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SYSTEMATICS

Classifier modeling and numerical taxonomy of *Actinidia* (Actinidiaceae) in Taiwan

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ABSTRACT. Although kiwifruit (*Actinidia*) is popular worldwide, its complex morphology has resulted in long-standing confusion regarding its nomenclature, classification, and identification. In an attempt to resolve this issue, we conducted a phylogenetic analysis on 72 wild *Actinidia* accessions in Taiwan. We used 60 morphological characters as taxonomic traits to construct a seriated heat map that revealed *A. callosa* var. *ephippioidea* and *A. rufa* (sensu Flora of Taiwan, 2nd Edition) as introgressive hybrids between *A. chinensis* var. *setosa* and *A. callosa* (sensu Flora of Taiwan, 2nd Edition), as well as five significant groups of *Actinida* in Taiwan. Based on these results, we coded the indicator response matrix for the logistic regression models as dichotomizers and used a Bayesian discriminant model as a polychotomizer. After classifier modeling, the two classifiers were combined to identify *Actinidia* specimens in domestic and international herbaria. As a result, a taxonomic revision was made: *A. callosa* var. *callosa* and *A. callosa* var. *ephippioidea* were revised as *A. rufa*; *A. rubricaulis* was revised as *A. callosa* var. *discolor*; *A. chinensis* var. *setosa* was elevated to *A. setosa*; and *A. tetramera* was a misidentification of *A. arguta*. Of these, only *A. setosa* is endemic to Taiwan.

Keywords: *Actinidia*; Bayesian discriminant analysis; Flora of Taiwan; Heat map; Logistic regression classifier; Introgressive hybridization; Phylogenetic analysis.

INTRODUCTION

Kiwifruit, of the genus *Actinidia*, also known as Chinese gooseberry or *mihoutao* (in Chinese), enjoys worldwide popularity. Wild *Actinidia* is distributed throughout East and Southeast Asia from Siberia to Sumatra. Classical Chinese texts such as the *Book of Odes* (BC. 1046-637), *Bencao Gangmu* (1596), and *Zhiwu Mingshi Tukao-Changbian* (1848), mentioned the genus and its primary uses as herbal medicine or edible fresh fruits (Warrington and Weston, 1990).

As Ferguson (1984) summarized, the first record of *Actinidia* is dated 1821, when Western botanist Wallich collected it in Nepal, assigning it number 6,634 in a catalog bearing his name. In 1836 Lindley named the genus *Actinidia* (Greek *aktis*, a ray) based on its stylar arrangement and described the first species, *A. callosa*. After several years, additional species and varieties were discovered and published, including *A. chinensis,* published by Planchon in 1847, and *A. eriantha* and *A. strigosa* published by Bentham in 1860. Early classification of the genus, however, was extremely confusing; many *Actinidia* species were initially placed in different genera. *Actinidia latifolia* was first placed in *Heptaca* (a doubtful genus in Tiliaceae) by Bentham in 1849, then in *Kadsura* (Schisandraceae) by Miquel in 1861. *Actinidia rufa, A. arguta,* and *A. polygama* were first placed in *Trochostigma* in 1843, then transferred to *Actinidia* several years later. *Actinidia kolomikta* was variously placed in *Prunus*, *Kalomikta*, and *Trochostigma* before finally being identified as *Actinidia* by Maximowicz in 1859.

Dunn first revised the genus *Actinidia* in 1911, establishing two sections, *Leiocarpae* and *Maculatae*, and recognizing 24 species and almost 40 varieties or forms worldwide. Li (1952) carried out the second revision of *Actinidia*, establishing the sections *Stellatae* and *Strigosae*, and describing 36 species and over 50 varieties or forms. Since then, *A. deliciosa* has been domesticated in New Zealand and named "kiwifruit," after an endemic wingless bird there. An increasing number of botanists and horticulturists have since studied the physiology, biochemistry, cytology, biology, etc. of *Actinidia,* and kiwifruit's popularity has grown (Hsieh et al., 2004). In 1984, Liang completed a revision of Chinese *Actinidia*, recognizing over 50 species, about the same number of varieties, and more than a dozen

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forms. Numerous cross-disciplinary studies indicated that the classification and placement of *Actinidia* remains confused, most likely due to its morphological complexity (Warrington and Weston, 1990). Li et al. (2007) recently revised the genus in China and Taiwan, describing 52 species, 44 of which are endemic.

