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New species of *Ophiopogon*, *Peliosanthes* and *Tupistra* (Asparagaceae s.l.) in the flora of Vietnam

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Five new species named *Peliosanthes aperta*, *P. elegans*, *P. kenhillii*, *Tupistra densiflora* and *T. patula* are described and illustrated. These species are very local in distribution and endemic to northern or southern Vietnam. Two other species, *Ophiopogon ogisui* and *Peliosanthes griffithii*, are recorded as new to the flora of Vietnam. A key to the species of *Tupistra* occurring in Indochina and its neighboring regions is also provided.

This paper focuses on the three genera *Ophiopogon* Ker Gawl., *Peliosanthes* Andrews (including *Lourya* Baill., *Neolourya* L. Rodrig.) and *Tupistra* Ker Gawl. (for the generic circumscription see Tanaka 2010a) occurring in Vietnam. In 'Flore Générale de l'Indo-Chine' (Vol. 6, fascicles 5 and 6 edited by Lecomte et al. 1934), *Ophiopogon* and *Peliosanthes* (*Neolourya*) were placed in the family Haemodoraceae (Rodriguez 1934a), while *Tupistra* (as *Gonioscypha*) was classified under the Liliaceae (Gagnepain 1934a). In more recent taxonomic treatises based on morphological and/or molecular studies, they have been placed in the Asparagaceae s.l. (Tanaka 2010a, 2010b, Averyanov and Tanaka 2012, 2013, Averyanov et al. 2013, 2014, 2015) or in the narrower family Ruscaceae s.l. (Kim et al. 2010) or Convallariaceae (Dahlgren et al. 1985, Conran and Tamura 1998, Tanaka 1999a, Yamashita and Tamura 2000). The Asparagaceae s.l. as circumscribed by the Angiosperm Phylogeny Group (2003, 2009) is very broad, comprising several groups that were formerly regarded as distinct families, like Ruscaceae (Convallariaceae), Aphyllanthaceae and Agavaceae. These families were treated as subfamilies under Asparagaceae by Chase et al. (2009), and the three genera in the present paper belong to the subfamily Nolinoideae that replaced the Ruscaceae.

Members of the three genera distributed in Vietnam have hitherto been studied by botanists like Decaisne (1867), Gagnepain (1934a, 1934b), Rodriguez (1928, 1934a, 1934b), Larsen (1961) and Jessop (1976). We have also conducted taxonomical and phytogeographical surveys of them in Vietnam and its adjacent regions in order to more closely elucidate their diversity (Tanaka 1998a, 1999a, 1999b, 1999c, 2000, 2001, 2003, 2004a, 2004b, 2010a, 2010b, Averyanov 2011, Averyanov and Tanaka 2012, 2013, Averyanov et al. 2013, 2014, 2015).

According to Tanaka, *Tupistra* consists of 20 species in total (2010a), and *Ophiopogon* distributed in south and southeast Asia comprises 16 species (2001; 1 species, *O. japonicus*, is excluded, since it is not distributed spontaneously here). *Peliosanthes* was reviewed by Jessop (1976) who concluded that it comprises only 1 species, *P. teta* Andrews. In this treatment many other congeners previously published as distinct were reduced to synonyms of *P. teta*. The only character he found to differ among plants of *Peliosanthes* was the number of flowers in the axils of each bract. Based on differences in this character and in distribution he distinguished two subspecies of *P. teta*. The taxonomic conclusion reached by Jessop is thus remarkably different from that of previous botanists. In order to see how his study was carried out, we reviewed his paper especially as to the methodology he employed. Jessop based his study on herbarium specimens, and he did not mention much about the morphological details of the flowers. Flowers of different taxa of *Peliosanthes* resemble each other in their basic structure, and they are mostly small and fleshy, so it is often difficult to fully grasp floral features from dried and strongly pressed specimens. Furthermore, herbarium specimens with flowers

are generally not amply available and often lack information about characters like floral color, as Jessop himself stated. These factors are likely to have affected his conclusion, because they usually obscure specific delimitations that might exist. Jessop (1976) further demonstrated that several quantitative characters like the leaf length and leaf width of the samples showed a continuous variation pattern. However, that result may be obtained in any plant group if quantitative characters are sampled collectively from many specimens of a genus including multiple species. In our studies based on living plants and/or herbarium specimens of *Peliosanthes* (Tanaka 2004a, 2004b, Averyanov and Tanaka 2012, 2013, Averyanov et al. 2013, 2014, 2015), not a few entities that appear distinct from other congeners were recognized. The degree of diversification into species in *Peliosanthes* appears not much different from that in other plant groups.

Indochina is very rich in species diversity, at least of several genera of Asparagaceae s.l. In our previous surveys, we found as many as 22 new species of the three genera in eastern Indochina (Vietnam, Laos and Cambodia), as listed below (Tanaka 1999a, 2000, 2004b, 2010b, Averyanov 2011, Averyanov and Tanaka 2012, 2013, Averyanov et al. 2013, 2014, 2015, Vislobokov et al. 2014).

Ophiopogon fruticulosus Aver., N. Tanaka & K. S. Nguyen
O. petraeus Aver. & N. Tanaka
O. rupestris Aver. & N. Tanaka
O. tristylatus Aver., N. Tanaka & Luu
O. vietnamensis N. Tanaka

Peliosanthes argenteostriata Aver. & N. Tanaka

P. cambodiana Aver. & N. Tanaka
P. densiflora Aver. & N. Tanaka
P. divaricatanthera N. Tanaka
P. grandiflora Aver. & N. Tanaka
P. hexagona Aver., N. Tanaka & K. S. Nguyen
P. lucida Aver., N. Tanaka & K. S. Nguyen
P. micrantha Aver. & N. Tanaka
P. nivea Aver. & N. Tanaka
P. nutans Aver. & N. Tanaka
P. retroflexa Aver. & N. Tanaka
P. subcoronata N. Tanaka
P. triandra Aver. & N. Tanaka

Tupistra breviscapa Aver. & N. Tanaka
T. khangii Aver., N. Tanaka & Vislobokov
T. laotica N. Tanaka
T. theana Aver. & N. Tanaka

The total number of new species of the three genera in the above list is: *Peliosanthes* 13, *Ophiopogon* 5, and *Tupistra* 4. Our field surveys in Indochina are still underway, and in our prospect, even more new species will be discovered. In this respect, the current state of our knowledge of these genera in eastern Indochina is quite incomplete.

In our latest survey in Vietnam, we discovered five additional new species, three of which belong to *Peliosanthes* (*P. aperta*, *P. elegans* and *P. kenhillii*) and two to *Tupistra* (*T. densiflora* and *T. patula*). Apart from them, we also found *Ophiopogon ogisui* and *Peliosanthes griffithii*, both of which are new to the flora of Vietnam. These seven species are reported herein with taxonomic remarks and records. We also provide a key to the species of *Tupistra* occurring in Indochina and its neighboring regions.

Material and methods

In order to accurately identify our material, herbarium specimens (including type material when available) of many known taxa of *Ophiopogon*, *Peliosanthes* and *Tupistra* kept at various herbaria were examined in advance. Surveys of these specimens form a basis of this and preceding studies (Tanaka 1998a, 1999a, 1999b, 1999c, 2000, 2001, 2004a, 2004b, 2010a, 2010b).

In circumscribing species, we followed the following species concept (definition): "a species is a group of individuals similar in attributes and differing distinctly in taxonomically important characters from other such groups" (Tanaka 1996), or in short: "species are groups of similar individuals differing distinctly from other such groups" (Tanaka 1998b). These definitions are complemented by the following explanation: 'similar' must be due to homology, and 'taxonomically important characters' should be considered for each particular case. We believe that they accord well with the so-called taxonomic species concept that appears to have been most widely accepted. In practice, all kinds of character states (or attributes) that (a group of) individuals possess were taken into account when delimiting taxa.

Flowers of the three genera are more or less fleshy, and their structures are generally largely distorted in the process of making herbarium specimens. So observations of flowers were made mostly on living plants in their habitats and/or in cultivation. Further, when possible, inflorescences and flowers were preserved in spirit for subsequent studies.

