



## The taxonomic entity and distribution of Korean *Sedum formosanum* (Crassulaceae) revealed in 133 years

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**ABSTRACT:** Korean *Sedum formosanum* N. E. Br. (Ju-geog-nip-gaet-bi-reum in Korean) was first recorded in 1887, 133 years ago. Since then, the species has not been collected and its current state has remained unclear. However, these plants were collected in 2020 and the corresponding taxonomic entity and distribution status were revealed. It is known to be distributed only in the southern region of Japan, the northern islands of the Philippines, and in Taiwan, with Taiwan being the collection site of the type specimen. However, on the basis of the findings of the fourth national natural environment survey, it has recently been established that this plant also grows in the crevices of rocks along the seashores of the Korean islands of Hataedo Island and Sangtaedo Island, Sinan-gun, Jeollanam-do. *S. formosanum* inhabiting Korea is a large succulent biennial that can attain a height of up to 65 cm and differs from its congeneric species in having erect follicles during the fruiting period. Notably, among the Korean *Sedum* species, *S. formosanum* is most similar to *S. tosaense*, although it can be distinguished from this species with respect to its monomorphic leaves that have rounded apices, and it also bears separate flowering and sterile stems. In this paper, we present a description and photographs of the Korean *S. formosanum*, indicate the differences between this and related species, and provide a key to related taxa.

**Keywords:** taxonomic entity, *S. formosanum*, *Sedum*, Crassulaceae, island region

The genus *Sedum* L. in Korea, which belongs to the Crassulaceae J. St.-Hil., has traditionally been recognized to include the *Phedimus* Raf. and *Hylotelephium* H. Ohba (Lee, 1980; Lee, 1996), or has been treated with *Phedimus* except for *Hylotelephium* (Park, 2007). However, many authors have recently recognized *Phedimus* and *Hylotelephium* as separate genera from the *Sedum* (Fu and Ohba, 2001; Ohba, 2001; Thiede and Egli, 2007; Moran, 2009). *Sedum sensu stricto* is the largest genus in the family, taxonomically including 420?470 taxa worldwide (Fu and Ohba, 2001; Thiede and Egli, 2007; Ohba, 2009). Geographically, they are mainly distributed in temperate and subtropical regions of the Northern Hemisphere, and a small number of taxa are known to be distributed to Africa and S America in the Southern Hemisphere (Fu and Ohba, 2001; Thiede and Egli, 2007).

*Sedum* s.s. can be distinguished from *Orostachys* Fischer and *Meterostachys* Nakai by the presence of stems without rosette

leaves at least during the flowering period, from *Tillaea* L. by the presence of twice the stamen number than petals, it is distinguished from *Hylotelephium* by the presence of yellowish flowers and carpels without stalks, and from *Phedimus* and *Rhodiola* L. by the presence of leaves with entire margins and non-thickened roots (Fu and Ohba, 2001; Ohba, 2001). Furthermore, Moon (2018) suggested the height of taxa, stem base habit, and the patterns of seed surface through key to the Korean *Sedum* and *Phedimus* as the identifying features of *Sedum*.

The Korean *Sedum* s.s. was first reported by Forbes and Hemsley (1887) when they identified three species, *S. alfredii* Hance, *S. formosanum* N. E. Br. and *S. sarmentosum* Bunge, based on the specimens of herbarium K 133 years ago, and then Palibin (1898) mentioned two species, *S. sarmentosum* and *S. alfredii*. Since then, taxonomic studies have been conducted on Korean *Sedum* (Kim, 1988; Moon, 2018), and

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described in the flora manuals written by several authors (Nakai, 1909, 1952; Chung, 1957; Park, 1974; Lee, 1980; Lee, 1996; Lee, 2007; Park, 2007).