The first preliminary report of *Actinidia* (*A. callosa* and *A. championii*) in Taiwan was published by Augustine Henry in 1896. Several years later, Dunn (1911) recorded a Taiwanese variety, *A. callosa* var. *formosana,* which was said to be originally published in *Bulletin de la Société Botanique de France* 52(4): 20 by Finet and Gagnepain in 1905 (-1907). Hayata (1914) also recorded this taxon but treated it as *A. championii*. In 1919, Hayata described three new species in Taiwan, i.e., *A. remoganensis*, *A. rankanensis*, and *A. arisanensis,* and elevated *A. callosa* var. *formosana* to species rank, designating the type with a Latin diagnosis. The following year, he described another new species, *A. gnaphalocarpa*, which he had previously placed with *A. championii.* In 1936, Kanehira first recorded *A. chinensis* in Taiwan, which Li (1952) considered as a new variety, *A. chinensis* var. *setosa*, based on distinguishable features in leaf shape and hair types. For the same reason, Liang and Ferguson (1985) further elevated it to species rank, but other botanists continued to treat it as a variety of *A. chinensis* (Nee and Tsay, 1992; Peng and Lu, 1996; Li et al., 2007). Chou et al. (2008) in their paper on the characterization of the physicochemical and antioxidant properties of Taiwanese kiwifruit, chosed specific rank, *A. setosa,* as the scientific name. In 1984, Liang recorded four species and a new variety, *A. callosa* var. *discolor*, in Taiwan. Peng and Lu (1996) described seven species and one variety of *Actinidia* in the Flora of Taiwan, 2nd ed. (abbreviated as 'FOT2' below), four species and the variety being new records. Li et al. (2007), in their treatment of Actinidiaceae for Flora of China, recorded five species and one variety in Taiwan, excluding previous records of *A. tetramera*, *A. callosa* var. *ephippioidea*, and *A. rubricaulis.*

The examples above demonstrate the controversy in the classification of *Actinidia*. Although recent molecular studies have helped resolve phylogenetic and identification problems concerning *Actinidia* (Li et al., 2002; Zhao et al., 2007), they have not helped much in resolving *Actinidia's* classification and nomenclature problems. In 1989, Tang and Xiang first tried to use statistical methods to resolve the classification of the *Clematoclethra* complex (Actinidiaceae) in China and pointed out that numerical taxonomy and statistics were effective ways to resolve classification issues of plant taxa, especially those with complex morphological characters. Xu et al. (1998) employed 11 leaf characters of *A. chinensis* cv. Tong-Shan no. 5 in conducting discriminant and cluster analyses to identify male and female plants. Discriminant analysis yielded a high rate of sexual identification of cultivars and cluster analysis implied that it was difficult to distinguish female from male plants by leaf characters. He et al. (2000a, b) selected micromorphological characters of foliar trichomes and performed quantitative taxonomic analyses to study the classification and phylogenetic relationships of 27 *Actinidia* species and two varieties in China. The results indicated that genus *Actinidia* is a monophyletic group. Phylogenetic analysis of 22 morphological characters revealed two monophyletic groups within *Actinidia* in China (Li et al., 2000). Yang (2001) used 19 fruit traits from 12 taxa of *Actinidia* in China in a Q and R-type cluster analyses. The results showed that many traits of *Actinidia* are closely related. In 2006, Guo and Zhang first tried to use dielectric properties of kiwifruit and a back propagation network of an artificial neural network to clear up the classification of two *A. deliciosa* cultivars, 'Hayward' and 'Qinmei', which are hardly distinguishable from each other. The study only used 20 samples of each variety and got recognition rates of 100% on training samples and up to 90% on test samples. Furthermore, Cuong et al. (2007) employed a principal component analysis and cluster analysis to resolve the nomenclature of the Actinidiaceae in Vietnam, and produced a taxonomic revision. Subsequently, Chen et al. (2008) selected 10 characters of the fruits and leaves of 11 *Actinidia* species to carry out a cluster analysis. The results implied that morphological traits of *Actinidia* are important for phylogenetic studies.

