Aster quanzhouensis (Asteraceae), a new riparian species from eastern China

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Abstract

Aster quanzhouensis sp. nov. (Asteraceae) from Fujian, eastern China, is described and illustrated. It grows on rocks in the riparian zone. Morphological, cytological and molecular investigations of A. quanzhouensis were carried out. The morphological data and phylogenetic analysis based on combined ITS, ETS and trnL-F dataset suggest that A. quanzhouensis is a separate species closely related to A. tonglingensis. The new species differs from the latter by the shorter stem length, leaf morphology, colour of phyllaries, number of ray florets, and achene shape. The cytological observation shows that the new species is diploid with a karyotype of 2n = 18.

Keywords

Asteraceae, Aster quanzhouensis, new species, taxonomy

Introduction

The genus Aster L. in its recent circumscription is restricted to Eurasia and comprises ~150 species, of which 123 occur in China (Chen et al. 2011), a main diversity centre of Aster (Li et al. 2012). Recently, ten new Aster species have been described, and almost all these species have a narrow distribution pattern known from only one or two populations in different regions of China (Zhang et al. 2015, 2019; Li et al. 2017, 2020; Xiao et al. 2019a, b, 2020, 2021; Xiong et al. 2019).
Recently, Guo-Jiao Yan, a young amateur naturalist and one of the authors of this paper, collected some unique samples from the riversides of the Min and Jin rivers, Quanzhou city, Fujian, eastern China. The morphological, cytological and phylogenetic data show that the specimens represent an undescribed species, which is reported herein.

**Materials and methods**

**Material collection**

Specimens of the new taxon were collected in Dehua and Yongchun counties (Fig. 1), Fujian, China. We collected leaf material and dried it with silica gel for molecular experiments. The voucher specimens were deposited at the Herbarium of Hunan Normal University (HNNU) and Jiangxi Agricultural University (JXAU).

**Morphological observations**

The description of the new species is based on living material, dry specimens and FAA-fixed materials. Twenty-one individuals were examined. The morphological comparison with *Aster tonglingensis* G.J.Zhang & T.G.Gao is based on the study of herbarium specimens, from PE, HNNU and JAXU. We compared the shape and size of the leaves, length of stems, phyllaries, number of florets, and achenes.

**Cytology**

Excised root tips from the cultivated plants of the new species were pretreated with 0.1% colchicine at 10 °C for 4 h, then fixed in Carnoy’s solution (95% ethanol and glacial acetic acid in 3:1 ratio) at 20 °C for 12 h. The root tips were then macerated in 1 M hydrochloric acid at 60 °C for 10 min, stained in Carbol fuchsin solution, washed in distilled water for 30 min and finally depigmented and squashed in 45% acetic acid (Li et al. 2011). Karyotype formulae were calculated based on measurements of mitotic metaphase chromosomes taken from photographs. The symbols used to describe the karyotypes followed Levan et al. (1964).

**Taxon sampling, DNA extraction, PCR reaction and sequencing**

Nuclear ribosomal DNA ITS and ETS sequences and plastid DNA *trnL-F* sequences of 66 species and varieties, representing major clades of the genus *Aster* and its relatives (Li et al. 2012, 2017, 2020; Zhang et al. 2015, 2019; Xiao et al. 2019a, b, 2020, 2021), were downloaded from GenBank (Appendix 1). Besides, eleven newly sequenced accessions are included from Dehua and Yongchun counties two individuals of *Aster quanzhouensis* (Appendix 1). The names of the taxa mentioned above follow Chen et al. (2011). *Grangea maderaspatana* (L.) Poir. and *Dichrocephala integrifolia* (L.f.) Kuntze were selected as outgroups following
Li et al. (2012). Voucher specimens of newly sequenced material were deposited in HNNU. Total DNA extraction, PCR and sequencing were carried out according to Li et al. (2012).