So far, a total of 10 taxa of *Sedum s.s.* are known to occur in Korea, including an endemic species *S. lepidopodum* Nakai (Nakai, 1940), three recently recorded species (*S. tosaense* Makino, *S. makinoi* Maxim, and *S. kiangananense* D. Q. Wang & Z. F. Wu) (Song et al., 2004; Park and Park, 2005; Suh et al., 2020), and one introduced species, *S. mexicanum* Britton (Park, 2009). Moreover, several authors (Maximowicz, 1883; Forbes and Hemsley, 1887; Palibin, 1898; Nakai, 1909, 1952; Lee, 1996) have mentioned that *S. alfredii* is distributed in southern islands or Jeju Island, but Kim (1988) predicted this as *S. bulbiferum* Makino. Similarly, *S. subtile* Miq. mentioned by Lee (1996, 2007) as being distributed in Jeju Island, is believed to be a misidentification of *S. tosaense*.

Forbes and Hemsley (1887) pointed out the distribution of *S. formosanum* in Korea, but Kim (1988) reported that no specimens were observed that could confirm its distribution through taxonomic study of *Sedum s.l.* Currently, *S. formosanum* is known to be distributed in Taiwan, southern Japan, and the northern Philippines, but its distribution and taxonomic entities in Korea remain unclear. Moreover, recent studies on *S. formosanum* abroad have not mentioned Korea as a distribution area.

However, a recent national survey of the natural environment confirmed that *S. formosanum* is distributed on the beachside of Hataedo and Sangtaedo islands, Sinan-gun, Jeollanam-do in Korea. Therefore, the authors report their entity through this article 133 years after the initial publication, providing evidence of the *S. formosanum* distribution in the Korean peninsula.

## Taxonomic Treatment

*Sedum formosanum* N. E. Br., Gard. Chron. Ser. 24: 134, 1885 (Figs. 1, 2).—**TYPE:** Taiwan. Kelung, *C. Ford s.n.* (K, GH, seen only photos!).

**Korean name:** 주걱잎갯비름 (Ju-geog-nip-gaet-bi-reum).

Herbs, biennial, fleshy, glabrous. Roots fibrous, sometimes adventitious leaf scars. Stems: first year stems stout, erect, only sterile, 1-trifurcate, ca. 10 cm height, overwintering, reddish brown later; second year stems erect, decumbent at bases, 1–2(–3)-trifurcate, 20.0–45.0(–65.0) cm height, up to 1 cm wide at bases, reddish brown and yellowish brown later, flowering all, sprawling after flowering period. Petioles sessile or nearly so. Leaves: first year leaves alternate with lax rosettes, spreading, green, spatulate to widely obovate; second year

leaves alternate, green or yellowish green later, flattish, thick, spatulate to widely obovate, 0.8–4.8 × 0.5–1.5 cm, bases long attenuate, margins entire, apices rounded. Inflorescences terminal, cymes, 1–2-trifurcate with 3(–4) primary axes; primary axes 2.0–15.0 cm long, ascending, 1 to several times irregularly and often unequally forking, with a flower at each fork; bracts leaflike, smaller than cauline leaves. Flowers 5(–6)-merous, 1.0–13.0 mm wide, sessile. Sepals 5, free, green or yellowish green later, fleshy, flattish, unequal in size, obovate to oblanceolate, 3.0–7.0 × 1.5–3.0 mm, apices rounded. Petals 5(–6), bright yellow, lanceolate, 5.0–6.0 × 1.3–1.6 mm, bases slightly connate, apices short acuminate. Stamens 10(–12), slightly shorter than petals, ascending at flowering, 2-whorled; anthers oblong-lanceolate, ca. 0.5 mm long, deep yellow. Carpels 5, ca. 5 mm long, free, connate at the bases, gibbous ventrally. Fruits follicles, star-shaped, erect, ca. 7 mm long. Seeds elliptical, 0.4–0.6 × ca 0.1 mm.