Specimens of the new species we are to describe here were collected in the field in 2014. Inflorescences and flowers were fixed and preserved in 60–70% ethanol. Measurements of floral parts for description were made on both living and liquid-preserved materials. Fresh flowers or floral parts were found to shrink up to ca 20–30% in size in the drying process of making herbarium specimens. This was taken into account when dried herbarium specimens were identified. In describing quantitative characters, infrequent extreme values (i.e. rarely occurring minimal and maximal values) of a variation range are parenthesized respectively before and after a normal variation range.

Ophiopogon ogisui M. N. Tamura & J. M. Xu (2007, p. 39, Fig. 1) (Fig. 1)

Type: China, Guangxi, Longzhu, Jinlong, Gaoshan, Banbi, ca 440 m a.s.l., Mikinori Ogisu 250 (holotype: PE, n.v.).

Habitat and phenology

Shady primary and secondary lowland forests of evergreen broad-leaved trees on limestone at elevations about 400–500 m a.s.l. Terrestrial herb. Flowering in October–November. Rare. Expected IUCN red list status: 'Data Deficient' (DD).

Figure 1. *Ophiopogon ogisui* M. N. Tamura & J. M. Xu. Digital Vietnamese flora 0224: Minh Duc Nguyen, L. Averyanov, sine n., 8 Nov 2014. Photos, correction and design by L. Averyanov.

Distribution

Northern Vietnam (lowland limestone areas stretching over the Chinese border), southern China (Guangxi).

Similar species

Ohiopogon ogisui is a new record to the flora of Vietnam. It is close to *O. tonkinensis* F. T. Wang & Tang (Tanaka 1999b), but differs in having subglobose urceolate perianth and longer pedicels. In China it is known only from the type locality near the Vietnamese border (Tamura and Xu 2007). It is noteworthy that both plants from Vietnam and China were found in limestone areas. As in the Chinese plant, the ovary of our plant is uni-locular.

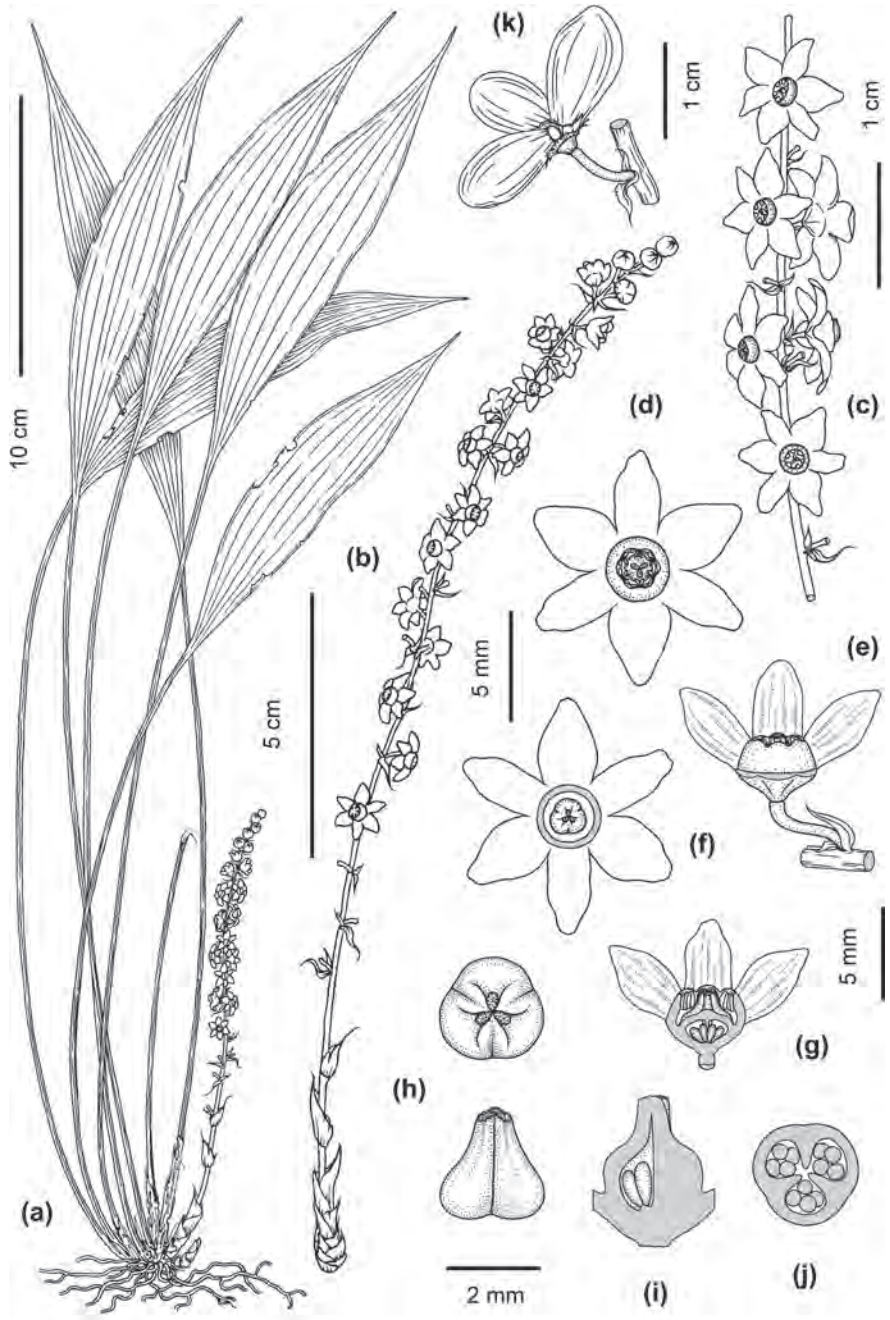

Figure 2. *Peliosanthes aperta* sp. nov. (a) flowering plant, (b) flowering stem, (c) portion of rachis with flowers, (d) flower, front view, (e) side view of pedicellate flower with 3 tepals removed, (f) front view of flower with corona removed, (g) sagittal section of flower, (h) pistil viewed from above (upper) and from side (below), (i) sagittal section of pistil showing interior of ovary, (j) transversal section of ovary, (k) three ripe seeds exposed. All drawn from the type Ba Vuong Truong, no. 1 by L. Averyanov and T. Maisak.

Additional specimens examined

Northern Vietnam, low limestone hills, cultivated in Hanoi, Minh Duc Nguyen, L. Averyanov, 8 Nov 2014 (LE!); digital Vietnamese flora 0224/Minh Duc Nguyen, L. Averyanov, s.n., 8 Nov 2014 (Fig. 1).

Peliosanthes aperta Aver., N. Tanaka & Vuong sp. nov. (Fig. 2, 3a)

Type: Southern Vietnam, Khanh Hoa province, Hon Ba nature reserve, around point 12°06′531″N, 108°59′409″E, ca 407 m a.s.l., terrestrial herb in evergreen forests, May 2014, Ba Vuong Truong, no 1 (holotype: LE!).

Etymology

The specific epithet refers to the widely open annular corona.

