







## Five newly recorded alien species of *Hydrocotyle* Tourn. ex L. (Araliaceae) in Java, Indonesia


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### Abstract

We provide the occurrence data on five newly recorded alien *Hydrocotyle* Tourn. ex L. species (Araliaceae) in Java, namely *H. acutiloba* (F.Muell.) N.A.Wakef., *H. bonariensis* Comm. ex Lam., *H. leucocephala* Cham. & Schtdl., *H. tripartita* R.Br. ex A.Rich., and *H. verticillata* Thunb. Most species were introduced as ornamental plants and naturalized in Java. *Hydrocotyle acutiloba* and *H. tripartita* might have been accidentally introduced as soil contaminants during the Dutch Colonial Era, but both species had been misidentified as *H. sibthorpioides*. Descriptions, a key, distribution map, and images of the species are provided.

### Keywords

Naturalized, non-native flora, ornamental, pennyworth

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## Introduction

*Hydrocotyle* Tourn. ex L. is a member of the Araliaceae, consisting of around 177 species. This genus is widely distributed in tropical to temperate regions (Orchard 1994; She et al. 2005; Perkins 2019), and it is characterized by being primarily an erect, prostrate, or

creeping herb with simple or palmate leaves, a spiral or rosette leaf arrangement, and the lack of a sheath at the base of the petiole (Backer and Bakhuizen van den Brink 1965; Orchard 1994; Bean and Henwood 2004; She et al. 2005; Perkins 2019). These morphological

features can easily distinguish *Hydrocotyle* from other genera of the family.

According to the *Flora of Java* (Backer and Bakhuizen van den Brink 1965), two species of *Hydrocotyle* are known from Java, namely *H. sibthorpioides* Lam. and *H. javanica* Thunb. Both species are widely distributed in the tropics and subtropics of the Old World and Australia, with *H. javanica* extending to the Pacific (Buwalda 1949; POWO 2022). Backer and Bakhuizen van den Brink (1965) noted that accounts of *H. sibthorpioides* in Java might have been mixed with other species. However, the diversity of *Hydrocotyle* in Java is poorly known.

Recently, we have collected and identified five additional alien species of *Hydrocotyle* in Java, namely *H. acutiloba* (F.Muell.) N.A.Wakef., *H. bonariensis* Comm. ex Lam., *H. leucocephala* Cham. & Schldl., *H. tripartita* R.Br. ex A.Rich., and *H. verticillata* Thunb. We also examined specimens of *Hydrocotyle* in Herbarium Bogoriense (BO) and Herbarium Bandungense (FIPIA) and compared these to our newly collected specimens.

### Methods

Fieldwork was conducted in Jakarta, West Java (Bandung City, Bandung Barat Regency, Bandung Regency, Bogor City, Bogor Regency, Cianjur Regency, Sumedang Regency, Sukabumi Regency), Central Java (Rembang Regency), and East Java (Surabaya, Madura Island) from December 2018 to January 2022 (Fig. 1). Our fieldwork was conducted using the exploration method based

on Rugayah et al. (2004). Collection and preservation of plant material follow RBGE (2017). Collected specimens have been deposited at Herbarium Bandungense (FIPIA), School of Life Sciences and Technology, Institut Teknologi Bandung, Sumedang, Indonesia.

The specimen examinations were carried out at Herbarium Bogoriense (BO) and Herbarium Bandungense (FIPIA) in August 2019. Plant materials collected during the fieldworks were identified using the works of Mathias (1936), Standley and Williams (1966), Webb and Johnson (1982), Standley and Ross (1986), Orchard (1994), Alvarez (2001), Bean and Henwood (2003), She et al. (2005), Khatun et al. (2011), Lim et al. (2014), and Verloove and Heyneman (2021).

### Results

#### Key to *Hydrocotyle* species in Java

- 1a Herbs with basifixed leaves, cordate to reniform ... 2
- 1b Herbs with peltate leaves ..... 6
- 2a Lamina deeply divided into 3 segments ..... *H. tripartita*
- 2b Lamina lobes shallow, rarely reach half ..... 3
- 3a Inflorescence branched with several pedunculate umbels ..... *H. javanica*
- 3b Inflorescences only consist of a single umbel ..... 4
- 4a Leaf lobes acute, styles 0.2–0.3 mm long..... *H. acutiloba*