Previous research shows that both statistical methods and morphological characters are crucial to the taxonomic study of *Actinidia*. Thus far, all numerical taxonomic work on *Actinidia* has been on the native species of China and Vietnam. The purpose of this study is to use numerical taxonomy to first resolve *Actinidia's* classification and nomenclature problems in Taiwan, then complete a taxonomic revision of the genus.

MATERIALS AND METHODS

This study was divided into two stages, as follows:

1. Investigation of *Actinidia* field populations and numerical classification

This stage refers to previous taxonomic studies of *Actinidia,* the field observations of the first author, and 60 selected botanical characters as investigated traits (Table 1), 34 of these traits being qualitative and 26, quantitative. A total of 72 wild *Actinidia* accessions were surveyed throughout Taiwan from 1999 to 2006, each of these comprises at least one mature male and female plant. All quantitative traits were measured in 100 samples of each accession, and average values to the second decimal place were considered representative of the operation values of each accession. All *Actinidia* accessions were identified according to FOT2; then coded, using the first two syllables of the *Actinidia* specific epithet as acronyms, followed by serial numbers. All species in the FOT2 but *A. tetramera* were represented in the 72 investigated accessions. These consisted of *A. callosa* var. *callosa* (coded Callo-01-19), *A. callosa* var. *ephippioidea* (one accession was coded Callo.

Table 1. List of 60 taxonomic characters and character states of *Actinidia* used in this study.

Character code	Character	Character states (code) for qualitative characters or unit for quantitative characters
X1	Average length of leaf blade	cm
X2	Average width of leaf blade	cm
X3	Length/width index of leaf blade	cm/cm
X4	Symmetry of leaf blade base	asymmetrical (0); symmetrical (1)
X5	No. of pairs of secondary veins	number of pairs
X6	Deciduousness	evergreen (0); semi-deciduous (1); deciduous (2)
X7	Maculate of leaf blade	absent (0); present (1)
X8	Dorsal color of leaves	green (0); yellowish-green (1); pale-green (2)
X9	Degree of leaf upper-surface vestiture	hairless (0); sparsely haired (1); densely haired (2); very densely haired (3)
X10	Under-surface vestiture features	hairless (0); pubescent (1); villous (2); strigose (3); hispid (4); stellate (5)
X11	Degree of leaf under-surface vestiture	hairless (0); sparsely haired (1); densely haired (2); very densely haired (3)
X12	Length of leaf under-surface vestiture	hairless (0); short (1); intermediate (2); long (3)
X13	Leaf domatia	absent (0); present (1)
X14	Leaf blade texture	membranous (0); mesophytic (1); coriaceous (2); chartaceous (3); cartilaginous (4)
X15	Leaf blade margin	entire with sparse serrate (0); dentate and serrate (1); serrate (2); spinose (3); dentate (4); doubly serrate (5); spinose and dentate (6); spinose and serrate (7)
X16	Leaf blade apex	caudate (0); acuminate (1); acute (2); obtuse (3); truncated (4); emarginated (5)
X17	Leaf blade base	attenuate (0); cuneate (1); narrowly cuneate (2); obtuse (3); cordate (4); obliquely cordate (5)
X18	Petiole length	cm
X19	Petiole thick	cm
X20	Degree of petiole vestiture	hairless (0); sparsely haired (1); densely haired (2); very densely haired (3)
X21	Length of petiole surface vestiture	hairless (0); short (1); intermediate (2); long (3)
X22	Petiole vestiture features	hairless (0); pubescent (1); villous (2); strigose (3); hispid (4); stellate (5)
X23	Petiole color	green (0); yellowish-green (1); yellowish-red (2); light-red (3)
X24	Pith type of 1-year-old branch	solid (0); white lamellate (1); brown lamellate (2)
X25	Degree of young shoot vestiture	hairless (0); sparsely haired (1); densely haired (2); very densely haired (3)
X26	Young shoot vestiture features	hairless (0); pubescent (1); villous (2); strigose (3); hispid (4); stellate (5)
X27	Degree of 1-year-old branch vestiture	hairless (0); sparsely haired (1); densely haired (2); very densely haired (3)
X28	Length of 1-year-old branch vestiture	hairless (0); short (1); intermediate (2); long (3)
X29	One-year old branch vestiture features	hairless (0); pubescent (1); villous (2); strigose (3); hispid (4); stellate (5)
X30	No. of petals of staminate flower	number of petals
X31	Petal length of staminate flower	cm
X32	Petal width of staminate flower	cm
X33	Petal color of staminate flower	white (0); light-red (1); yellow (2)
X34	Sepal length of staminate flower	cm
X35	Sepal width of staminate flower	cm
X36	Sepal length/width index of staminate flower	cm/cm
X37	No. of sepals of staminate flower	number of sepals
X38	Filament length of staminate flower	cm