Description

Terrestrial rhizomatous perennial herb. Rhizome subterranean, plagiotropic, simple or with a few branches, 1.0–1.5(2.0) cm long, bearing many semi-woody, dull gray–brown wiry roots

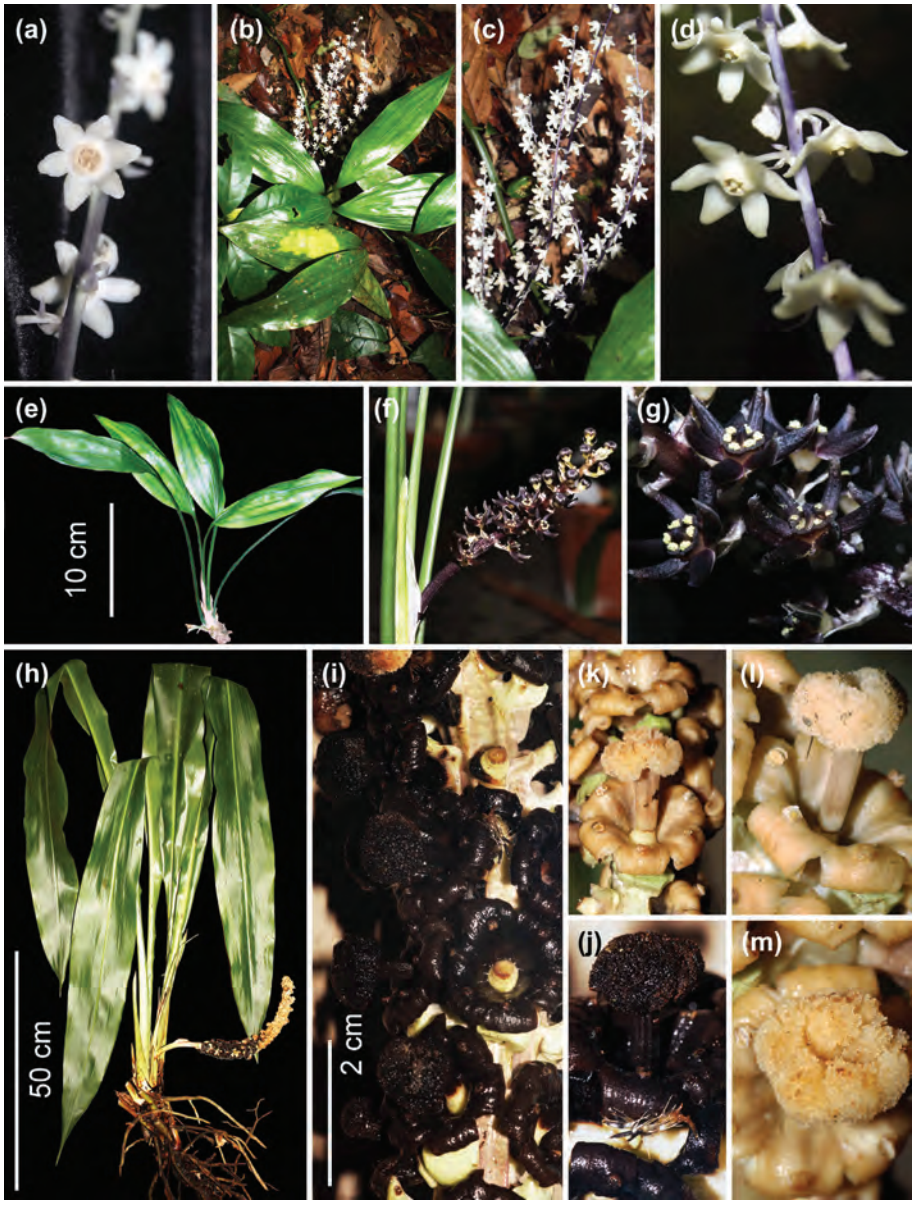

Figure 3. Three species studied. *Peliosanthes aperta* (a) (Ba Vuong Truong, no. 1, type); *P. elegans* (b)–(d) (Ba Vuong Truong, no. 2, type); *P. griffithii* (e)–(g) (L. Averyanov et al. CPC 6962a); *Tupistra patula* (h)–(m) (L. Averyanov et al. CPC 7492, type). Photos by Ba Vuong Truong, L. Averyanov and P. Efimov.

covered densely with light gray root hairs. Stems ascending to erect, about 5 mm tall, densely covered with remnants of whitish scarious scales (cataphylls). The scaly leaves at anthesis ovate to oblong, shortly acuminate, scarious or papyraceous, conduplicate, distichous, proximally imbricate, loosely embracing base of peduncle, 0.5–2.0(3.0) cm long, (3)4–6(8) mm wide. Leaves suberect to arching, petiolate, to 35–45 cm tall; petiole rigid, slightly curved, (15)20–25(30) cm long; leaf blade narrowly elliptic, shortly acuminate with acute apex, entire along margins, glabrous, glossy, uniformly green on both sides, (14)16–20(22) cm long, (3.0)3.5–4.0(4.5) cm wide; longitudinal veins many, prominent, crossed sub-perpendicularly with many dichotomously branching transversal veinlets. Flowering stem (scape) arising axillary; peduncle and rachis white with dirty violet tint, distally bearing a sub-dense raceme; peduncle rather slender, straight, erect, (2.5)3.0–4.0(5.0) cm long, 1–2 mm in diameter, bracteate; the sterile bracts (6)8–10(12), triangular-ovate, cordate at base, slightly conduplicate, shortly attenuate or acuminate, whitish, scarious, (0.3)0.5–1.0(1.5) mm long and (2.5)3.0–5.0(6.0) mm wide, proximal bracts closely located and imbricate at the peduncle base; rachis loosely many-flowered, finely angled longitudinally, (5)6–10(12) cm long. Floral bracts 2, variable in size along rachis, proximal ones much larger, diminishing upward, distally antrorse, white to light violet, scarious; bract located below flower, narrowly triangular, cordate at base, acuminate at apex, slightly concave, (2.0)3.5–4.5(5.0) mm long, (0.6)1.0–2.0(2.5) mm wide; bracteole lateral to flower, subsimilar in shape, twice smaller, (0.8)1.0–1.5(1.8) mm long, (0.6)0.8(1.0) mm wide.

Flowers solitary in bracteal axil, pedicellate, broadly open, (8.5)9.0–11.0(11.5) mm across, horizontal or ascending; basal syntepalous part broadly obconical, 3.0–3.5 mm across, 1.5 mm long, jointed with a distinct articulation to a terete, horizontal or ascending pedicel; pedicel (1.0)2.0–3.5(5.0) mm long, 0.5–0.8 mm in diameter. Perianth segments 6, white, straightly spreading, blunt to rounded at apex, with entire, sometimes slightly undulate, not revolute margins, (3.0)3.5–4.0 mm long; outer segments narrowly ovate (2.2)2.5(2.8) mm wide; the inner oblong, (1.8)2.0(2.2)wide. Corona pure white or yellowish, annular, slightly incurved distally, (2.6)2.8–3.2(3.5) mm across, 1.5 mm high; distal inner margin almost vertical, shallowly 6-lobed; orifice 2.0–2.5 mm in diameter. Anthers 6, sessile, introrse, inserted at distal inner margin of corona, broadly ovoid, 0.6–0.8 mm long and wide, light yellowish. Ovary half-inferior; free part hemispheric, 0.4–0.5 mm high, 1.5–1.8 mm across, at base almost orbicular or very obscurely 3-lobed in cross section, angulate longitudinally; the interior imperfectly partitioned into 3 chambers by 3 septa; each chamber slightly open with narrow longitudinal slit at central axial portion of ovary, containing 4 ovules on basal placenta; style conical, triangular in cross section, 1.0–1.2 mm tall, 0.8 mm in diameter at base; stigma 3-partite, the lobes obovate, finely papillulate. Seeds narrowly ovoid to ovoid, 11–14 mm long, 7–9 mm in diameter, dark glossy green.

Habitat and phenology

Terrestrial herb. Shady humid primary and secondary evergreen broad-leaved forests on granite at elevation about 400 m a.s.l. Flowering in April–May. Occasional. Expected IUCN red list status: 'Data Deficient' (DD).

Distribution

Southern Vietnam (Khanh Hoa province, Hon Ba Mountains). Endemic to southern Vietnam.

Similar species

With its slender, somewhat laxly-flowered scape bearing white flowers, *Peliosanthes aperta* may look somewhat similar to *P. elegans* described below, but it differs markedly in the horizontal or ascending flowers with an annular, widely open and often somewhat yellowish corona, and by the shape of the pistil.

Peliosanthes elegans Aver., N. Tanaka & Vuong sp. nov. (Fig. 3b–d, 4)

Type: southern Vietnam, Khanh Hoa province, Hon Ba nature reserve, around point 12°06′531″N, 108°59′409″E, ca 407 m a.s.l., terrestrial herb in evergreen forests, May 2014, Ba Vuong Truong, no 2 (holotype: LE!).

Etymology

The specific epithet refers to the elegant habit with a slender loose raceme of many white flowers.