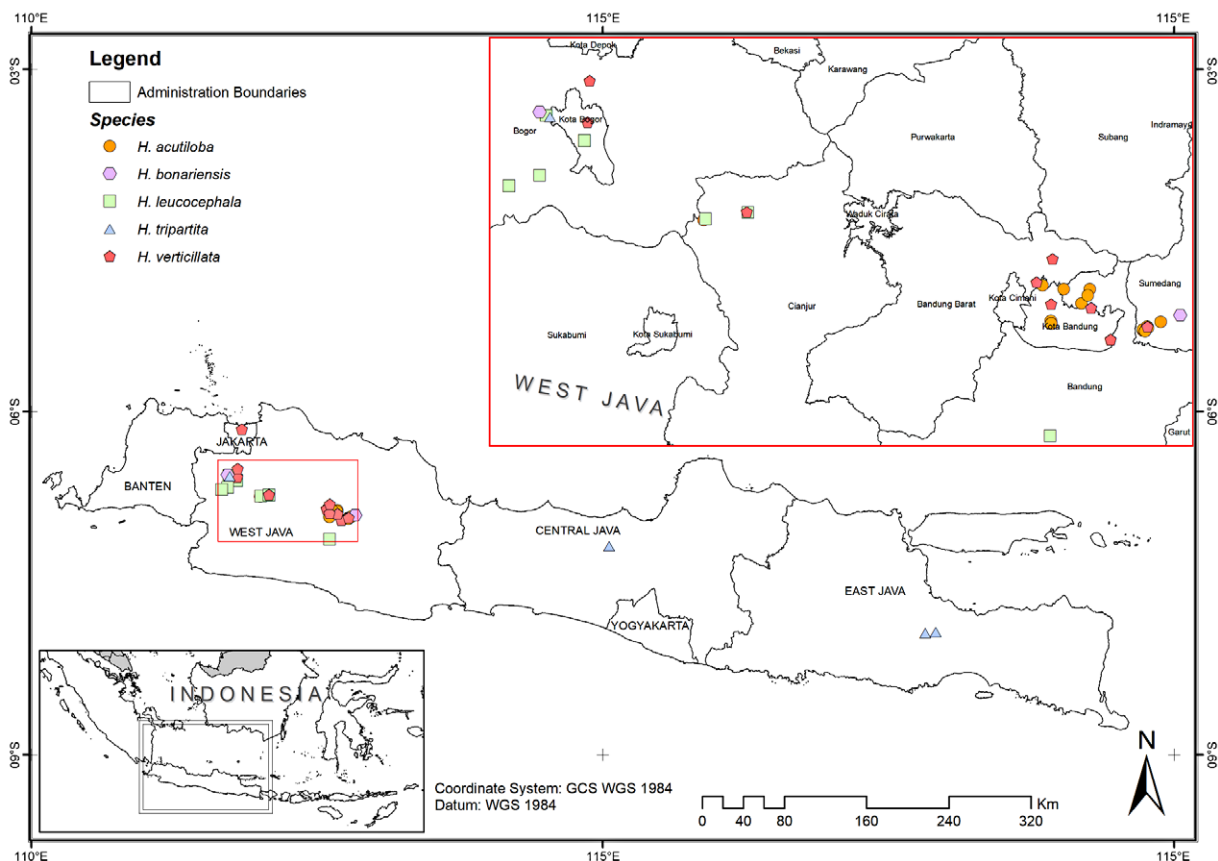


Figure 1. Distribution map of newly recorded alien species of *Hydrocotyle* in Java, Indonesia.

- 4b Leaf lobes obtuse, rounded, or truncate, styles more than 0.3 mm long ..... 5
- 5a Leaves not fleshy, peduncles 0.5–1.5 cm long, petals greenish-white, ovary green ..... *H. sibthorpioides*
- 5b Leaves fleshy, peduncles 4–20 cm long, petals white, ovary white ..... *H. leucocephala*
- 6a Lamina orbicular, inflorescence spike-like, not branched ..... *H. verticillata*
- 6a Lamina broadly elliptic, inflorescence with many branches ..... *H. bonariensis*

***Hydrocotyle acutiloba* (F.Muell.) N.A.Wakef.**

Figure 2

**New records.** INDONESIA; JAVA – West Java • Preanger Reg., Tjibodas, bij Sindanglaja; 1915; collection number 2064; BO • Bandoeng, tuin Hotel van Hengel; 08.II.1948; collection number 3735; FIPIA • Bandoeng; 30.X.1949; collection number 3734; FIPIA • Bandung, Jl. Setiabudhi No. 9, Negla; VII.1973; collection number 9025; FIPIA • Bandung, Cibeunying Kidul, Pasir Layung; 06°53'10"S, 107°39'49"E; 31.X.2021; collection number 643; FIPIA • Bandung Regency, Cimenyan; 06°51'40"S, 107°40'43"E; 29.X.2021; collection number 639 & 642; FIPIA • Bandung, Coblong Subdistrict, Jl. Ganesha No. 10, main gate of ITB; 06°53'35"S, 107°36'38"E; 22.I.2022; collection number 673; FIPIA • Bandung Regency, Cimenyan, Ciburial, Jl. Bukit Pakar Timur III; 06°51'41"S, 107°37'59"E; 21.XI.2021; collection number 664; FIPIA • Sumedang Regency, Jatinangor, Cikuda, near Jembatan Cincin; 06°55'35"S, 107°46'41"E; 13.X.2021; collection numbers 630 & 631; FIPIA • Sumedang Regency, Jatinangor, Ciseke Besar;

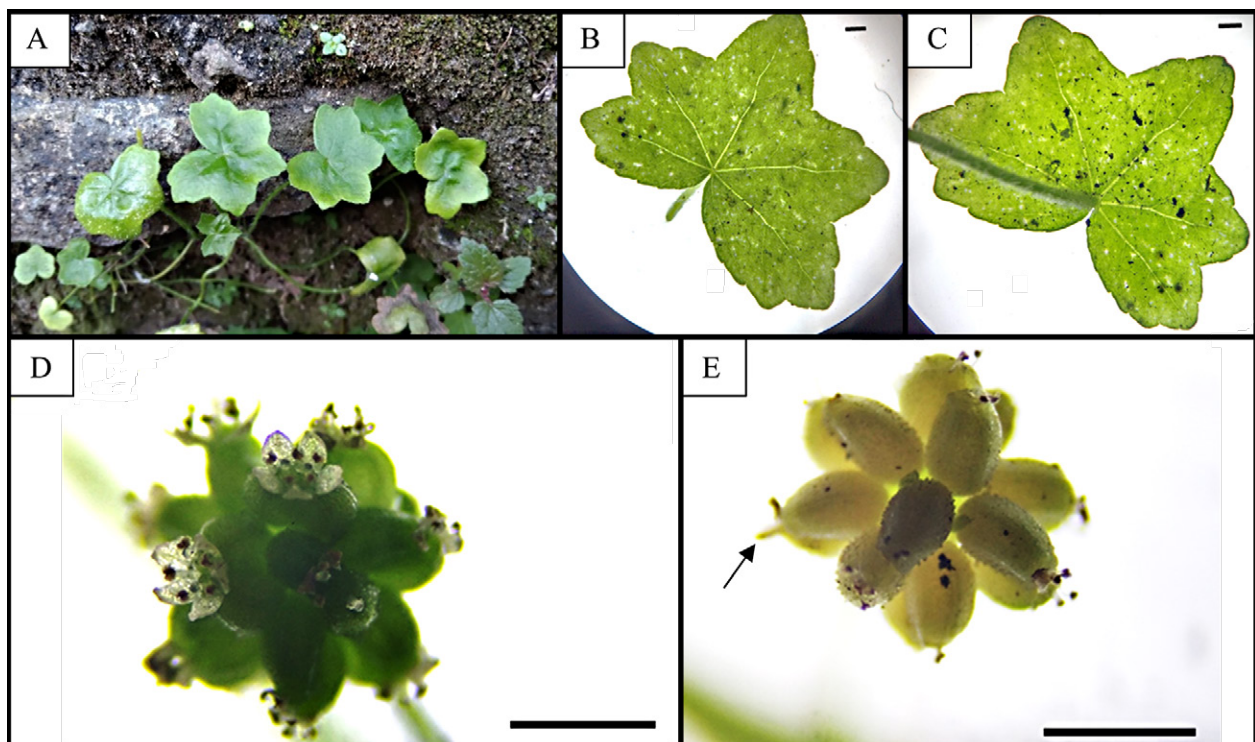
06°56'05"S, 107°46'30"E; 13.X.2021; collection numbers 634 & 635; FIPIA • Sumedang Regency, Tanjungsari Subdistrict, Cinanjung; 06°55'05"S, 107°48'07"E; 31.X.2021; collection number TJR 001; FIPIA.