Table 1. (Continuation)

Character code	Character	Character states (code) for qualitative characters or unit for quantitative characters
X39	Anther color of staminate flower	purplish-black (0); yellow (1)
X40	No. of petals of pistillate flower	number of petals
X41	Petal length of pistillate flower	cm
X42	Petal width of pistillate flower	cm
X43	Petal length/width index of pistillate flower	cm/cm
X44	Petal color of pistillate flower	white (0); light-red (1); yellow (2)
X45	Sepal length of pistillate flower	cm
X46	Sepal width of pistillate flower	cm
X47	No. of sepals of pistillate flower	number of sepals
X48	No. of styles of pistillate flower	number of styles
X49	Ovary length of pistillate flower	cm
X50	Anther color of pistillate flower	purplish-black (0); yellow (1)
X51	Fruit length	cm
X52	Fruit width	cm
X53	Length/width index of fruit	cm/cm
X54	Fruit color	green (0); greenish-brown (1); brownish-yellow (2)
X55	Degree of fruit vestiture	hairless (0); sparsely haired (1); densely haired (2); very densely haired (3)
X56	Length of fruit vestiture	hairless (0); short (1); intermediate (2); long (3)
X57	Fruit vestiture features	hairless (0); pubescent (1); villous (2); strigose (3); hispid (4); stellate (5)
X58	Fruit apex	obtuse (0); round (1)
X59	Fruit spot	absent (0); with minor spots (1); with obvious spots (2)
X60	Persistent calyx on fruit	absent (0); reflexed (1); reflexed and unreflexed (2); unreflexed (3)

ephip-01), *A. latifolia* (coded Lati-01-14), *A. rufa* (coded Rufa-01-03), *A. arguta* (coded Argu-01-10), *A. chinensis* var. *setosa* (coded Seto-01-12), and *A. rubricaulis* (coded Rubri-01-13), for a total of six species and one variety of *Actinidia* in Taiwan.

An *Actinidia* accession was taken as an operational taxonomic unit (OTU). The survey locations of *Actinidia* accessions are shown in Figure 1, excluding some that are endangered. Subsequently, all of the OTU data were filed in R language (Ihaka and Gentleman, 1996), measurements of similarity used Gower's similarity coefficient (Gower, 1971). R language was employed to analyze phylogenetic relationships among all *Actinidia* accessions (Paradis, 2006; Wiens, 2000). In order to understand the gradient relationships of all accessions in this study, we employed a simulated annealing algorithm and R language to create a Q-Q-type seriated heat map to elucidate all groups of *Actinidia* species. We then combined the results with the phylogenetic and gradient relationships to clarify the classification of *Actinidia* in Taiwan (Claude, 2008).

2. Specimen identification and discriminant analysis

Based on the results of the previous stage, the indicator response matrix was coded and combined with the character variables of previous OTUs as training data to conduct model variable selection and classifier modeling. All data computing and analysis at this stage were programmed in R language. We selected logistic regression models as dichotomizers and a Bayesian discriminant model as a polychotomizer to be the classifiers of *Actinidia* in Taiwan. In the dichotomizers, the dependent variable of the logistic regression was designated to have a binomial distribution and employed the forward selection of a greedy algorithm and a stepwise regression for variable selection. We then used Akaike's information criterion to select the best variable combinations of the classifier regression models for each *Actinidia* species. In the polychotomizer, we took the Bayesian discriminant model as a multi-class classifier, then used a non-subjective prior for Bayesian discriminant modeling and variable selection until the iterations reached a 100% recognition rate for each taxa of *Actinidia* (cf. Albert, 2009; Hastie et al., 2001). Consequently, the dichotomizers and polychotomizer were combined to identify *Actinidia* specimens or images of specimens in the herbaria. Based on the results of the discriminant analysis, the correct scientific names of all specimens in this study were confirmed, and we completed a taxonomic revision of *Actinidia* in Taiwan.