Description

Terrestrial rhizomatous perennial herb. Rhizome subterranean, plagiotropic, simple or with a few branches, 1.0–1.5(2.0) cm long, bearing many semi-woody, dull gray-brown wiry roots densely covered with light gray root hairs. Stems ascending to erect, about 5 mm tall, densely covered with remnants of whitish scarious scales; the scaly leaves ovate, acuminate, scarious to papyraceous, conduplicate, distichous, proximally imbricate, embracing base of peduncle, (0.5)1.0–2.5(3.0) cm long, (2.0)2.5–5.0(6.0) mm wide. Leaves suberect or arching, petiolate, to 40–50 cm long; petiole rigid, slightly curved, (16)20–30(35) cm long; leaf blade narrowly elliptic to elliptic, shortly acuminate, entire along margins, glabrous, glossy, uniformly green on both sides, (12)15–18(20) cm long, (3.0)3.5–6.0(6.5) cm wide; longitudinal veins many, prominent, crossed subperpendicularly with many dichotomously branching transversal veinlets. Flowering stem (scape) arising axillary, peduncle and rachis light violet, distally bearing a sub-dense raceme; peduncle rather slender, straight, slightly flexuose or arching, (6)8–10(12) cm long, 1–2 mm in diameter, bracteate; the sterile bracts (5)6–10(14), triangular-ovate, conduplicate, acuminate or attenuate, whitish, scarious, (0.5)1.0–1.5(2.0) cm long and (2)3–5(6) mm wide; proximal bracts borne closely at the peduncle base; rachis loosely many-flowered, finely angled longitudinally, (9)11–15(18) long. Floral bracts 2, variable in size along rachis, proximal ones much larger, diminishing toward the apex, distally antrorse, white to light violet, scarious; bract located below flower, narrowly triangular, acuminate, slightly concave, (2.0)3.5–7.0(12.0) mm long, (0.8)1.0–3.0(3.5) mm wide; bracteole lateral to flower, subsimilar in shape, twice smaller, (1.0)1.5–2.5(3.0) mm long, (0.6)0.8–1.0(1.2) mm wide. Flowers entirely pure white, solitary in bracteal axil, pedicellate, broadly open, (10.5)12.0–13.0(13.5) mm across, nodding; proximal syntepalous part broadly obconic, 4.5–5.0 mm across, 0.5–1.0 mm long, jointed with distinct articulation to terete, decurved pedicel (3.0)4.0–5.0(6.5) mm long, 0.5–0.8 mm in diameter. Perianth segments 6, subsimilar, narrowly ovate, obtuse or subacute, (3.0)3.5–4.0(4.5) mm long, (2.4)2.6–3.0(3.5) mm wide, straightly spreading, margins scarious, entire, sometimes slightly undulate, not revolute. Corona broadly conic, its base scarcely demarcated from tepals, (4.0)4.5–5.0(5.5) mm across, about 1 mm high; distal margin slightly 6-lobed; orifice (1.8)2.0–2.2 mm in diameter. Anthers 6, sessile, introrse, inserted at margin of orifice, broadly ovoid, 0.8–1.0(1.2) mm long and wide, light yellowish. Ovary half-inferior; free part shortly conical, 0.5–0.6 mm high, 2.4–2.6 mm across, obscurely 3(6)-lobed at base, angulate longitudinally, the interior imperfectly partitioned into 3 chambers by 3 septa; each chamber slightly open with narrow longitudinal slit at central axial portion of ovary, containing 4 ovules on basal placenta; style conical, 3-angular in cross section, 1.2–1.4 mm tall, 1 mm in diameter at base; stigma 3-partite, its lobes obovate, finely papillulate. Seeds ovoid, 10–12 mm long, 6–7 mm in diameter, dark glossy green.

Habitat and phenology

Terrestrial herb. Shady humid primary and secondary evergreen broad-leaved forests on granite at elevation about 400 m a.s.l. Flowering in April–May. Occasional. Expected IUCN red list status: 'Data Deficient' (DD).

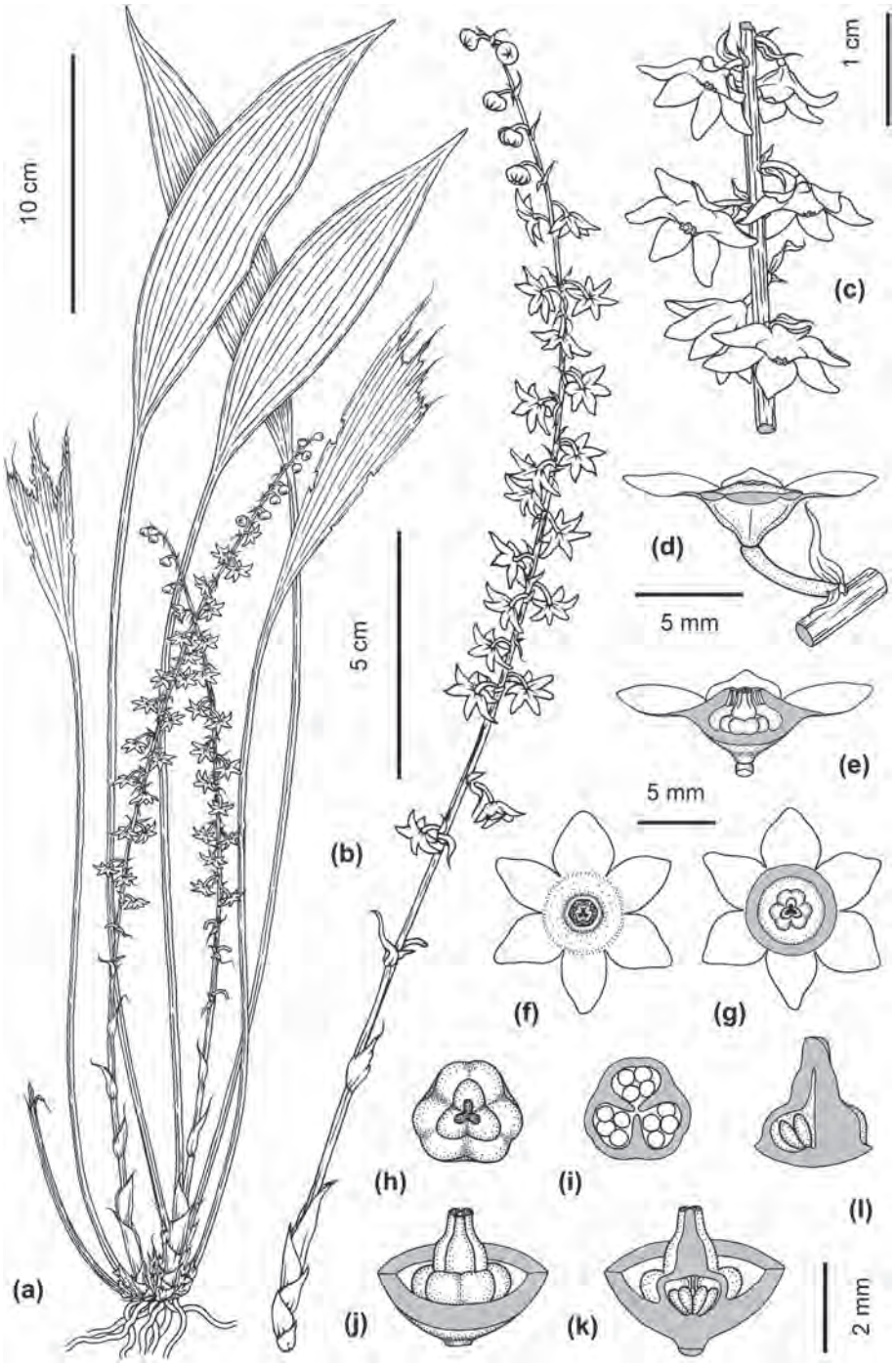

Figure 4. *Peliosanthes elegans* sp. nov. (a) flowering plant, (b) flowering stem, (c) portion of rachis with flowers, (d) side view of pedicellate flower with 3 tepals removed, (e) sagittal section of flower with intact pistil, (f) flower in front view, (g) front view of flower with corona removed, (h) pistil, view from above, (i) transversal section of ovary, (j) pistil located in floral base, (k) tangential longitudinal section of pistil, showing inside of frontal ovarian locule, (l) sagittal section of pistil showing interior of an ovarian locule. All drawn from the type Ba Vuong Truong, no. 2 by L. Averyanov and T. Maisak.

