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.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Leaf</th>
<th>Pedicel</th>
<th>Capsule</th>
<th>Seed</th>
<th>Seed ratio (L/W)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Length (mm)</td>
<td>Width (mm)</td>
<td>Length (mm)</td>
<td>Width (mm)</td>
<td>Length (mm)</td>
</tr>
<tr>
<td>L. procumbens</td>
<td>Minimum</td>
<td>6.0</td>
<td>3.2</td>
<td>3.8</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>10.3</td>
<td>5.5</td>
<td>7.5</td>
<td>2.8</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>21.7</td>
<td>10.3</td>
<td>13.3</td>
<td>3.3</td>
</tr>
<tr>
<td>L. dubia</td>
<td>Minimum</td>
<td>12.8</td>
<td>6.4</td>
<td>2.8</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>23.8</td>
<td>9.0</td>
<td>4.6</td>
<td>5.3</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>29.3</td>
<td>12.1</td>
<td>7.7</td>
<td>6.3</td>
</tr>
<tr>
<td>L. dubia var. anagallidea</td>
<td>Minimum</td>
<td>5.8</td>
<td>3.0</td>
<td>3.5</td>
<td>3.9</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>9.3</td>
<td>5.5</td>
<td>7.9</td>
<td>4.4</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>15.1</td>
<td>8.4</td>
<td>9.2</td>
<td>5.9</td>
</tr>
<tr>
<td>Torenia crustacea</td>
<td>Minimum</td>
<td>7.8</td>
<td>3.0</td>
<td>9.4</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>10.5</td>
<td>5.3</td>
<td>14.7</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>15.4</td>
<td>8.2</td>
<td>20.9</td>
<td>6.0</td>
</tr>
<tr>
<td>Vandellia micrantha</td>
<td>Minimum</td>
<td>10.9</td>
<td>2.2</td>
<td>6.3</td>
<td>8.6</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>19.3</td>
<td>3.8</td>
<td>10.9</td>
<td>10.8</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>31.6</td>
<td>6.9</td>
<td>16.5</td>
<td>14.2</td>
</tr>
<tr>
<td>Bonnaya antipoda</td>
<td>Minimum</td>
<td>14.0</td>
<td>5.4</td>
<td>3.5</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
<td>26.8</td>
<td>8.9</td>
<td>5.7</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>39.7</td>
<td>13.8</td>
<td>9.3</td>
<td>8.9</td>
</tr>
</tbody>
</table>

L/W, ratio length and width.
Table 2. Morphological characters of the Linderniaceae taxa in Korea.

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

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

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).

![Inflorescence types](https://via.placeholder.com/150)

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:](image)

**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, pusticulate.

**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 pusticulate.

**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 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


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-oblanceolate, 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 cylindric, 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.


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, pusticulate.


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 nervetd, 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 (Hrvník et al., 2016), Russia: (West Siberia, Far East), Kazakhstan (Alt.) (Kosachev, 2017).


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 nervetd. 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
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 deeply 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 Lindernia 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.


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 cylindric, apex acute, longer than persistent calyx. Seeds numerous, ovoid, surface irregular wrinkles, pusticulate.


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 locale produced into a long tail equalling locale. 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.


**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. & Schldl.; *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 verbentifolia* (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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