Phylogenetic analysis

Boundaries of the ITS, ETS and trnL-F regions were determined through comparison with previously published sequences (Li et al. 2012). DNA sequences were aligned initially using Clustal X1.83 (Jeanmougin et al. 1998), performed by MUSCLEv3.8.31 (Edgar 2004), and adjusted manually in PhyDE ver0.9971 (Müller et al. 2010). The optimal model of DNA substitutions was selected using the Akaike information criterion (Akaike 1973) as applied in jModelTest 2.1.4 (Darriba et al. 2012) prior to the maximum likelihood (ML) analyses and Bayesian inference (BI). The best fit models for ITS, ETS and trnL-F were GTR + G, GTR + I + G and TVM+I, respectively. Phylogenetic trees were constructed using maximum likelihood (ML) and Bayesian inference (BI). Maximum likelihood (ML) and Bayesian inference (BI) analyses were conducted using RAxML 7.2.6 and MrBayes 3.1.2 (Huelsenbeck and Ronquist 2001; Stamatakis 2006), respectively. For BI, four chains, each starting with a random tree, were run for 1,000,000 generations with trees sampled every 1000 generations. The average standard deviation of split frequencies (< 0.01) was used to assess the convergence of the two runs. After the first ca. 25% discarded as burn-in, the remaining trees were imported into PAUP* v.4.0b10 and a 50% majority-rule consensus tree was produced to obtain posterior probabilities (PP) of the clades. Before the datasets were combined, the incongruence length difference test (Farris et al. 1994) was performed on PAUP* v.4.0b10 (Swofford 2001).

Results

*Aster quanzhouensis* M.Tang, G.J.Yan & W.P.Li, sp. nov.
urn:lsid:ipni.org:names:77297480-1
Figs 1–3

**Type.** China, Fujian province, Quanzhou city, Dehua county, Nancheng town, alt. ca. 500 m, 25°34.20′N, 118°29.65′E, 5 Oct 2021, Guo-Jiao Yan, YGJ2110003 (Holo-type: HNNU!, isotypes: HNNU!, JXAU!) (Fig. 3).

**Additional collection seen.** China. Fujian province, Quanzhou city, Yongchun county, alt. ca. 500 m, 25°24′N, 118°21′E, 30 Nov 2021, Guo-Jiao Yan, YGJ21113001 (HNNU!).

**Diagnosis.** *Aster quanzhouensis* differs from *A. tonglingensis* by its stems only 21–30 (60) cm (vs. 70–100 cm) long, narrowly lanceolate (vs. lanceolate) rosulate leaves, purplish-red (vs. green) apices of the phyllaries, 9–20 (40) (vs. more than 30) capitula, 7–11 (vs. ca. 15) ray florets, 11–14 × ca. 2 mm (vs. 7–10 × ca. 2 mm) lamina, two- or three-ribbed (vs. 4-ribbed) achenes and flowering period (Sep to early Dec vs. Jul) (Figs 2, 3, Table 1).
Description. Perennial herb, 21–30 (60) cm high. Rhizomes thin, with adventitious roots, stolons absent. Stem solitary, erect, unbranched except for inflorescence, glabrous or puberulent in upper part. Leaves slightly leathery, narrowly lanceolate, apex acute, base gradually narrowing, subclasping, abaxially light green, adaxially dark green and glossy, 3-veined, midvein abaxially prominent; rosulate leaves 4–13 × 0.4–1.7 cm, margin serrate, petiole 3–11 cm long, both surfaces glabrous; lower cauline leaves persistent at anthesis or rarely withered, 3–10 × 0.3–0.8 cm, sessile or with obscure petioles, margin entire or serrate, abaxially glabrous, adaxially sparsely strigose; middle cauline leaves sessile or with obscure petiole, 4–7 × 0.3–0.4 cm, margin entire or serrate, abaxially glabrous, adaxially sparsely strigose; upper leaves sessile, margin entire. Capitula 9–20 (40) in a terminal corymbose cyme, peduncle puberulent. Involucre campanulate, 5–8 mm in diameter; phyllaries in 5–7 rows, imbricate, lanceolate,
Figure 2. Images of living plants of *Aster quanzhouensis* A habitat B habit C seedling D stem E rosetate leaves F top view of the capitulum G a disk floret (left) and a ray floret (right) H style branches of a disk floret I receptacle J fruits K dorsal view of a capitulum L phyllaries (from outer to inner, left to right).
Figure 3. Holotype of *Aster quanzhouensis* M.Tang, G.J.Yan & W.P.Li.
Aster quanzhouensis, a new riparian species (Asteraceae) from eastern China