**Flowering:** June to early August.

**Habitat:** Approximately 50 individuals were found growing along with *Lysimachia mauritiana* Lam. [Primulaceae Batsch ex Borkh.] in open and dried stone crevices within a 70 × 7 m area of a *Pinus thunbergii* Parl. and *Euonymus japonicus* Thunb. plant community, located adjacent to the island's coast. Given that the native habitat of plants lies along the side of the coastal road, the population is considered to be highly susceptible to disturbance, by both road maintenance projects and the disposal or stacking of fishing gear in the vicinity of habitat, thereby threatening the viability and survival of *S. formosanum* on Hataedo Island.

**Distribution:** Japan (South), Korea (Jeollanam-do), Philippines (North), Taiwan.

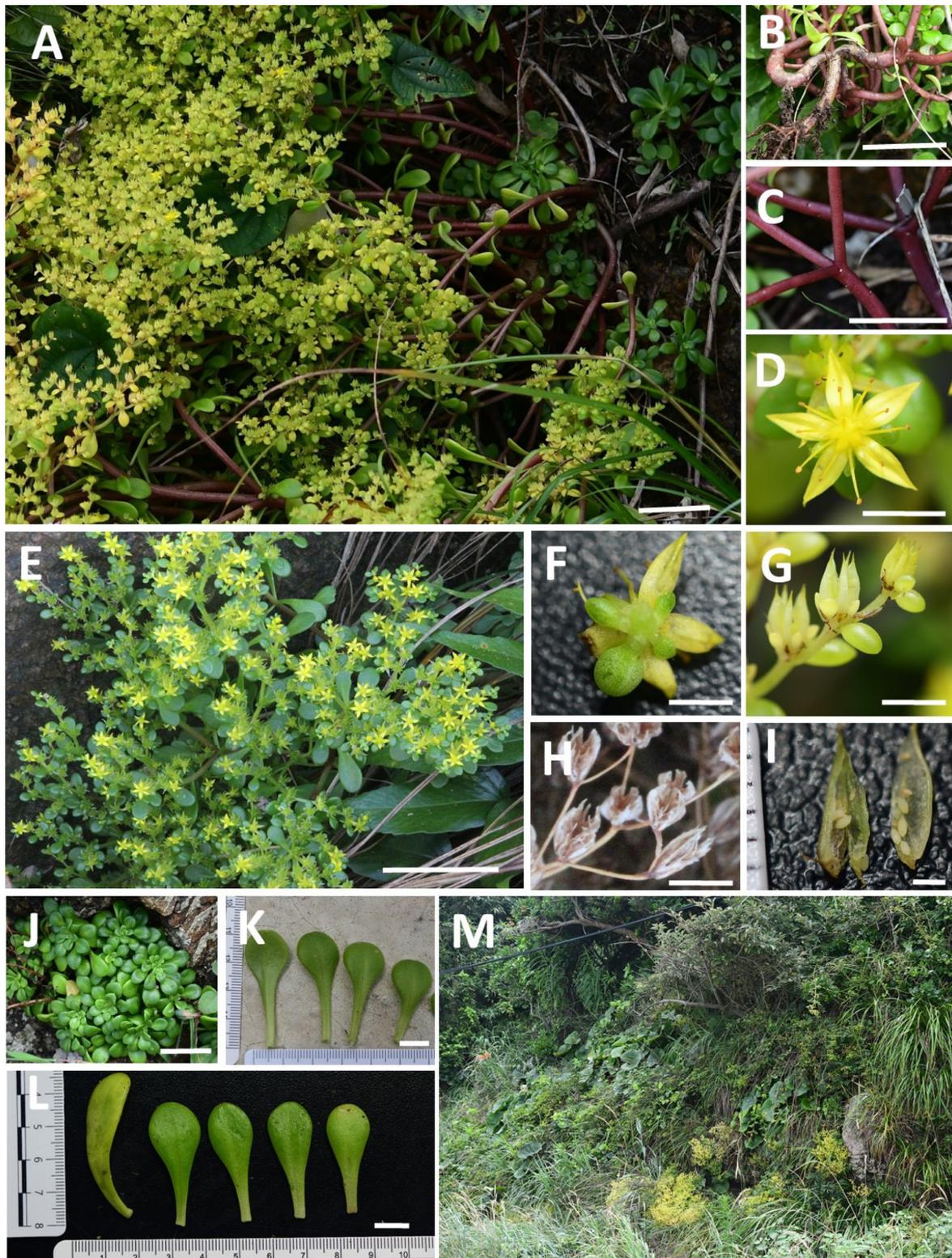
**Specimens examined:** KOREA. Jeollanam-do: Sinan-gun, Hataedo Island, 3 Aug 2020, *C. H. Kim & S. S. Choi 20001* (19 sheets, JNU).