**Identification.** Herb, creeping, rooting at nodes; stem filiform, green, glabrous to villous. Leaves simple, alternate; stipules scarious, scale-like; petioles 2.2–19.3 cm long, green, glabrous to villous; lamina reniform, 1.8–3.5 × 2–3.7 cm, 5–7-lobed, lobes acute, adaxial surface shiny green, glabrous, abaxial surface pale green, pubescent. Inflorescences umbellate, 13–26-flowered, axillary; peduncle 8–50 mm long, densely hairy at the apex. Flowers bisexual, actinomorphic, star-shaped; flowers sessile or shortly pedicellate; sepals absent; petals free, 5, ovate, c. 0.25 mm long, apex acute, white; stamens 5, free, c. 0.25 mm long; filaments filiform, white; anthers brownish; ovary orbicular, flattened, green; disc oblong, flattened, green; styles 2, filiform, c. 0.25 mm long, white; stigma capitate, white. Fruits schizocarpous, suborbicular, c. 0.5 × 1 mm, mericarps slightly flattened, ribbed, yellow, verrucose, styles persistent.

**Distribution.** *Hydrocotyle acutiloba* is native to large parts of eastern Australia, from Queensland to Victoria (Bean and Henwood 2003; POWO 2022) and extends to the south of Western Australia (AVH 2022).

**Ecology.** In Java, it is now naturalized in open areas, gardens, and ditches, and along roadsides at 705–1145 m a.s.l.

**Notes.** *Hydrocotyle acutiloba* is endemic to Australia. It is recognized as a weed in Queensland (Brisbane City Council 2022).



**Figure 2.** *Hydrocotyle acutiloba*. A. Habit. B. Leaf adaxial surface. C. Leaf abaxial surface. D. Umbellate inflorescence. E. Fruit with persistent style (arrow). Scale bar = 1 mm.

The first recorded occurrence of this species in Java in Cibodas, Cianjur Regency, 1915, was likely due to an unintentional introduction as a weed. It is assumed that this species' presence there is related to the massive introduction of many cultivated plants since the end of the 19<sup>th</sup> century to the Tjibodas Research Station, currently known as Cibodas Botanic Gardens. Cibodas was a well-known acclimatization area for many alien and cultivated species from temperate regions, including Australia, since the colonial era. Afterward, the plantation expansion to the east might have spread this species to Bandung and surrounding areas (Fig. 1). The lowest distribution of the species in Cianjur, Bandung, and Sumedang is approximately 700 m a.s.l., which infers that this species is likely adapted to highlands only.

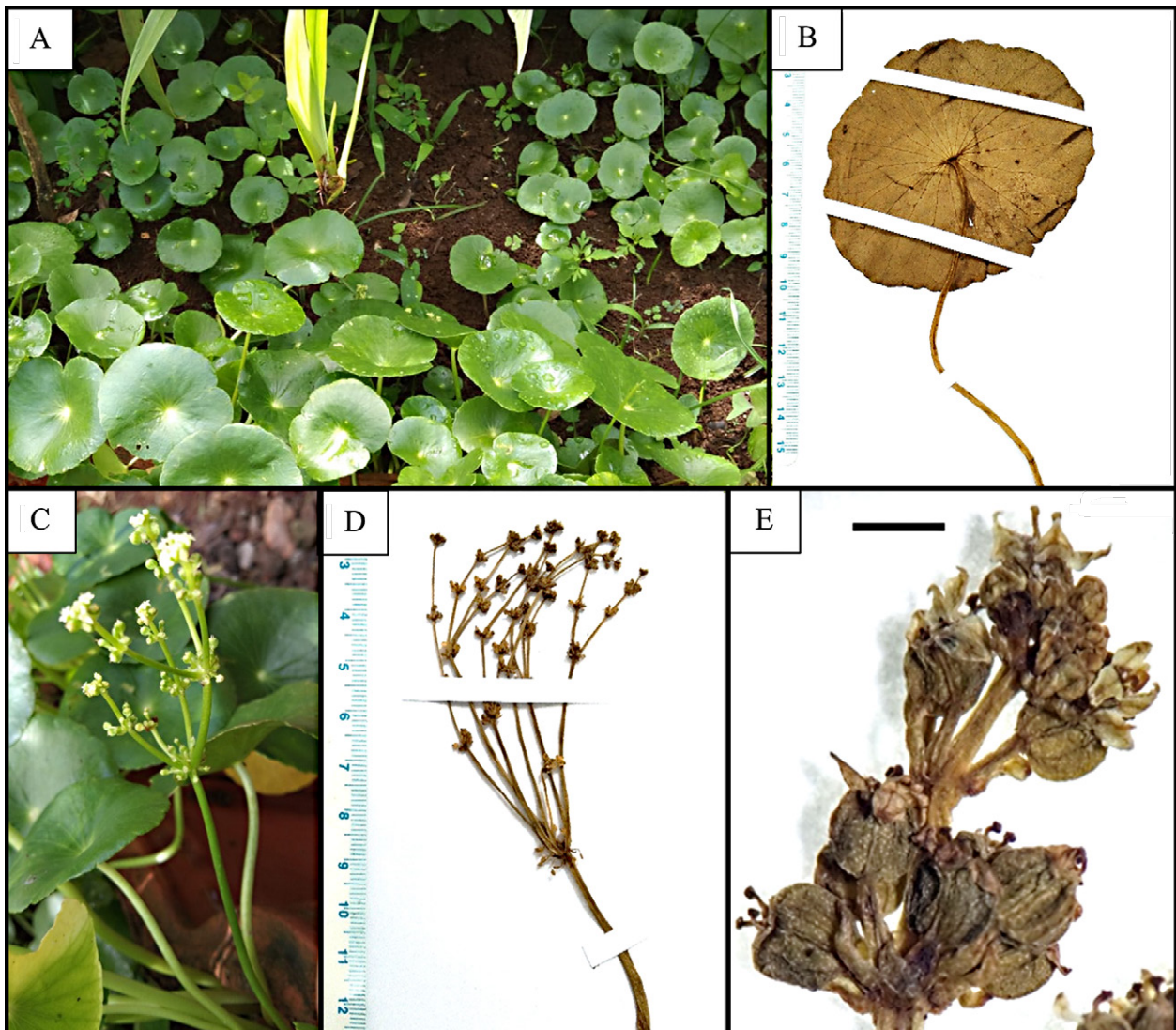
The BO and FIPIA herbaria specimens collected in 1915–1973 had been determined as *H. sibthorpioides* according to Backer (1948) and Backer and Bakhuizen van den Brink (1965). However, they (Backer and Bakhuizen van den Brink 1965) recognized the different characters among the specimens.