the outer rows shorter than the inner ones, reflexed, densely pilose, with ciliate margin; outer phyllaries 3.2–6.2 × 1.1–2 mm; middle phyllaries 4.6–13 × 1.5–2.2 mm, with narrowly scarious margin, tip purplish-red; inner phyllaries 10.1–13.0 × 1.5–1.7 mm, with broadly scarious margin, tip purplish-red. Receptacles flat, alveolate. Ray florets 7–11, female, tube ca. 4 mm, glabrous, ligules whitish, lanceolate, 11–14 × ca. 2 mm, with four nerves, apex with two or three teeth. Disc florets (11) 18–24, hermaphrodite, yellow, tube puberulent, ca. 3 mm, thin but expanded at base, 5-lobed, lobes spreading to reflexed, narrowly triangular, unequal, 1.1–1.5 mm, glandular; anthers ca. 1.8 mm (excluding collar), apical appendage 0.35–0.45 mm long, narrowly lanceolate, anther collar ca. 0.4 mm long; style arm appendage lanceolate, ca. 2.5 mm, stigmatic lines 1.2–1.4 mm, equal to the sterile style tip appendages. Achenes 4.5–5.5 × 0.9–1.4 mm, narrowly oblong, strigose, eglandular, two- or three-ribbed. Pappus uniseriate, dirty white, 8–11 mm, nearly as long as disc corolla at anthesis.

**Phenology.** Flowering from September to early December and fruiting from October to December.

**Etymology.** The species is named after its type locality, Quanzhou city, Fujian province, China.

**Vernacular name.** quán zhōu zǐ wăn (Chinese pronunciation); 泉州紫菀 (Chinese name).

**Distribution and habitat.** Aster quanzhouensis is known from Dehua and Yongchun counties, Quanzhou city, Fujian province, China. The new species grows on rocks in riparian habitats at an altitude of ca. 500 m a.s.l.

**Conservation status.** Aster quanzhouensis seems to be a narrowly distributed species, currently known only in rocky areas along two streams (Jin river and Min river) in Quanzhou city, and each population with ca. 150 (total < 1000) individuals were found. The habitat of A. quanzhouensis is easily disturbed or damaged. Further fieldwork is needed to evaluate the exact distribution of the species, and it is possible that other populations could be found in similar habitats of the Jin and Min rivers. Therefore, we only temporarily assign the species to the category DD (Data Deficient) according to the International Union for Conservation of Nature (IUCN 2022).

**Table 1.** Comparison of Aster quanzhouensis and A. tonglingensis. The data of the latter species were taken from Zhang et al. (2019).

| Characters          | Aster quanzhouensis | A. tonglingensis |
|---------------------|---------------------|-----------------|
| Stem                | 21–30(60) cm, solitary | 70–100 cm, solitary or two to three |
| Basal leaves        | narrowly lanceolate, 4–13 × 0.4–1.7 cm | lanceolate, 4–18 × 0.8–2.5 cm |
| Capitula            | 9–20 (40) | More than 30 |
| Phyllaries          | 5–7-seriate, apex purplish-red | 5–7-seriate, apex green |
| Ray florets         | 7–11 | ca. 15 |
| Achenes             | 2–3-ribbed | 4-ribbed |
| Pappus              | 8–11 mm | ca. 7 mm |
| Flowering period    | Sep to early Dec | Jul |
Cytology

The somatic chromosomes of the new species at metaphase are illustrated in Fig. 4. The two populations have a same karyotype formula, \(2n = 18\), and Stebbins’ 1A-type (Stebbins 1971), but differs in ratio of long to short arm of chromosomes (the former is 1.02–1.55, while the latter 1.06–1.45), the chromosomes length (the former is 1.49–2.72, while the latter 1.71–2.77), and the AI value (the former is 0.54, while the latter 0.57).