RESULTS

Classification of *Actinidia* accessions in Taiwan

Figure 2 shows the phylogenetic relationships between *Actinidia* accessions in this study. From the phylogenetic tree, *A. chinensis* var. *setosa* and *A. rufa* in the FOT2 were combined to form a separate branch. Although all phylogenetic relationships between *A. chinensis* var. *setosa* accessions were very consistent, those between accessions of *A. rufa* were highly variable. *Actinidia arguta*, *A. latifolia*, *A. callosa* var. *calloa*, *A. callosa* var. *ephippioidea*, and *A. rubricaulis* formed another highly diversed branch; the branch with the highest diversity was found between *A. callosa* accessions, and the most consistent relationships were between accessions of *A. arguta*. On all branches, *A. callosa* var. *callosa* and *A. callosa* var. *ephippioidea* showed the closest phylogenetic relationship, followed by *A. chinensis* var. *setosa* and *A. rufa*. The remaining species, *A. latifolia*, *A. arguta,* and *A. rubricaulis*, were located on more independent branches. Furthermore, there were no significant phylogenetic correlations between *Actinidia* accessions and geographic distribution.

Figure 3 shows the Q-Q type seriated heat map of *Actinidia* accessions, where 72 accessions were divided into 5 observable groups. On the map, accessions of *A. rufa* and *A. callosa* var. *ephippioidea* were between accessions of *A. callosa* var. *callosa* and *A. chinensis* var. *setosa*; thus creating a slightly fuzzy boundary for the *A. callosa* var. *callosa* group. During our investigations *A. rufa* and *A. callosa* var. *ephippioidea* were found only in the areas where *A. chinensis* var. *setosa* and *A. callosa* var. *callosa* accessions overlapped. Comparing all characters of the four taxa, we found that most characters of *A. callosa* var. *ephippioidea* and *A. rufa* were intermediate between those of *A. chinensis* var. *setosa* and *A. callosa* var. *callosa,* creating a series gradient phenomenon. However, *A. rufa* has some traits that also belong to *A. chinensis* var. *setosa,* so it was combined into a separate branch with *A. chinensis* var. *setosa* on the phylogenetic tree. In contrast, in terms of overall similarity, *A. rufa* and *A. callosa* var. *ephippioidea* were closer to *A. callosa* var. *callosa*, not *A. chinensis* var. *setosa*, which affected the boundary of the *A. callosa* var. *callosa* group on the seriated heat map. A comparison of the characters, wild habitats, population locations, previous studies (cf. Mallet, 2007; Peng and Ku, 2009; Suezawa, 1989) and the results of the seriated heat map of the aforementioned four taxa suggests that *A. rufa* and *A. callosa* var. *ephippioidea* represent natural hybrids between *A. chinensis* var. *setosa* and *A. callosa* var. *callosa*, which show a one-way introgression hybridization trend toward *A. callosa* var. *callosa* (cf. Wiens, 2000).

Natural hybrids led to the incongruency between the phylogenetic tree and seriated heat map. *Actinidia callosa* var. *callosa* was closer to *A. rubricaulis* on the phylogenetic tree, but was next to *A. chinensis* var. *setosa* on the heat map because of hybridization between *Actinidia callosa* var. *callosa* and *A. chinensis* var. *setosa*. This also led

Figure 1. Distribution map of wild *Actinidia* accessions in this study. Some endangered accessions are not shown on this map. The code of accession names are based on identifications in the *Flora of Taiwan* 2nd ed. Lati-01-14 are *A. latifolia*. Callo-01-19 are *A. callosa* var. *callosa*. Argu-01-10 are *A. arguta*. Seto-01-12 are *A. chinensis* var. *setosa*. Rubri-01-13 are *A. rubricaulis*. Rufa-01-03 are *A. rufa*. Callo.ephip-01 is *A. callosa* var. *ephippioidea*.