***Hydrocotyle bonariensis* Comm. ex Lam.**

Figure 3

**New records.** INDONESIA. JAVA – West Java • Bogor Regency, Dramaga Subdistrict, Babakan, IPB University, Jl. Soka No. 23; 06°33'09"S, 106°43'11"E; 13.X.2021; collection number 211003; FIPIA • Sumedang Regency, Pamulihan Subdistrict, Haurngombong; 06°54'23"S, 107°50'09"E; 28.VI.2020; collection number HRG-03; FIPIA • Sumedang Regency, Pamulihan Subdistrict, Haurngombong; 06°54'24"S, 107°50.1"E; 18.XII.2021; collection number 668; FIPIA.

**Identification.** Herb, creeping, rooting at nodes; stem creeping underground. Leaves simple, alternate; petioles 7–34 cm long, green, glabrous; lamina peltate, elliptic to orbicular, 2–7 × 2.2–9.2 cm, shallowly 19–31-lobed, lobes truncate or obtuse to rounded, adaxial surface shiny green, glabrous, abaxial surface pale green, fleshy, glabrous. Inflorescences compound umbel, axillary; peduncles equalling petioles, rays 3–8 cm long, bearing whorls of flowers, glabrous. Flowers bisexual, actinomorphic, star-shaped; pedicels c. 1 mm long; sepals absent; petals



**Figure 3.** *Hydrocotyle bonariensis*. **A.** Habit. **B.** Leaf abaxial surface. **C.** Fresh inflorescence. **D.** Dried inflorescence. **E.** Flowers and fruits. Scale bar = 1 mm.

free, 5, ovate c. 0.5 mm long, apex acute, white; stamens 5, free, c. 0.7 mm long; filaments filiform, white; anthers brownish; ovary orbicular, flattened, green; disc oblong, flattened, yellowish; styles 2, filiform, c. 0.5 mm long, white; stigma capitate, white. Fruits schizocarpous, sub-orbicular, c. 2–2.5 × 1.5–3 mm, mericarps slightly flattened, ribbed, green, glabrous, styles persistent.

**Distribution.** South America is the native distributional area of *H. bonariensis* (Pérez-Moreau 1938; Orchard 1994).

**Ecology.** Found in roadsides and gardens at 183–873 m a.s.l.

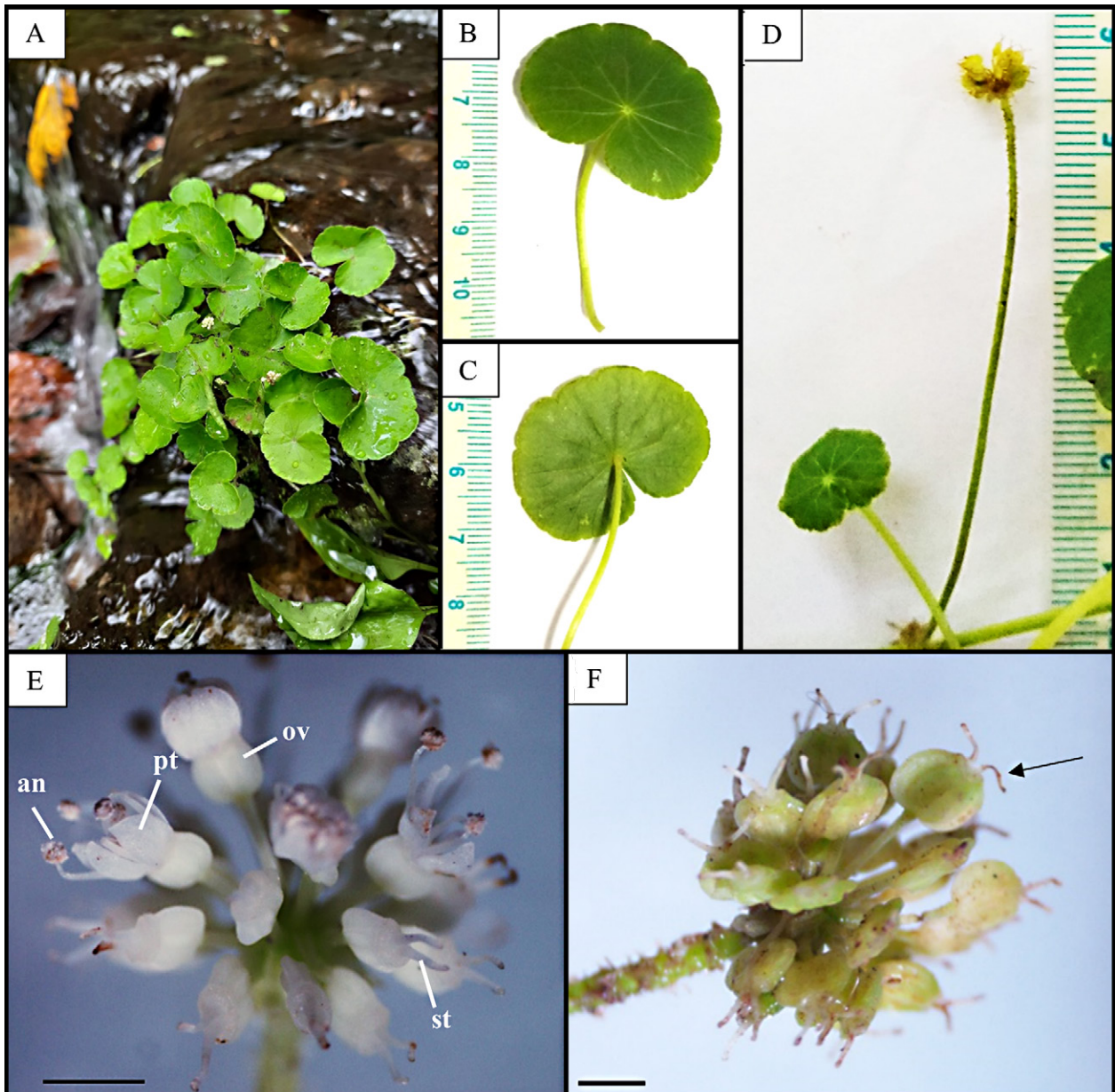
**Notes.** There are two peltate *Hydrocotyle* species in Java, *H. bonariensis* and *H. verticillata*. These species are often misidentified because of the similarity of their vegetative characters. *Hydrocotyle bonariensis* is differentiated from *H. verticillata* through its larger leaves and

many-branched umbels. The species is native to South America, and it has been introduced to Java as an ornamental groundcover and is often sold for the aquascape. Our study revealed that *H. bonariensis* has escaped from cultivation in Java. It was found growing on the roadside around Jl. Soka, IPB University, Dramaga, Bogor. Outside of its native range, this species has been reported from Australia, where it is naturalized in brackish and sandy coastal areas (Orchard 1994).