![Figure 4. Micrographs of somatic metaphase chromosomes (A, C) and the karyotype (B, D) of Aster quanzhouensis from two different populations. (A, B Dehua county, Quanzhou, Fujian, China; C, D Yongchun county, Quanzhou, Fujian, China).](image)

Molecular phylogeny

The aligned lengths of ITS, ETS and trnL-F are 647 bp, 568 bp and 957 bp, respectively, yielding a concatenated alignment of 2172 bp. Character state changes were equally weighted and gaps were treated as missing data. ML and BI analyses produced similar topology and only the ML tree was presented in Fig. 5, with ML bootstrap (LP), and PP values for each clade. The phylogenetic results showed that the two samples of the new taxon were grouped together with strong support (PP = 1.00, LP = 100%) and are closely related to Aster tonglingensis with strong support (PP = 1.00, LP = 99%). According to these results, A. quanzhouensis is nested within the core Aster clade (PP = 1.00, LP = 100%) that is the redefined genus Aster in Eurasia (Li et al. 2012; Nesom 2020a, b).
Aster quanzhouensis, a new riparian species (Asteraceae) from eastern China

Figure 5. The phylogram of the maximum likelihood (ML) tree from the combined data (ITS, ETS and trnL-F), showing the phylogenetic position of Aster quanzhouensis. Bootstrap support values (1,000 replicates) for maximum parsimony (MP ≥ 50%, left) and Bayesian posterior probabilities (PP ≥ 0.90, right) are provided above the branches. The samples of Aster quanzhouensis are shown in bold.
Discussion

Morphological observations showed that *Aster quanzhouensis* has a perennial life form, lanceolate stigmatic appendage of disc florets, compressed fruits with two- or three-ribbed and uniseriate pappus (Figs 2, 3). All *Aster* species share these characters. In the phylogenetic tree (Fig. 5), *A. quanzhouensis* is deeply nested within the core *Aster* (Li et al. 2012). Morphological and phylogenetic analyses support that *A. quanzhouensis* is sister to *A. tonglingensis*. As mentioned above, the two species can be easily distinguished from each other (Figs 2, 3, Table 1).

Narrowly lanceolate leaves are rare in Eurasian *Aster* and can be found only in a few species, such as *A. huangpingensis* W.P.Li & Z.Li, *A. dolichophyllus* Y.Ling and *A. tonglingensis*. Our phylogenetic analyses (Fig. 5) revealed that the species with narrowly lanceolate leaves are nested in unrelated lineages of the genus *Aster* and are probably the result of convergent evolution. It is noteworthy to mention that they are all distributed in the same habitats confined to riparian rocks (Chen et al. 2011; Zhang et al. 2019; Li et al. 2020). The same leaf character may be related to their habitat. When the water level rises in some periods during the course of the year, these species were submerged and their narrowly lanceolate leaves may represent adaptation to water flowing in the rivers or streams.

Karyotype variation usually accompanies evolutionary divergence, a general phenomenon observed in plants and animals (Rieseberg 2001). Two populations of the *Aster quanzhouensis* were found with the same karyotype formula and Stebbins’ type, with only slight differences in the karyotypic indexes, which might mean that *A. quanzhouensis* is a young species.

*Aster quanzhouensis* is known only from two populations (Dehua and Yongchun counties) restricted to Quanzhou, Fujian, China, while *A. tonglingensis* is restricted to Mt. Tongling Natural Reserve, Wencheng county, Zhejiang (Zhang et al. 2019). These two species occupy the same ecological conditions, but are geographically separated by a distance of 400 km.