Distribution

Southern Vietnam (Khanh Hoa province, Hon Ba Mountains). Endemic to southern Vietnam.

Similar species

Peliosanthes elegans shares white nutant flowers with *P. albida* Baker (Baker 1890) described from the Malay Peninsula, but markedly differs by the more slender flowering stem, relatively longer peduncles, longer pedicels, larger flowers, and pistils and coronas of different shape. It also shares nutant flowers and low, nearly flat, broadly conical coronas with *P. nutans* Aver. & N. Tanaka (Averyanov and Tanaka 2012), but strikingly differs in having longer, erect or suberect flowering stems, more numerous, pure white flowers, and pistils of a different shape.

Peliosanthes griffithii Baker (1879, p. 506) (Fig. 3e–g)

Type: India, Himalaya orientalis in sylvis ad Darjeeling, Griffith 5840 (holotype: K!).

Habitat and phenology
Primary and secondary submontane broad-leaved evergreen forests on sandstone at elevations 700–1000 m a.s.l. Terrestrial herb, common on shady humid steep slopes. Flowering in October (in cultivation). Locally common. Expected IUCN red list status: 'Least Concern' (LC).

Distribution
Northern Vietnam: Son La province (Van Ho district), northeast India, Nepal, Bhutan.

Similar species
The occurrence of *Peliosanthes griffithii* in Vietnam is a new record. The species is very close to *P. serrulata* L. Rodr. (1934b, p. 96) described from southern Vietnam and Cambodia (Syntypes: Cochinchine ile de Phu Quoc, Pierre 6688 – P!; Cambodge, Kampot, Chevalier 31824 – P!). We have found only very slight difference in the shape of the style between the two species. The leaf blades of *P. serrulata* are serrulate at margins, but those of *P. griffithii* are also often slightly serrulate at least partially, and hence this character state seems not so significant in their taxonomy. Further studies based on more samples from wider areas may reveal a conspecific status of the two species. *Peliosanthes serrulata* has been reported from Laos (Newman et al. 2007), but it needs a re-examination as to its identity, as this is possibly *P. griffithii*. The discovery of *P. griffithii* in Vietnam indicates that this species is more widely distributed in Asian countries from Nepal to Vietnam than previously recorded. This may also imply that the species will be discovered in the areas between Indochina and eastern Himalaya, like Bhutan and Vietnam, in the future.

Additional specimens examined
Northern Vietnam, Son La province, Van Ho district, Chieng Xuan municipality, Co Hong village, territory of Xuan Nha natural reserve, Pha Luong Mountain around point 20°42′14.2″N, 104°43′53.9″E, 12 Nov 2013. L. Averyanov et al. CPC 6962a (LE, Fig. 3e–g).

Peliosanthes kenhillii Aver., N. Tanaka & K. S. Nguyen sp. nov. (Fig. 5)

Type: Northern Vietnam, Ninh Binh province, Nho Quan district, Cuc Phuong National Park, around point 20°15′03.6″N, 105°41′58.7″E, ca 165 m a.s.l., scattered in closed lowland secondary forests of evergreen broad-leaved trees at the base of limestone hills, common, 9 Dec 2014, Khang Sinh Nguyen, NSK 760 (holotype: LE!, isotype: LE!). Plate: digital Vietnamese flora 0222/NSK 760 (Fig. 5).

Etymology
The specific epithet is dedicated to the excellent Australian botanist, Dr Kenneth D. Hill (1948–2010), who helped us greatly in carrying out a series of field sessions in northern Vietnam.

Description
Terrestrial or occasionally lithophytic, rhizomatous perennial herb. Rhizome subterranean, plagiotropic, 2–4(4) cm long, simple or with a few branches, bearing many roots; the roots white or dull gray-brown, thick, fleshy, very rigid, wiry, becoming ligneous with age. Stems ascending to erect, 5(10) mm long, loosely covered with light brownish fibrous remnants of sheath leaves (cataphylls). Cataphylls linear to lanceolate, subtubular, embracing petiole, dull brownish at anthesis, later becoming partially disintegrated, (6)10–14(16) cm long, (6)7–10(12) mm wide. Leaves suberect to arching, petiolate, to (40)55–65(70) cm long; petiole rigid, slightly curved to almost straight, terete, (25)30–40(45) cm long; leaf blade broadly elliptic, shortly acuminate with subacute apex, usually slightly undulate along margins, glabrous, glossy, uniformly green on both sides, somewhat firm, (18)20–26(30) cm long, (6)7–12(14) cm wide; longitudinal veins many, prominent, subperpendicularly crossed with many dichotomously branched transversal veinlets. Scape (flowering stem) bearing a sub-dense raceme arising axillary; peduncle and rachis light greenish–violet to dark violet; peduncle straight, stout, very short, bracteate, (0.5)1.0–2.5(4.0) cm long, (2.0)3.0–3.5(4.0) mm in diameter; the sterile bracts (2)3–4(5), triangular, conduplicate, acuminate, papyraceous or scarious, dull yellowish-brown, (0.5)1.0–1.5(2.0) mm long and 3–6 mm wide; rachis many-flowered, longitudinally finely ridged, (10)12–20(24) cm long. Floral bracts 2, distally antrorse, light violet, scarious; bract located below flower, narrowly subtriangular, cordate at base, distally acuminate to subulate, concave, (8)10–12(14) mm long, (2.5)3.5–4.5(5.0) mm wide; bracteole lateral to flower, broadly ovate-triangular, twice smaller, (2.0)3.5–4.5(5.0) mm long, (1.0)1.5–2.0(2.5) mm wide. Flowers solitary in bracteal axil, pedicellate, broadly open, (9)10–12(13) mm across, directed sideward or slightly upward; perianth tube broadly obconical, 4.5–5.0 mm across, 1.2–1.6(2.0) mm long, jointed at base with articulation to pedicel; pedicel short, terete, longitudinally finely ribbed, almost horizontal or slightly upturned, 1.5–2.0 mm long, 0.8–1.0 mm in diameter. Perianth segments subsimilar, narrowly ovate to ovate-triangular, obtuse, light green to dark dirty brown–violet, spreading, 4.0–5.0(5.5) mm long, 3.0–3.5(4.0) mm wide; margins scarious, entire, strongly revolute. Corona white, radially sparsely striped with dull brown–violet, nearly circular, obscurely hexagonal or slightly 6-lobed, slightly convex to almost flat at apex, very fleshy at base, (4.5)5.0–5.5(6.0) mm across, about 1 mm high, its distal margin almost entire or obscurely 6-subdentate, forming an orifice 1.5–1.8 mm in diameter. Anthers 6, sessile, introrse, inserted at distal edges of corona, broadly ovoid, 0.3–0.5 mm long, and wide, light yellowish. Ovary half-inferior, free part hemispheric, 0.8–1.0 mm high, (2.0)2.2–2.4(2.6) mm wide, obscurely 6-angulate longitudinally, the interior imperfectly partitioned into 3 chambers by 3 septa; each chamber slightly open with narrow longitudinal slit at central axial portion of ovary, containing 4 narrowly ovoid ovules on basal placenta; style broadly conical, 0.5–0.6 mm tall; stigma obscurely 3-partite, the lobes obovate, glabrous.

Figure 5. *Peliosanthes kenhillii* sp. nov. Digital Vietnamese flora 0222: Khang Sinh Nguyen, NSK 760. Photos, correction and design by L. Averyanov.

Habitat and phenology

Shady primary and secondary forests of evergreen broad-leaved trees developed on alluvial soils of lowland valleys between karstic limestone hills at elevations about 150–200 m a.s.l. Terrestrial and occasionally lithophytic herb. Flowering in November–December. Locally common. Expected IUCN red list status: 'Vulnerable' (VU) (A1ac; B1f, 2a; C1; D1).

Distribution

Northern Vietnam (Ninh Binh province, Nho Quan district). Local endemic of northern Vietnam.

Similar species

This new species is quite unique in having leaves with a broad, elliptic blade and long petiole, very short peduncle,

star-like flowers with strongly revolute, spreading tepals, and a nearly flat-topped whitish corona with sparse radial purplish stripes. By these characters it is readily distinguishable from all other congeners.