*Sedum formosanum* was described as a new species by Brown (1885) based on the type specimens collected by Ford from Keelung, northeast Taiwan, and recently, *S. danjoense* Takuro Ito, H., Nakan. & Kokub and *S. formosanum* subsp. *miyakojimense* Takuro Ito, Yokota & Kokub. which are similar to *S. formosanum*, were also described as new taxa (Ito et al., 2017, 2020). Notably, Ito et al. (2017) used life cycle, stem branching pattern, number of carpels, the shape of sepals and follicles, and habitat as major diagnostic characters to differentiate similar taxa, including *S. formosanum*.

The Korean *S. formosanum* was recorded earlier by Forbes and Hemsley (1887) as growing on the southern island, based on the Oldham's specimen (266). Since then, Kim (1988) has



**Fig. 1.** Voucher specimen of *Sedum formosanum* collected from Hataedo Island by the authors. Lower left side of specimen is the sterile stem of the first year, while right side shows the branching fertile stem of the second year.



**Fig. 2.** *Sedum formosanum*. **A.** Flowering plant with reddish brown stem and yellowish inflorescence. **B, C.** Stems with trifurcate patterns at base (**B**) and above middle (**C**). **D.** Flower with 5-petals and 10-stamens. **E.** Cymose inflorescence in flowering stem. **F.** Sepals with unequal in size. **G, H.** Carpels in younger fruit stage (**G**) and adult stage (**H**). **I.** Seed in very early maturing stage. **J.** Sterile stem of first year. **K, L.** Leaf blades on sterile stems (**K**) and flowering stems (**L**). **M.** Habitat around beach. Scale bars = 5 cm (**A–C, E, J**), 1 cm (**K, L**), 5 mm (**D, F–H**), 1 mm (**I**) (photos by S. S. Choi and C. H. Kim).

reserved her decision on the taxonomic entity of Korean *S. formosanum* because she did not observe the Oldham's specimen during her monographic study of the Korean genus *Sedum*, but again, no author has mentioned its presence and distribution to date. Meanwhile, Maximowicz (1883) reported that *S. alfredii* was distributed in Korea based on C. Wilford's specimen, and then, Forbes and Hemsley (1887), Palibin (1898), Nakai (1909, 1952), and Lee (1996) also agreed with his view. In particular, Lee (1996) mentioned that *S. alfredii* was distributed on Jeju Island, Korea, while *S. formosanum* was treated as a synonym of this taxon, suggesting that there are no bulbils as a diagnostic character. Previously, some authors (e.g., Liu and Chung, 1977) have considered *S. formosanum* as a synonym of *S. alfredii*. However, Ohba (1984) and Ito et al. (2014) suggested that the two taxa could be treated as separate species based on the analysis of different characters, including erect carpels during the fruiting period, native habitat, and internal transcribed spacer (ITS) sequences. According to Fu and Ohba (2001), *S. formosanum* has a branched flower stem from the base, has an erect follicle, inhabits near the coast, while *S. alfredii* usually has a simple flower stem, has an obliquely ascending or horizontal follicle, and inhabits mountains at 2,000–3,000 m above sea level. Based on ITS sequencing, *S. formosanum* was established to be phylogenetically closer to the two Taiwanese endemic species, *S. nokoense* Yamam. and *S. erythrospermum* Hayata, compared with any other *Sedum* taxa, including the Chinese *S. alfredii* (Ito et al., 2014, 2017). As a result, it may be unreasonable to treat the two taxa as the same species; moreover, considering that *S. alfredii* is distributed in mountains at altitudes of 2,000–3,000 m, it is highly unlikely that this species will be distributed on Jeju Island. As Kim (1988) pointed out, plants known as *S. alfredii* in Korea are expected to be *S. bulbiferum*.