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Aster quanzhouensis, a new riparian species (Asteraceae) from eastern China

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Appendix I

Table A1. Taxa sampled, vouchers and GenBank accessions. The newly sequenced samples are highlighted in bold.

| Accessions                   | Voucher information or references                     | Accession number |
|------------------------------|-------------------------------------------------------|------------------|
| Aster quanzhouensis M.Tang,  | Guo-Jiao Yan, YGJ2110001, Dehuan county, Fujian, China | ON055150 ON055152 ON055154 |
| G.J.Yan & W.P.Li 1           |                                                        |                  |
| Aster quanzhouensis M.Tang,  | Guo-Jiao Yan, YGJ2112001, Yongchun county, Fujian, China | ON055151 ON055153 ON055155 |
| G.J.Yan & W.P.Li 2           |                                                        |                  |
| A. sanqingshanica J.W.Xiao & | Xiao et al. (2021)                                      | MW419955 MW419952 ON055156 |
| W.P.Li                        |                                                        |                  |
| A. marchandii H.Lév.          | Xiao et al. (2021)                                      | MW419957 MW419954 ON055157 |
Aster quanzhouensis, a new riparian species (Asteraceae) from eastern China

| Accessions | Voucher information or references | Accession number |
|------------|-----------------------------------|------------------|
| A. dianchuanensis | Xiao et al. (2019b) | MK693180 MK693190 MK693202 |
| A. brevicaulis | Xiao et al. (2019a) | MH638204 MH638209 MH638218 |
| A. tongolensis Franch. | Xiao et al. (2019b) | MK693183 MK693193 JN543834 |
| A. ageratoides var. lasiocladus (Hayata) Hand.-Mazz. | Li et al. (2012) | JN543781 JN543782 JN543783 |
| A. dianchuanensis | Li et al. (2017) | KY428860 KY428852 MH638219 |
| A. mangshanensis Y.Ling | Xiao et al. (2019a) | JN543760 JN543761 JN543762 |
| A. oregophilus Franch. | Li et al. (2012) | JN543826 JN543827 JN543828 |
| A. dolichopodus Y.Ling | Li et al. (2012) | JN543775 JN543776 JN543777 |
| A. vestitus Franch. | Li et al. (2012) | JN543769 JN543770 JN543771 |
| A. souliei Franch. | Li et al. (2012) | JN543835 JN543836 JN543837 |
| A. megalanthus Y.Ling | Xiao et al. (2019b) | MK693187 MK693197 MK693207 |
| A. smithianus Hand.-Mazz. | Xiao et al. (2020) | MT731676 MT731599 ON055158 |
| A. heterolepis Hand.-Mazz. | Li et al. (2012) | JN543715 JN543716 JN543717 |
| A. altaicus var. millefolius (Vaniot) Hand.-Mazz. | Li et al. (2012) | JN543784 JN543785 JN543786 |
| A. crenatifolius Hand.-Mazz. | Li et al. (2012) | JN543712 JN543713 JN543714 |
| A. fanjingshanicus Y.L.Chen & D.J.Liu | Li et al. (2012) | JN543718 JN543719 JN543720 |
| A. pekinensis (Hance) F.H.Chen | Li et al. (2012) | JN543711 JN543712 JN543713 |
| A. shimadae (Kitamura) Nemoto | Xiao et al. (2020) | MT731676 MT731599 ON055158 |
| A. indicus L. | Li et al. (2012) | JN543715 JN543716 JN543717 |
| A. incisus Fisch. | Li et al. (2012) | JN543721 JN543722 JN543723 |
| A. chuanshanensis W.P.Li | Li et al. (2012) | JN543784 JN543785 JN543786 |
| A. homochlamydeus Hand.-Mazz. | Li et al. (2012) | JN543760 JN543761 JN543762 |
| A. handelii Onno | Li et al. (2012) | JN543745 JN543746 JN543747 |