Tupistra densiflora Aver., N. Tanaka & Nghiem sp. nov. (Fig. 6)

Type: Northern Vietnam, Bac Kan province, Cho Don district, Ban Thi municipality, Phia Khao village, around point 12°16′53.0″N, 105°31′20.2″E, secondary humid evergreen broad-leaved forest on rocky limestone along trail to old lead minerals mines at elevation about 850 m a.s.l., rare, 11 Dec 2014, Duc Trong Nghiem, sine n. (holotype: LE!). Plate: digital Vietnamese flora 0223/Duc Trong Nghiem, s.n. (Fig. 6).

Etymology
The specific epithet refers to the densely flowered spike.

Description
Lithophytic or occasionally terrestrial rosulate perennial herb. Rhizome suberect or ascending, simple or with a few branches, terete, stout, somewhat ligneous, yellowish–white, (5)10–15(20) cm long, (2.0)2.5–3.5(4.0) cm in diameter, covered with yellowish–brown to dark brown, partially disintegrated bracts that are 1–3 cm long and wide. Roots numerous, fleshy, cord-like, thick, 0.5–1.0 cm in diameter, densely covered with white to light dull yellowish root hairs in most part. Stem erect, short, (4)5–8(10) cm tall, covered with distichous, conduplicate leaf bases and partially decaying sheath leaves (cataphylls). Sheath leaves straight, ensiform, conduplicate, light green, (15)20–35(40) cm long, (1)2–4(5) cm wide (when flattened), soon becoming dry, rigid, papyraceous and dark brown to almost black, fugacious. Leaves basal, (5)6–8(10), erect to slightly arcuate, subsessile, equitant, indistinctly petiolate, narrowly oblanceolate, (1.0)1.4–1.8(2.0) m long, (5)6–10(12) cm wide, gradually tapering to rigid, canaliculate, petiole-like base, acute or acuminate at apex, rigid, leathery, uniformly green, glossy, with midvein strongly prominent abaxially. Peduncle arising from apical part of stem, axillary, erect, straight, becoming slightly thicker upward, irregularly angled, naked, fleshy, rigid, (5)6–10(12) cm long, (5)8–10(12) mm in diameter, white with dirty purple tint to dull dirty brownish–purple. Inflorescence a dense spadix-like spike of numerous flowers, (8)10–25(30) cm long, 1.8–2.2 cm in diameter; rachis several-angled longitudinally, fleshy, slightly raised around flower pits. Floral bracts 2 per flower, concave, fleshy, white with purple tint at the base, in fruit becoming dry, papyraceous, dull brownish; outer bract lying below flower, transversely rectangular, bail-shaped, during anthesis 3–4 mm long and 4.5–5.5 mm wide, three times shorter than perianth; inner bract (bracteole) lying lateral to flower, ovate, 2–3 mm long, 1.5–2.0 mm wide. Flowers many, sessile, campanulate, broadly open, (1.0)1.5–2.0 cm across; perianth (7)8–10(11) mm long from base to apex, 6-cleft distally, the proximal syntepalous part cup or bowl-shaped, white, fleshy, the distal segments ovate, concave, round and recurved at apex, light dull brownish–pink to olive–pink, (4.0)4.5–5.5(6.0) mm long, 3.5–4.5 mm wide. Stamens 6, opposite to perianth segments; filaments shortly conic, inserted at perianth segment 1.5–2.0 mm above its base, slightly incurved, 1 mm long, fleshy, white; anthers dorsifixed, broadly ellipsoid, 1.0–1.2 mm long and wide, light dull yellow. Pistil mushroom-shaped, usually slightly ascending. Ovary externally indistinct, obscurely 3-lobed longitudinally, 3-loculed, each locule with 2 narrowly ovoid ovules on axial placenta. Style columnar, 3–4(5) mm long, 2.0–2.5 mm in diameter, slightly broadened upward, white, slightly exceeding anthers in height. Stigma white to slightly yellowish, hemispheric, large, (6)7–8(10) mm in diameter, concealing proximal interior of flower, its surface papillulate, marginally 6-dentate, revolute, the segments triangular, 1.0–1.5 mm long. Fruit, berry-like, almost globular, irregularly prickly tuberculate, (2.0)2.5(3.0) cm in diameter, dark brownish–green to almost black, 3-locular, 1–3-seeded, indehiscent.

Habitat and phenology
Primary and secondary humid evergreen broad-leaved forests on eroded marble-like crystalline limestone at elevations about 850 m a.s.l. Obligate lithophyte in pockets of shady limestone cliffs. Flowering in November–January. Very rare. Expected IUCN red list status: 'Endangered' (EN) (A1ac, 2; B1a, 2a, bi, ii; C2ai, ii; D).

Distribution
Northern Vietnam (Bac Kan province, Cho Don district). Local endemic of northern Vietnam.

Similar species
Tupistra densiflora may have some affinity with *T. khangii* Aver., N. Tanaka & Vislobokov (Vislobokov et al. 2014), but differs markedly by the shorter pistil with a much larger stigma nearly entirely covering the proximal interior of the flower and not splitting into segments in later stages of anthesis. It also somewhat resembles *T. stoliczkana* Kurz and *T. veratrifolia* Kurz ex Dunn in having a mushroom- or umbrella-shaped pistil of which the stigma has 6 decurved deltoid segments at the margin (Tanaka 2010a). The stigmata of *T. densiflora* are, however, significantly larger than those (3.5–4.5 mm across) of the last two species. Further, the proximal syntepalous part of the perianth (i.e. perianth tube) of *T. densiflora* is cup- or bowl-shaped, while that of the last two is shortly terete. The new species is not at all identical with *T. grandistigma* F. T. Wang & S. Yun Liang known from Yunnan, China, from which it differs by several characters including the shape of fertile bracts, shape of perianth segments, shape and relative size (to perianth) of stigmata, and the color of perianth (Tanaka 2010a).

The large stigma nearly entirely conceals the proximal interior of the flower, and the denticulate margin strides over the stamens, largely enclosing the anthers. Pollinators are supposed to be very small to get in and out of the basal floral chamber through small slits at the orifice of the perianth tube. It seems probable that a close tie with a specific pollinator has promoted the evolution of this flower. It is therfore desirable to conduct pollination biological studies on this species.