As reported by Ito et al. (2017, 2020), *S. formosanum* has been confirmed to be a biennial plant that germinates in the first year, during which it gradually grows and overwinters with leaves, and then in the following year produces flowering stems, blooms, produces fruit, and dies. Some authors (Ohwi, 1984; Fu and Ohba, 2001), however, have described *S. formosanum* as a perennial.

*Sedum formosanum* is characterized by one alternate leaf at each node of the stem, while *S. makinoi* bears two opposite leaves; *S. sarmentosum* has 3-whorled leaves, while *S. mexicanum* and *S. kiangnanense* are easily distinguishable by having at least 3–5- and 4–5-whorled leaves on their sterile stems, respectively. Furthermore, *S. formosanum* is easily distinguished from taxa with linear, linear-lanceolate, or terete-

oblong leaf blades such as *S. polytrichoides* Hemsl., as they have spatulate or obovate leaf blades with rounded apices. *S. formosanum* is also distinguished from *S. tosaense*, which has leaves with emarginate apices. In addition, *S. formosanum* differs from most Korean *Sedum* taxa in that the carpels of fruits grow erect during the fruiting period, whereas the carpels of other taxa are spreading or ascending. Moreover, *S. formosanum* can be distinguished by the fact that the leaves on sterile and flowering stems are similar in shape, whereas *S. tosaense* and *S. kiangnanense* have dimorphic leaves, and is also conspicuously different from *S. bulbiferum* in that it lacks bulbils on the axils of leaves (Table 1).

The *S. formosanum* plants found growing on Hataedo Island usually reach a height of 45 cm, but can attain heights of 65 cm, albeit rarely, which is taller than the heights previously reported for *Sedum* taxa in Korea: 10–15 cm (Ohwi, 1984; Fu and Ohba, 2001), 10–25 cm (Ohba, 2001), and 10–30 cm (Ito et al., 2020). Therefore, the size of *S. formosanum* differs substantially from the maximum height (15 cm) of *Sedum* indicated in Moon's key to the genera (2018). *S. formosanum* has been given the local Korean name “Ju-geog-nip-gaet-bi-reum,” in reference to the plant's spatula-shaped leaves and its native habitats are beaches.

The following key to the related Korean *Sedum* taxa has been prepared only for those species with subcircular, obovate, or spatulate leaf blades among taxa with one or two leaves on each node of the stems. Consequently, taxa such as *S. sarmentosum*, *S. mexicanum*, and *S. kiangnanense*, which have three or more leaves on each stem node, and taxa such as *S. uniflorum* subsp. *oryzifolium* (Makino) H. Ohba, *S. japonicum* Siebold ex Miq., *S. polytrichoides*, and *S. lepidopodum*, which are characterized by linear and terete-oblong leaf blades, have not been included in the key.

### Key to *S. formosanum* and related Korean *Sedum* taxa

1. Stems typically with bulbils in the leaf axils; leaves generally oblanceolate or rhombic ovate on flowering stems; flowers nearly sterile ..... *S. bulbiferum* 말뚝비름
1. Stems without bulbils in the leaf axils; leaves generally spatulate to obovate, sometimes subcircular on flowering stems; flowers fertile.
  2. Stems with distinct segmental nodes; upper leaves somewhat ascending on sterile stems; leaves opposite, rarely verticillate on flowering stems .....  
..... *S. makinoi* 둥근잎비름
  2. Stems without segmental nodes; upper leaves also