***Hydrocotyle leucocephala* Cham. & Schlttdl.**

Figure 4

**New records.** INDONESIA. JAVA – West Java • Bogor Regency, Dramaga Subdistrict, IPB University, in front of Stevia Canteen; 06°33'32"S, 106°43'52"E; 05.I.2019; collection number 019002; FIPIA • Bogor Regency, Tenjolaya, Gn. Malang, Jln. Curug Luhur Indah;



**Figure 4.** *Hydrocotyle leucocephala*. **A.** Habit. **B.** Leaf adaxial surface. **C.** Leaf abaxial surface. **D.** Umbellate inflorescence. **E.** Flower parts (an = anther; ov = ovary; pt = petal; st = styles). **F.** Fruit with persistent style (arrow). Scale bar S = 1 mm.

06°39'47"S, 106°43'10"E; 15.IX.2021; collection number 210901; FIPIA • Bogor Regency, Pamijahan Subdistrict, Gn. Sari, Jl. Raya Gn. Salak Endah; 06°40'53"S, 106°39'57"E; 03.X.2021; collection number 211002; FIPIA • Bogor, Bogor Tengah, Subdistrict Paedang, Bogor Botanic Gardens, parking area of the Conservation Building; 06°36'08"S, 106°47'51"E; 21.I.2019; collection number 27; FIPIA • Cianjur Regency, Cipanas, Cibodas Botanic Gardens; 06°44'20"S, 107°00'30"E; 12.IX.2021; collection number 730; FIPIA • Cianjur Regency, Cipanas, Taman Bunga Nusantara; 06°43'39"S, 107°04'56"E; 24.X.2021; collection number 732; FIPIA • Bandung Regency, Banjaran Subdistrict, Gunung Puntang; 07°07'01"S, 107°36'35"E; 01.XII.2021, D. Juanda leg.; FIPIA DEP-42.

**Identification.** Herb, creeping, rooting at nodes; stem white to brownish green, glabrous. Leaves simple, alternate; stipules scarious, scale-like; petioles 2–20 cm long, green, glabrous to villous at the apex; lamina ovate to reniform, 1.5–5 × 1.8–6.5 cm, shallowly 12–13-lobed, lobes truncate to obtuse, adaxial surface shiny green, abaxial surface pale, fleshy. Inflorescences umbellate, 15–45-flowered, axillary; peduncle 4–20 cm long, villous at the apex. Flowers bisexual, actinomorphic; pedicels 1.5–2.5 mm long, filiform; sepals absent; petals valvate, free, 5, ovate, c. 1 mm long, apex acute to obtuse, greenish or white; stamens 5, free, c. 1 mm long; filaments filiform, white; anthers brownish; ovary suborbicular, flattened, white; disc oblong, flattened, white; styles 2, filiform, c. 0.5 mm, white; stigma capitate, brownish purple. Fruits schizocarpous, suborbicular, c. 1–1.5 × 1.8–2 mm, broader than long, mericarps laterally flattened, ribbed, greenish, glabrous, styles persistent.

**Distribution.** The species is native to Brazil and has been introduced to other tropical regions for aquascape (Pérez-Moreau 1938; Alvarez 2001; Corrêa and Pirani 2005).

**Ecology.** Our study revealed that *H. leucocephala* grows in roadsides, riversides, open areas, and paddy fields at 186–1284 m a.s.l.

**Notes.** In 1866–1920 this species was grown in the Bogor Botanic Gardens originating from Brazil (Binnendijk and Teysmann 1866; Wigman Jr. 1920) and may have escaped from cultivation there, as this species was found there in 2019. Several other populations were found in various locations, such as the parking lot near the conservation building, plot V.G., V.L., V.M., and XI.D. The occurrence of this species in Indonesia may be due to its use as an aquarium plant which possibly is dispersed when aquaria are emptied (Ecroyd 2007). This species is thought to be a widespread contaminant in the soil of ornamental plants introduced to Argentina (Alvarez 2001) and has been reported to be naturalized in Auckland, New Zealand (Ecroyd 2007). In Java, *H. leucocephala* is established and spread along water bodies to nearby natural habitats. This species may compete with indigenous plant species in natural aquatic and semi-aquatic ecosystems and threatens the survival of indigenous species

(Nissanka et al. 2018). This plant also grows well with *Centella asiatica* (L.) Urb. (Apiaceae).

### *Hydrocotyle tripartita* R.Br. ex A.Rich

Figure 5

**New records.** INDONESIA. JAVA – **West Java** • Bogor City, Balumbang Jaya, Babakan Lio; 06°33'39"S, 106°44'14"E; X.2021; collection number 370–371; FIPIA – **Central Java** • Kali Trotjok, bov. Tjandirata; 27.III.1912; collection number 295; BO – **East Java** • Passoeroean, Smeroe; 31.V.1912; collection number 3566; BO • Passoeroean, Lawang, G. Tengger; collection number 116; BO.

**Identification.** Herb, creeping, rooting at nodes; stem brownish-green, glabrous. Leaves simple, alternate; stipules scarious, scale-like; petioles 1.3–2 cm long, green, glabrous; lamina reniform, 4–7 × 6–13 mm, leaf margin deeply 3-lobed, adaxial surface shiny green, abaxial surface pale, glabrous on both sides. Inflorescences umbellate, 5–6-flowered, axillary; peduncle c. 5 mm long. Flowers bisexual, actinomorphic, star-shaped; pedicels 0.5 mm long, filiform; sepals absent; petals free, 5, ovate, c. 0.5–0.7 mm long, apex acute to obtuse, white, tinged with purple; stamens 5, free, c. 0.5 mm; filaments filiform, purple; anthers yellowish; ovary suborbicular, flattened, white; disc oblong, flattened, green; styles 2, filiform, c. 0.2 mm, purple; stigma capitate, purple. Fruits schizocarpous, suborbicular, 0.5 × 0.6 mm, mericarps laterally flattened, ribbed, green, glabrous, styles persistent.