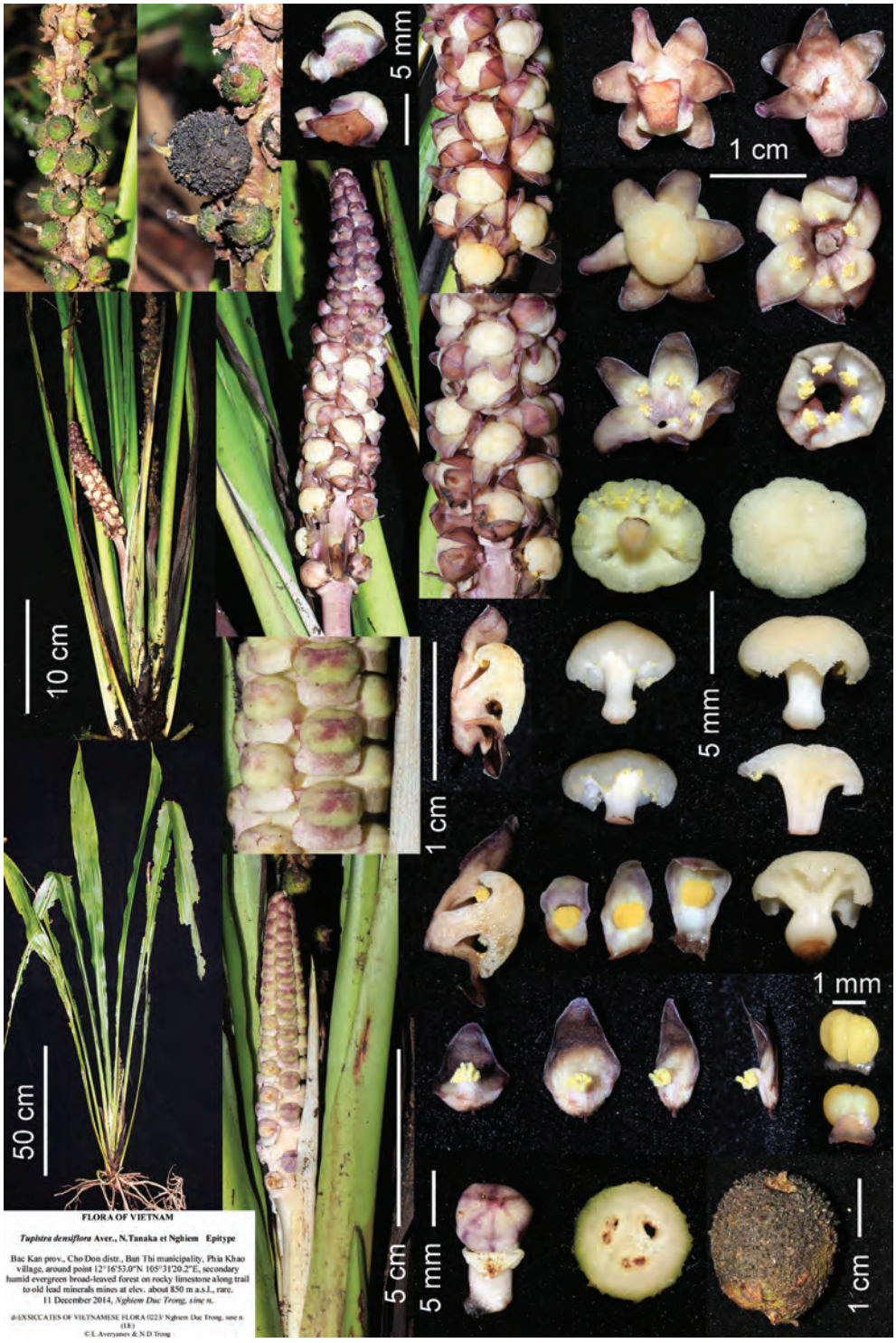

Figure 6. *Tupistra densiflora* sp. nov. Digital Vietnamese flora 0223: Duc Trong Nghiem, s.n. Photos of Duc Trong Nghiem, correction and design by L. Averyanov.

The new species appears to be a very rare plant, judging from our surveys made in 2014 in the 'Species and habitat conservation area' of the south Xuan Lac Reserve, which is officially protected and allied to the Na Hang Nature Reserve (Tuyen Quang province) and Ba Be National Park (Bac Kan province). The mature individuals of the new species we found therein were less than 10 in all. Judging from this sparsity, the new species may conform to endangered species (EN) defined under the IUCN red list criteria.

Some of the most common associates, including trees, shrubs, lianas and herbs, in the habitat of the new species were as follows; *Gouania javanica* Miq., *G. leptostachya* DC. (Rhamnaceae), *Gynostemma laxum* (Wall.) Cogn., *G. longipes* C. Y. Wu, *G. pentaphyllum* (Thunb.) Makino (Cucurbitaceae), *Impatiens bonii* Hook.f. (Balsaminaceae), *Lysimachia insignis* Hemsl. (Primulaceae), *Mahonia napaulensis* DC. (Berberidaceae), *Rubia cordifolia* L. (Rubiaceae), *Rohdea wattii* (C. B. Clarke) Yamashita & M. N. Tamura

(Asparagaceae), *Holcoglossum wangii* Christenson and *Vanilla* sp. (Orchidaceae).

Tupistra patula Aver., N. Tanaka & K. S. Nguyen sp. nov. (Fig. 3h–m, 7)

Type: Northern Vietnam, Ha Giang province, Bac Me district, Thuong Tan municipality, humid primary forest of evergreen broad-leaved trees on very steep slopes and along rocky ridge composed of solid crystalline highly eroded limestone at elevations 1200–1285 m a.s.l. around point 22°38′19.0″N, 105°17′06.5″E, not common, 16 Nov 2014, L. Averyanov, T. H. Nguyen, K. S. Nguyen, T. Maisak, L. Osinovetz, CPC 7492 (holotype: Herbarium of the Center for Plant Conservation, Hanoi!; isotype: LE!).

Etymology

The specific epithet refers to the outwardly expanded flowering stem.

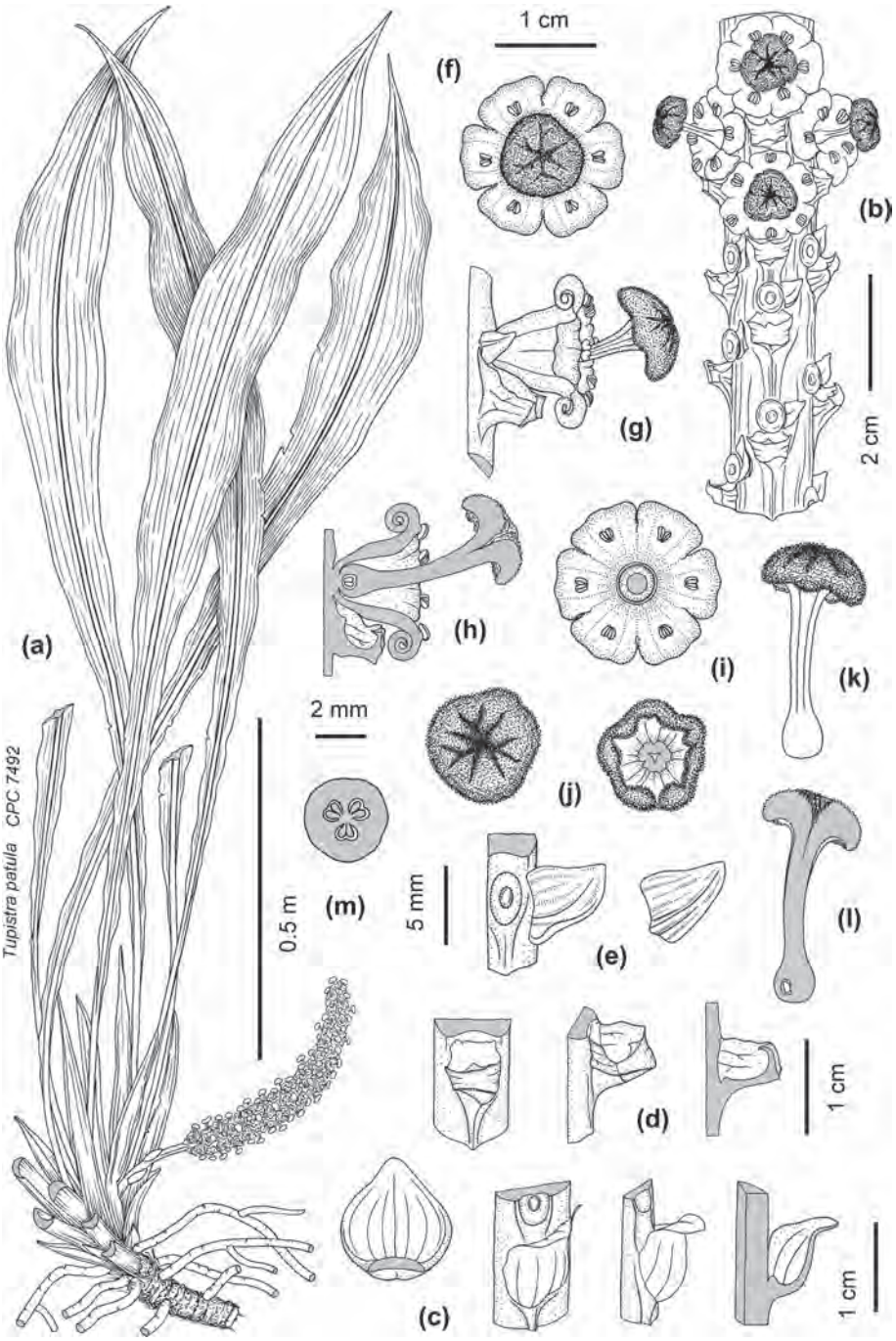

Figure 7. *Tupistra patula* sp. nov. (a) flowering plant, (b) portion of rachis with several flowers removed, (c) floral bracts from basal part of rachis, (d) floral bracts from middle and apical part of rachis, (e) bracteole, (f) flower in front view, (g) flower, side view, (h) sagittal section of flower, (i) front view of flower with pistil removed, (j) stigma in frontal view (left) and rear view (right), (k) pistil in side view, (l) longitudinal section of pistil, (m) transversal section of ovary. All drawn from the type L. Averyanov et al., CPC 7492 by L. Averyanov and T. Maisak.