**Table 1.** Comparison of several major characteristics of *Sedum s.s.* in Korea.

Taxa	Phyllotaxy on sterile stem	Caulесcent leaf			Bulbil	Follicles	Articulated node of stem	Life cycle	Height (cm)
		Shape	Apex	Dimorphism <sup>a</sup>					
<i>S. formosanum</i>	Alternate	Spatulate, obovate	Rounded	×	×	Erect	×	Biennial	20–45(–65)
<i>S. tosaense</i>	Alternate	Spatulate, obovate	Emarginate	○	×	Spreading	×	Perennial	10–20
<i>S. bulbiferum</i>	Alternate	Oblanceolate	Obtuse	×	○	-	×	Biennial	5–30
<i>S. uniflorum</i> subsp. <i>oryzifolium</i>	Alternate	Terete-oblong	Rounded	×	×	Spreading	×	Perennial	5–12
<i>S. japonicum</i>	Alternate	Terete-oblong	Rounded	×	×	Ascending	×	Perennial	5–15
<i>S. polytrichoides</i>	Alternate	Linear	Acute	×	×	Ascending	×	Perennial	5–12
<i>S. lepidopodum</i>	Alternate	Linear	Acute	×	×	Spreading	×	Perennial	5–15
<i>S. makinoi</i>	Opposite	Obovate	Rounded	×	×	Ascending	○	Perennial	5–12
<i>S. sarmentosum</i>	3-verticillate	Elliptic, rhombic	Acute obtuse	×	×	Ascending	×	Perennial	10–15
<i>S. kiangnanese</i>	4–5-verticillate	Spatulate, oblanceolate, linear	Obtuse acute	○	×	Spreading	×	Perennial	10–25
<i>S. mexicanum</i>	3–5-verticillate	Linear-lanceolate	Obtuse	×	×	-	×	Perennial	10–25

<sup>a</sup>Most taxa of the Korean *Sedum* have similar leaves on sterile and flowering stems, but some taxa have dimorphic leaves.

spreading on sterile stems; leaves alternate on flowering stems.

3. Perennial plants with simultaneously flowering and sterile stems; leaves dimorphic, with emarginate apices; carpels spreading during the fruiting period ..  
..... *S. tosaense* 주걱비름
3. Biennial plants with separately flowering and sterile stems; leaves monomorphic, with rounded apices; carpels erect during the fruiting period .....  
..... *S. formosanum* 주걱잎갯비름

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## Conflict of Interest

The authors declare that there are no conflicts of interest.

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## 133년만에 밝혀진 한국산 주걱잎갯비름(돌나물과)의 분류학적 실체 및 분포

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**적 요:** 한국산 주걱잎갯비름(*Sedum formosanum* N. E. Br.)은 133년 전에 기록된 후, 이제야 이의 분류학적 실체 및 분포 현황이 밝혀졌다. 이들은 그동안 기준표본 채집지인 타이완을 비롯하여 일본의 남부, 필리핀 북부 섬지역에만 국한하여 분포하는 것으로 알려져 왔다. 그러나 이는 제4차 전국 자연환경조사를 통해 전라남도 신안군 하태도 및 상태도의 바닷가 바위 틈새에서 생육하는 것으로 확인되었다. 한국산 주걱잎갯비름은 높이 최대 65 cm에 달하는 2년생 다육식물로 결실기에 골돌과의 심피가 곧추서는 점에서 속내 대부분의 식물들과 다르다. 특히, 주걱잎갯비름은 한국산 돌나물속 중, 주걱비름과 비슷하지만 엽선이 단일형으로 엽선이 원두이며, 꽃 피는 줄기와 꽃이 없는 줄기를 따로따로 갖는 점에서 구별된다. 주걱잎갯비름에 대한 기재, 근연종과 차이점, 검색표 및 사진 등을 수록하였다.

**주요어:** 분류학적 실체, 주걱잎갯비름, 돌나물속, 돌나물과, 섬 지역