**Distribution.** The native distribution of *H. tripartita* is Australia (Webb and Johnson 1982).

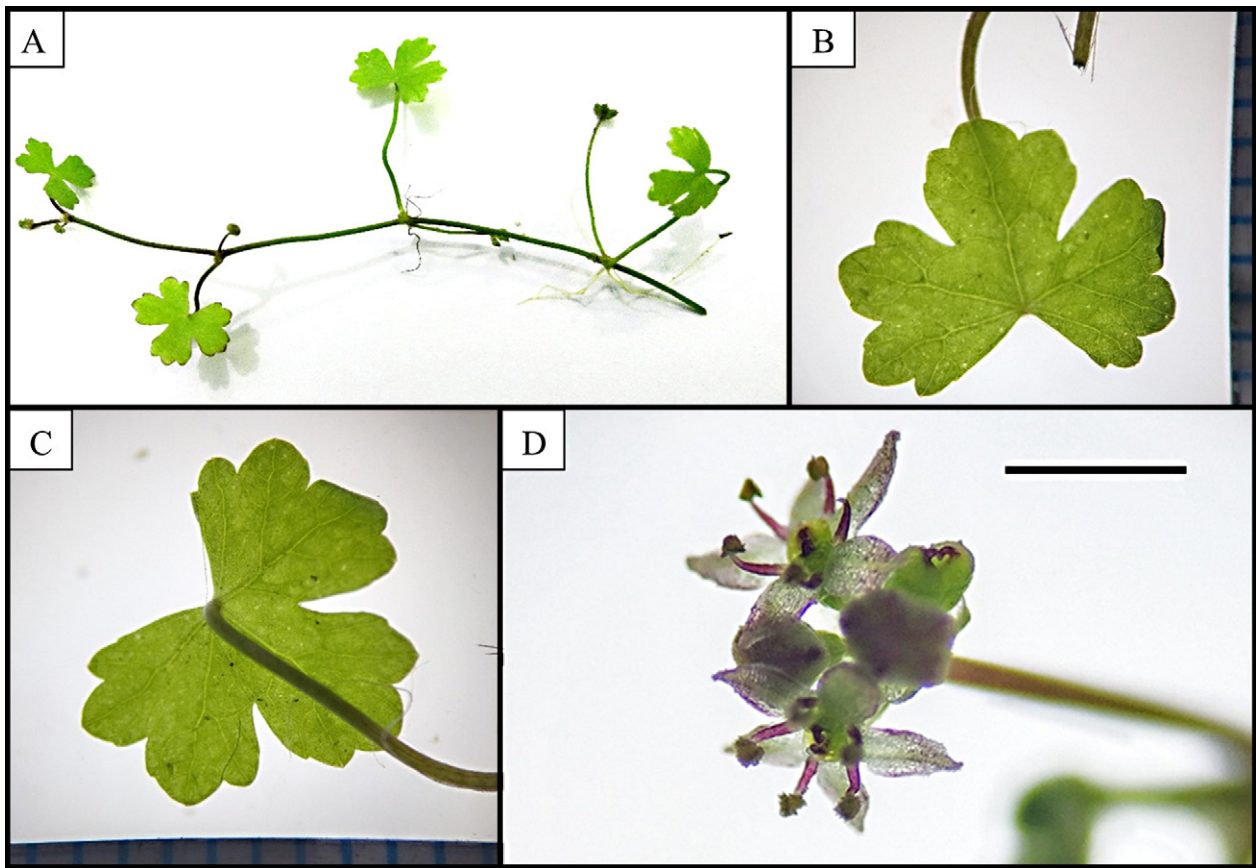
**Ecology.** *Hydrocotyle tripartita* may be a naturalized alien plant in the mountainous regions of Java. The first evidence of *H. tripartita* naturalized in Java is 1912, in Kali Trotjok.

**Note.** *Hydrocotyle tripartita* is native to Australia, where it often grows on the edge of rainforests and at high elevations (Bean and Henwood 2003). This species has also been reported as a naturalized species in Auckland in 1940–1970 (Esler and Astridge 1987). In Indonesia, based on our herbarium study, *H. tripartita* was collected for the first time in the mountains of Java Island in 1912, including in Kali Trocoh, Temanggung Regency, Central Java Province Mount Tengger, and Mount Semeru, Pasuruan Regency, East Java Province. However, this species also occurs lowland urban areas (170 m a.s.l.) such as Babakan Lio, Bogor City, West Java Province. *Hydrocotyle tripartita* is highly adaptable and has great potential as an invasive plant. In Spain, *H. tripartita* is, although data deficient, included in the ornamental traded plants that are potentially invasive (Bayón and Vilà 2019).

### *Hydrocotyle verticillata* Thunb.

Figure 6

**New records.** INDONESIA. JAVA – **Jakarta** • Pademangan, PPK Kemayoran; 06°09'11"S, 106°50'39"E; 30.IX.2021; collection number 338; FIPIA – **West Java**



**Figure 5.** *Hydrocotyle tripartite*. **A.** Habit. **B.** Leaf adaxial surface. **C.** Leaf abaxial surface. **D.** Umbellate inflorescence. Scale bar = 1 mm.

• Bogor Regency, Cibinong, Sukahati, Jl. H. Nehran 2, Casariva Residenza; 6°29'54"S, 106°48'25"E; X.2021; collection number 53; FIPIA • Bogor, Tanah Sareal Sub-district, Tanah Sareal, Jl. Bangau No. 20; 06°34'13"S, 106°48'11"E; 09.I.2022; collection number 376; FIPIA • Cianjur Regency, Cipanas, Taman Bunga Nusantara; 06°43'37"S, 107°04'49"E; 24.X.2021; collection number 733; FIPIA • Bandung Barat Regency, Lembang, Manoko; 06°48'31"S, 107°36'49"E; 01.XII.2021; Jajat leg.; FIPIA DEP43 • Bandung Barat Regency, Ciwaruga Village, Setiabudhi Regency Wing II, Jl. Safir Biru IV; 06°50'57"S, 107°35'09"E; 30.III.2019; collection number BBR 01; FIPIA • Bandung, ITB, Dayang Sumbi Gate; 06°53'15"S, 107°36'41"E; 03.I.2019; collection number 199; FIPIA • Bandung, Mandalajati Subdistrict, Sindanglaya; 06°53'39"S, 107°40'50"E; 03.I.2019; collection numbers 195–198; FIPIA • Bandung, Cileunyi, Cibiru Hilir, near Cimekar Station; 06°56'57"S, 107°42'53"E; 30.I.2019; collection number 200; FIPIA • Sumedang Regency, Jatinangor, Cikuda, near Jembatan Cincin; 06°55'36"S, 107°46'44"E; 13.X.2021; collection number 632; FIPIA.