Description

Terrestrial rosulate perennial herb. Rhizome ascending, simple or rarely with a few branches, terete, stout, somewhat ligneous, dark-brown, (20)25–35(40) cm long, (2.5)3.0–4.0(5.0) cm in diameter, covered with dark-brown disintegrated remnants of bracts 1–3 cm long and wide. Roots many, cord-like, thick, fleshy, 0.5–1.0 cm in diameter, densely covered with white to light dull yellowish root hairs in most part; stilt-like roots above ground greenish. Stem erect, short, (4)5–8(10) cm tall, covered with distichous, conduplicate leaf bases and light green sheath leaves (cataphylls). Sheath leaves straight, ensiform, conduplicate, (5)10–30(40) cm long, (1.0)1.5–6.0(8.0) cm wide (when flattened), rigid, persistent, light-green. Leaves (3)4–6(7), basal, equitant, erect to slightly arcuate, narrowly oblanceolate, gradually tapering to a rigid, canaliculate, petiole-like base, acute or acuminate at apex, (1.2)1.6–2.0(2.2) m long, (10)12–16(18) cm wide, rigid, leathery, uniformly dark green, glossy; midvein strongly prominent abaxially. Flowering stem sigmoidly ascending (S-shaped due to double curvature at peduncle and inflorescence). Peduncle arising from apical part of stem, axillary, excurved, light green, fleshy, rigid, shallowly grooved, (10)12–14(16) cm long, 1.0–1.4 cm in diameter, naked or with 1–2 whitish, narrowly ovate, sterile bracts that are 3–4 cm long. Inflorescence a spadix-like dense spike with numerous flowers, (22)25–35(40) cm long, 3–4 cm in diameter; rachis gradually curved upward, slightly angled longitudinally, fleshy, slightly raised around flower pits. Floral bracts 2 per flower, concave, fleshy, white to light greenish; outer bract lying below flower, ovoid (in basal portion of inflorescence) to transversely rectangular, bail-shaped, (4)5–10(12) mm long and wide, three time shorter than perianth; inner bract (bracteole) lying lateral to flower, obliquely triangular with antrorse apex, or broadly ovate, concave, usually keeled adaxially, (2.5)3.5–5.5(6.0) mm long and wide. Flowers many, sessile, broadly open. Perianth campanulate, (6.5)7.0–9.0(9.5) mm long from base to apex, (1.5)1.6–1.8(2.0) cm across, fleshy, entirely dull pale yellow, becoming black after anthesis, distally 6-cleft; proximal part syntepalous, obconically cup-shaped; distal segments ovate, (5)6–7(8) mm long, (5.5)6.0–7.0(7.5) mm wide, helically strongly recurved. Stamens 6, opposite to perianth segments; filaments shortly cylindric, 0.6–0.8 mm long, 1.0–1.2 mm in diameter, fleshy, inserted at the base of perianth segments; anthers dorsifixed, broadly ovoid, 1.5–1.8 mm long and wide, light dull yellow. Pistil mushroom-shaped, horizontal or slightly ascending. Ovary superior, externally rather indistinct, ovoid, (3.0)3.5–4.0(4.5) mm in diameter, 3-loculed, each locule with 2 narrowly ovoid, laterally flattened ovules on axial placenta. Style columnar, slightly broadened upward, often slightly ascending, much exceeding perianth, shallowly angled longitudinally, glabrous, (10)11–12(13) mm long, 2.0–2.5 mm in diameter. Stigma hemispheric, (8.5)9.0–10.0 (11.0) mm across, entire or obscurely 3-lobed, irregularly and subradially fissured centrally, papillulate, margins irregularly undulate or shallowly lobed, revolute.

Habitat and phenology

Primary and secondary humid evergreen broad-leaved forests on eroded marble-like crystalline limestone at elevations about 1200–1300 m a.s.l. Terrestrial herb in shady swampy location of very steep slope. Flowering in October–November. Not common. Expected IUCN red list status: 'Data Deficient' (DD).

Distribution

Northern Vietnam (Ha Giang province, Bac Me district). Local endemic to northern Vietnam.

Similar species

Tupistra patula appears to be allied to *T. khangii* Aver., N. Tanaka & Vislobokov (Vislobokov et al. 2014), but differs markedly by the sigmoid flowering stem bearing truncate fertile bracts (except proximal ones), dull dirty pale yellow perianth, and larger stigma not splitting into segments in the later stages of anthesis. It also differs from *T. hongheensis* G. W. Hu & H. Li (Hu et al. 2013) by the shorter ascending rhizome, distinctly sigmoid flowering stem, dirty yellowish perianth, and stamens located at the base of the perianth segment. The new species also resembles *T. grandistigma* F. T. Wang & S. Yun Liang (Liang 1978, Tanaka 2010a), but is distinguishable by the sigmoid flowering stem, dirty yellowish perianth, usually shorter and ovate perianth segments, obconic and distally more expanded (open) perianth tube, and by the shape of fertile bracts and stigmata.

A key to the species of *Tupistra* occurring in Indochina (Vietnam, Laos, Thailand) and its neighboring regions including south China

(Species indigenous to the Malay Peninsula and the Himalayan region are excluded, while *Tupistra squalida*, whose provenance is not precisely known, is included).

1. Flowering stem excurved with descending or nearly horizontal spike ……. 2
   – Flowering stem erect or sigmoidally assurgent ……. 3
2. Rhizome ascending; spike usually descending, 5.5–10 cm long …… *T. fungilliformis* (north Vietnam – our unpubl. data; south China)
   – Rhizome (erect or) creeping; spike nearly horizontal, 2.5–4.5 cm long ……..…… *T. pingbianensis* (south China, data based on Huang and Liu 1996)
3. Flowering stem sigmoidally assurgent …….. 4
   – Flowering stem erect (or suberect) ……... 5
4. Stigma 3-cleft to 3-sected with orbicular lobes, 4.0–5.5 mm across …… *T. squalida* (Provenance unknown)
   – Stigma irregularly shallowly lobed at margin, (8.5) 9.0–10.0(11.0) mm across …….. *T. patula* (north Vietnam)
5. Rhizome creeping, to 1 m long …….. …… *T. hongheensis* (south China)
   – Rhizome erect or ascending, usually to 40 cm long ……. 6
6. Stigma less than 2 mm across ……. 7
   – Stigma usually more than 2 mm across …… 8
7. Peduncle 4–6(8) cm long …… *T. breviscapa* (south Laos)
   – Peduncle (20)30–40(55) cm long ……. ……*T. theana* (central Vietnam)

8. Peduncle ca 60 cm long (in fruit) …….. *T. laotica* (central Laos)
– Peduncle usually less than 35 cm long …… 9
9. Style 2–4(5) mm long (ovary not included) …… 10
– Style 6–11 mm long (ovary not included) …… 11
10. Fertile outer bracts (located below flower) transversely rectangular with truncate apex; perianth cup- or bowl-shaped proximally; stigma (6)7–8(10) mm across …… *T. densiflora* (north Vietnam)
– Fertile outer bracts (located below flower) ovate, deltoid or oblong; only distal bracts subtruncate at apex; perianth shortly terete proximally; stigma 3.5–4.5 mm across …… *T. stoliczkana* (incl. *T. veratrifolia*) (northeast India, south Myanmar, central and southwest Thailand)
11. Stigma purple ……..…… *T. longispica* (south China)
– Stigma white ……. 12
12. Stigma markedly splitting into segments after peak anthesis …….. *T. khangii* (north Vietnam)
– Stigma not markedly splitting after peak anthesis …… 13
13. Perianth internally white, sometimes tinged purple; stigma thinly peltate, to 3.5(4.3) mm across …… …… *T. muricata* (incl. *T. albiflora*) (north Thailand, central Laos, south China)
– Perianth internally dark purple; stigma subcapitate or capitate, 4.5–11.0 mm across ……... …… *T. grandistigma* (south China)

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