| A. maackii Regel | Li et al. (2012) | JN543814 JN543815 JN543816 |
| A. verticillatus (Reinw.) Brouillet | Li et al. (2012) | JN543706 JN543707 JN543708 |
| A. tianmenshanensis | Zhang et al. (2015) | KP313677 KP313690 KP313703 |
| A. tianmenshanensis G.J.Zhang & T.G.Gao | Zhang et al. (2019) | MH807119 MH807124 MH807126 |
| A. procerus Hemsl. | Zhang et al. (2015) | KP313683 KP313696 KP313709 |
| A. amellus Grierson | Li et al. (2012) | JN543742 JN543743 JN543744 |
| A. alpinus L. | Li et al. (2012) | JN543820 JN543821 JN543822 |
| A. falcifolius Hand.-Mazz. | Li et al. (2012) | JN543802 JN543803 JN543804 |
| A. poliothamnus Diels | Li et al. (2012) | JN543763 JN543764 JN543765 |
| A. scaber Thunb. | Li et al. (2012) | JN315934 JN315958 JN315910 |
| A. huangpingensis | Zhang et al. (2020) | ON055160 |
| A. dolichophyllus Y.Ling | Zhang et al. (2019); Li et al. (2020) | MH740707 MH740707 ON055160 |
| A. hersileoides C.K.Schneid. | Li et al. (2012) | JN543787 JN543788 JN543789 |
| A. nitidus C.C.Chang | Li et al. (2012) | JN543790 JN543791 JN543792 |
| A. salvinensis Onno | Zhang et al. (2015) | KP313689 KP313702 KP313715 |
| A. diplostephioideae (DC.) Benth. ex C.B.Clarke | Li et al. (2012) | JN543847 JN543848 JN543849 |
| A. setchuenensis Franch. | Li et al. (2012) | JN543850 JN543851 JN543852 |
| A. yunnanensis Franch. | Li et al. (2012) | JN543853 JN543854 JN543855 |
| A. brachytrichus Franch. | Li et al. (2012) | JN543833 JN543835 JN543840 |
| A. asteroides (DC.) Kuntze | Li et al. (2012) | JN543841 JN543842 JN543843 |
| A. flaccidus Bunge | Li et al. (2012) | JN543844 JN543845 JN543846 |
| A. batangensis Bureau & Franch. | Li et al. (2012) | JN543859 JN543860 JN543861 |
| Accessions | Voucher information or references | Accession number |
|------------|----------------------------------|------------------|
| *A. panduratus* Nees ex Walp. | Li et al. (2012) | JN543757 JN543758 JN543759 |
| *A. auriculatus* Franch. | Li et al. (2012) | JN543754 JN543755 JN543756 |
| *A. pycnophyllus* Franchet ex W.W.Sm. | Li et al. (2012) | JN543799 JN543800 JN543801 |
| *A. longiperiolutus* C.C.Chang | Li et al. (2012) | JN315936 JN315960 JN315912 |
| *A. lavandulifolius* Hand.-Mazz. | Li et al. (2012) | JN543796 JN543797 JN543798 |
| *A. argyropholis* Hand.-Mazz. | Li et al. (2012) | JN543793 JN543794 JN543795 |
| *A. albescens* (DC.) Wall. ex Hand.-Mazz. var. albescens | Li et al. (2012) | JN543862 JN543863 JN543864 |
| *Sheareria nana* S.Moore | Li et al. (2012) | JN543703 JN543704 JN543705 |
| *Arctogeran gramineum* (L.) DC. | Li et al. (2012) | JN315928 JN315952 JN315904 |
| *Asterothamnus fraticosus* (C.Winkl.) Novopokr. | Li et al. (2012) | JN315929 JN315953 JN315905 |
| *A. centraliasiaticus* Novopokr. | Li et al. (2012) | JN315930 JN315954 JN315906 |
| *Callistephus chinensis* (L.) Nees | Li et al. (2012) | JN315931 JN315955 JN315907 |
| *Myriactis wightii* DC. | Li et al. (2012) | JN315922 JN315946 JN315898 |
| *M. nepalensis* Less. | Li et al. (2012) | JN315921 JN315945 JN315897 |
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| *Turczaninovia fastigiata* (Fisch.) DC | Li et al. (2012) | JN543739 JN543740 JN543741 |
| *Grangea maderaspatana* (L.f.) Kuntze | Li et al. (2012) | JN315920 JN315944 JN315896 |
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