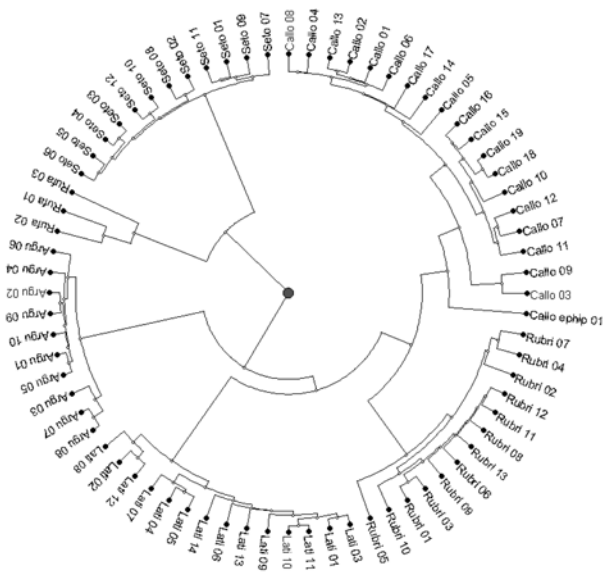

Figure 2. Phylogenetic tree of *Actinidia* accessions in Taiwan. *Actinidia* accessions in the phylogenetic tree were coded based on the abbreviations of specific epithets from the *Flora of Taiwan* 2nd ed.,

Table 2. Identification results of important *Actinidia* specimens in international herbaria. For the polychotomizers, 1 is for *A. latifolia*, 2 is for *A. callosa*, 3 is for *A. arguta*, 4 is for *A. chinensis* var. *setosa*, and 5 is for *A. rubricaulis* as per the *Flora of Taiwan* 2nd edition.

Specimen number in the herbarium (Herbarium code or collector's number)	Polychotomizer	Dichotomizers	Description of specimens
50939 (HAST)	2	○	Voucher specimen of *A. callosa* Lindl. var. *ephippioidea* C. F. Liang in the FOT2
759 (HAST)	3	○	Voucher specimen of *A. tetramera* Maxim. in the FOT2
17446 (HAST)	2	○	Voucher specimen of *A. rufa* (Sieb. & Zucc.) Planch. ex Miq. in the FOT2
761 (HAST)	5	*	Voucher specimen of *A. rubricaulis* Dunn. in the FOT2
760 (HAST)	3	○	Specimen of *A. callosa* var. *formosana* Finet. & Gagnep.
46836 (HAST)	1	○	Voucher specimen of *A. latifolia* (Gardn. & Champ.) Merr. in the FOT2
758 (HAST)	2	○	Voucher specimen of *A. callosa* Lindl. in the FOT2
103514 (HITBC)	5	○	Specimen of *A. callosa* Lindl. of China
106761 (HITBC)	2	×	Specimen of *A. callosa* Lindl. of China
009839 (HITBC)	2	○	Specimen of *Actinidia callosa* Lindl. of China
106761 (HITBC)	2	×	Specimen of *Actinidia callosa* Lindl. of China
00122814 (IBK)	5	*	Paratype of *A. callosa* var. *discolor* of China
00122790 (IBK)	5	○	Paratype of *A. callosa* var. *discolor* of China
00190557 (IBK)	5	○	Holotype of *A. callosa* var. *discolor* of China
00123032 (IBK)	4	×	Specimen of *A. deliciosa* (A. Chev.) C. F. Liang & A. R. Ferguson of China
00123033 (IBK)	4	×	Specimen of *A. deliciosa* (A. Chev.) C. F. Liang & A. R. Ferguson of China
00124359 (IBK)	1	○	Specimen of *A. zhejiangensis* C. F. Liang
00123011 (IBK)	4	×	Specimen of *Actinidia chengkournsis* C. Y. Chang of China
00122800 (IBK)	5	○	Specimen of *Actinidia callosa* var. *discolor* of China.
000229481 (K)	4	×	Type of *A. chinensis* Planch.
000229484 (K)	4	×	Type of *A. chinensis* Planch.
000442641 (K)	1	○	Type of *Heptaca latifolia* Gardn. & Champ. of Hong Kong
000442642 (K)	1	○	Type of *Heptaca latifolia* Gardn. & Champ. of Hong Kong
00428787 (NY)	2	*	Type specimen of *A. callosa* Lindl.
00428824 (NY)	2	×	Type of *A. tetramera* Maxim.
222799 (TAI)	4	○	Specimen of *A. chinensis* var. *setosa* Li
183057 (TAI)	5	○	Specimen of *A. rubricaulis* Dunn of Taiwan
12718 (TAIE)	3	○	Specimen of *A. arguta* (Sieb. & Zucc.) Planch. ex Miq.
16684 (TAIF)	5	*	Type of *A. rankanensis* Hayata.
16685 (TAIF)	5	*	Type of *A. rankanensis* Hayata.
083484 (TAIF)	2	○	Specimen of *A. rufa* (Sieb. & Zucc.) Planch. ex Miq. of Japan
16697 (TAIF)	1	○	Isotype of *A. gnaphalocarpa* Hayata.
083643 (TAIF)	1	○	Voucher specimen of *A. latifolia* (Gardn. & Champ.) Merr. in the FOT2
094191 (TAIF)	3	○	Specimen of *A. arguta* of Taiwan
080645 (TAIF)	3	○	Voucher specimen of *A. arguta* (Sieb. & Zucc.) Planch. ex Miq. in the FOT2
140149 (TAIF)	2	○	Specimen of *A. callosa* Lindl. of Taiwan