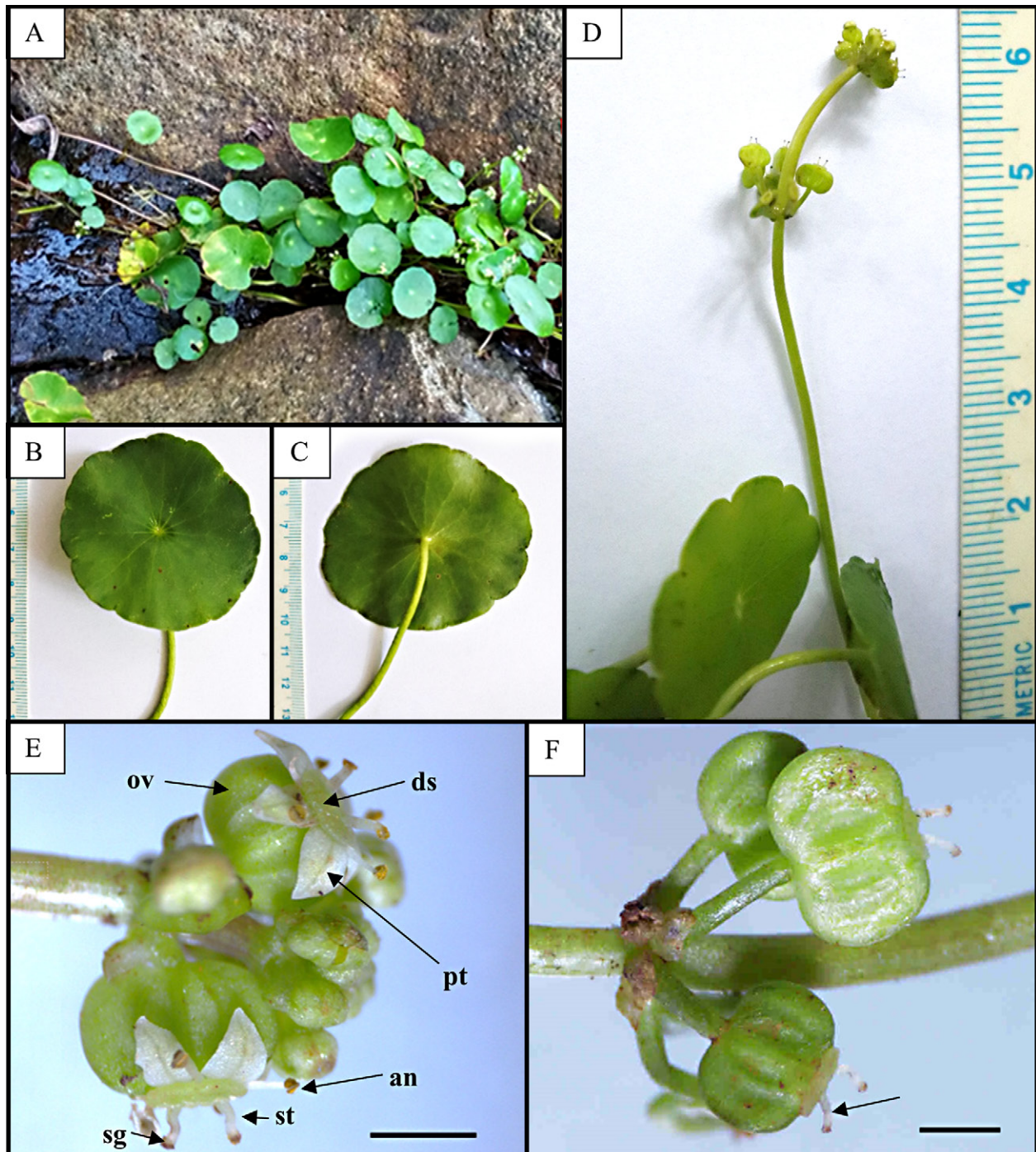
**Identification.** Herb, creeping, rooting at nodes; stem greenish-white, glabrous. Leaves simple, alternate; stipules scarious, scale-like; petioles 0.6–32 cm long, green, glabrous; lamina peltate, 0.8–6.1 × 0.8–7 cm, shallowly 11–17-lobed, lobes truncate or obtuse to rounded, adaxial surface shiny green, abaxial surface shiny yellowish-green, fleshy. Inflorescences verticillate, not branched,

axillary; peduncles 2.1–7.4 cm long with 2–4 verticillate flowers clustered at 0.8–2.5 cm apart, each cluster consists of 5–12 flowers, glabrous. Flowers bisexual, actinomorphic, star-shaped; bracts reddish; pedicels 1–4 mm long, filiform; sepals absent; petals free, 5, ovate, c. 1 mm long, white; stamens 5, free, c. 0.5 mm; filaments filiform, white; anther yellowish; ovary suborbicular-oblong, flattened, white; disc oblong, flattened, greenish; styles 2, filiform, c. 0.5 mm, white; stigma capitate, brownish. Fruits schizocarpous, oblong, 1.5–2 × 2–3 mm, broader than long, mericarps laterally flattened, ribbed, green, glabrous, styles persistent.

**Distribution.** It is naturally distributed in North and South America. The species is cultivated as an ornamental aquatic plant, and it has been introduced to other countries, namely Bangladesh, Denmark, USA (Hawaii), France, and Singapore (Mathias 1936; Pérez-Moreau 1938; Khatun et al. 2010; Lim et al. 2014).

**Ecology.** In Java, *H. verticillata* grows in open areas, roadsides, grassy areas, gardens, ditches, and ponds, and on riversides at 2–1259 m a.s.l.

**Notes.** McChesney (1994) categorized the habitus of this species as “creeping emergent”, which reflects the creeping mode of growth (Rejmánková 1992). Creeping emergent growth characteristically has the root attached in the substrate and long prostrate or ascending stems sent out and branched at nodes; the stems are not strong enough to grow vertically (Lim et al. 2014). The adventitious roots that develop on these long stems



**Figure 6.** *Hydrocotyle verticillata*. **A.** Habit. **B.** Leaf adaxial surface. **C.** Leaf abaxial surface. **D.** Verticillate inflorescence. **E.** Flower parts (an = anther; ds = disc; ov = ovary; pt = petal; sg = stigma; st = styles). **F.** Fruit with persistent style (arrow). Scale bar = 1 mm.

are often without direct contact with the substrate (Rejmánková 1992) and absorb nutrients directly from the water (Lim et al. 2014). The characteristics of *H. verticillata* are rapid growth, high nitrogen accumulation, and rapid decomposition in high-nutrient sites (Rejmánková 1992).

*Hydrocotyle verticillata* is classified as a stress-tolerant species. It can survive in areas with the low groundwater and in soggy conditions. This species is also an indicator of disturbances at sites. They can grow generally in undisturbed and non-polluted habitats, but they will proliferate in disturbed and nutrient-rich environ-

ments (Rejmánková 1992). Studies have examined the use of *H. verticillata* as phytoremediation agents in wastewater (Rejmánková and Bayer 1995; Strosnider et al. 2011).

Based on the morphological characteristics and widespread planting, this species is often confused with *Centella asiatica* (Lim et al. 2014).

## Discussion

We newly identified five alien species of *Hydrocotyle* in Java: *H. acutiloba*, *H. bonariensis*, *H. leucocephala*, *H. tripartita*, and *H. verticillata*. These discoveries



increase the number of *Hydrocotyle* species in Java to seven. According to early herbarium specimens examined from BO, *H. tripartita* were introduced to Java as early as 1912, and *H. acutiloba* as early as 1915. The massive introduction of plants at the end of the 19<sup>th</sup> century was likely the cause of accidental dispersal of plants or seeds on soil or in exchange materials. Prior to our study, all specimens of *H. acutiloba* (BO; FIPIA) and *H. tripartita* (BO) were identified as *H. sibthorpioides*. Because of the similar vegetative characteristics and habitat preferences, it is understandable that these species were misidentified (Fig. 7). Furthermore, *H. acutiloba* was introduced to Java before its first description in 1951, which account for specimens to be considered *H. sibthorpioides*.

Other species that are also frequently misidentified are *H. bonariensis* and *H. verticillata*. Both have peltate leaves, so without flowers, they have often considered the same species. In Java, *H. bonariensis* are often sold under the name *H. verticillata*. The branching of inflorescences can distinguish these species; *H. bonariensis* has a many-branched umbel (Fig. 3C), while *H. bonariensis* has unbranched inflorescences (Fig. 6D).

Most of the *Hydrocotyle* species, such as *H. bonariensis*, *H. leucocephala*, and *H. verticillata*, are sold as ornamental groundcover. Moreover, *H. tripartita* is traded as an aquascape plant in Indonesia. The trading of ornamental plants has been proven to increase and introduce alien aquatic plants worldwide (Kadono 2004; Brunel 2009), and some exotic aquatic plants may escape from cultivation and spread quickly in the wild (Kadono 2004; Nissanka et al. 2018). This is in accordance with our observation of a naturalized population of *H. verticillata* around a street kiosk selling ornamental plants in Jatinangor, Sumedang Regency.

Based on our observations, all the *Hydrocotyle* species reported here propagate vegetatively with stolons, in addition to producing fruits. This mechanism supports widespread establishment of populations in the wild (Richardson et al. 2000; Kadono 2004; Meléndez-Ackerman and Rojas-Sandoval 2021). Stolon fragments rise to the soil surface during vegetative reproduction and are carried away by the water, causing them to grow

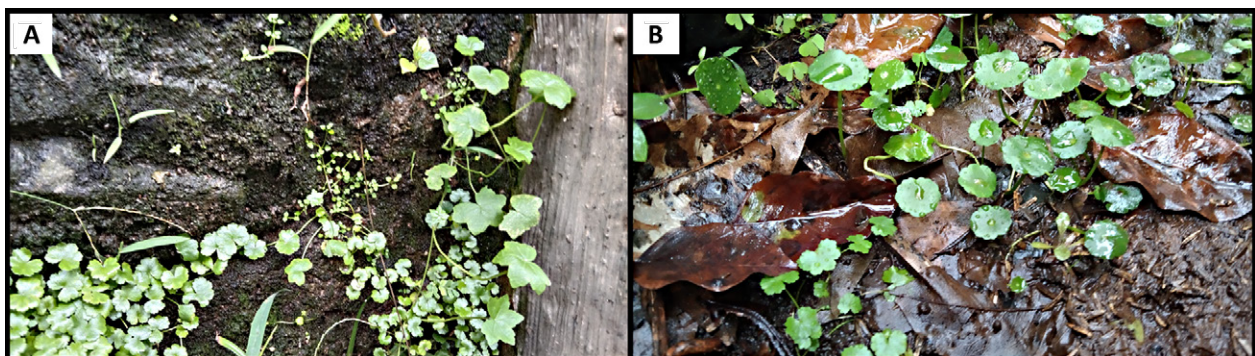
into new plants and later into new populations (Emert and Clapp 1998).

Some species of *Hydrocotyle* are considered weeds due to their ability to naturalize in environments outside of their native habitat (Esler 1988; Rejmánková and Bayer 1995; Alvarez 2001; Bean and Henwood 2003; Knight and Miller 2004; Ecroyd 2007; Lim et al. 2014; Bayón and Vilà 2019). *Hydrocotyle verticillata*, which is native to subtropical countries in the Americas and Australia, is naturalized in Java on account of its ability to grow well even in extreme winter conditions. This species' rapid expansion can cover whole areas, such as ponds (Verloove and Heyneman 2021). *Hydrocotyle tripartita* is also reported as a weed (Webb and Johnson 1982). *Hydrocotyle vulgaris* L. is another species with a survival strategy during harsh winter months. This species produces smaller leaves during the winter and returns to normal by the end of spring (McChesney 1994). The other *Hydrocotyle* species, *H. dipleura* A.R.Bean, prefers to grow in extreme environments with high salinity levels (Bean and Henwood 2003). McChesney (1994) reported that *H. bonariensis* could survive in a saline environment by the other end of the stolons growing/ rooted in non-saline soil.

Geographic isolation, such as mountainous highland areas, may restrict the distribution of *Hydrocotyle* species. *Hydrocotyle acutiloba* is the only species found above 700 m altitude in our study. It is reasonable to assume that this species' potential for naturalization will be limited by its occurrence only in highland areas. Other species, including *H. oraria* A.R.Bean and *H. paludosa* A.R.Bean, prefer to grow associated with *Melaleuca* (Myrtaceae) species (Bean and Henwood 2003). *Hydrocotyle* requires a specific type of soil to grow. For instance, *H. novae-zelandiae* DC. can grow in sand-dune environments and has etiolate stolons (McChesney 1994), whereas *H. miranda* A.R.Bean & Henwood prefers clay-loam soils (Bean and Henwood 2003).

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**Figure 7.** *Hydrocotyle sibthorpioides* shared the same habitat as (A) *H. acutiloba* and (B) *H. verticillata* at the observation sites in Jatinangor, Sumedang, West Java.

study specimens in that collection. We are grateful to the reviewers and editor for their insightful comments.

## Authors' Contributions

Conceptualization: MRH, ASDI. Data curation: P, PWKH, MRH, ZAA, APD, ASDI. Formal analysis: P, ASDI, APD, PWKH, MRH. Investigation: MRH, APD, ASDI, PWKH, P, ZAA. Methodology: ASDI, MRH. Supervision: RRI. Validation: ASDI. Writing – original draft: P, MRH, ASDI, ZAA, APD, PWKH, RRI. Writing – review and editing: P, ASDI, RRI, PWKH, MRH, APD, ZAA.

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