Table 2. (Continuation)

Specimen number in the herbarium (Herbarium code or collector's number)	Polychotomizer	Dichotomizers	Description of specimens
099736 (TAIF)	2	○	Specimen of *A. callosa* Lindl. of Taiwan
126875 (TAIF)	3	○	Specimen of *A. callosa* Lindl. of Taiwan
094740 (TAIF)	2	○	Specimen of *A. callosa* Lindl. of Taiwan
077374 (TAIF)	1	○	Specimen of *A. latifolia* (Gardn. & Champ.) Merr.
101270 (TAIF)	1	○	Specimen of *A. latifolia* (Gardn. & Champ.) Merr.
117529 (TAIF)	1	○	Specimen of *A. latifolia* (Gardn. & Champ.) Merr.
075479 (TAIF)	4	○	Specimen of *A. chinensis* var. *setosa* Li
096937 (TAIF)	1	○	Voucher specimen of *A. latifolia* (Gardn. & Champ.) Merr. in the FOT2
03141 (TI)	5	*	Holotype of *A. arisanensis* Hayata.
03142 (TI)	5	*	Holotype of *A. rankanensis* Hayata.
03143 (TI)	5	*	Holotype of *A. remoganensis* Hayata.
T. Soma s.n. (TI)	2	○	Voucher specimen of *A. formosana* in Icones Plantanum Formosanarum, Vol. VIII
Hayata s.n. (TI)	2	○	Voucher specimen of *A. formosana* in Icones Plantanum Formosanarum, Vol. VIII (Ochobi)
Faurie s.n. (TI)	2	○	Voucher specimen of *A. formosana* in Icones Plantanum Formosanarum, Vol. VIII
Hayata s.n. (TI)	1	○	Type of *A. gnaphalocarpa* Hayata. (Suisha)
Hayata s.n. (TI)	1	○	Type of *A. gnaphalocarpa* Hayata. (Uraisha)
S56391 (TNM)	3	○	Specimen of *A. arguta* of China
S10113 (TNM)	3	×	Specimen of *A. chinensis* Planch. var. *setosa* Li
S11128 (TNM)	5	*	Voucher specimen of *A. callosa* Lindl. in the FOT2
S43479 (TNM)	2	○	Specimen of *A. callosa* Lindl. of Taiwan
S10031 (TNM)	2	○	Specimen of *A. callosa* Lindl. var. *formosana* Finet. & Gagnep.
S13435 (TNM)	5	○	Voucher specimen of *Actinidia rubricaulis* Dunn. in the FOT2
S5990 (TNM)	2	○	Specimen of *A. callosa* Lindl. var. *formosana* Finet. & Gagnep.
S12005 (TNM)	5	○	Voucher specimen of *Actinidia rubricaulis* Dunn. in the FOT2
S17543 (TNM)	5	○	Specimen of *A. callosa* Lindl. var. *formosana* Finet. & Gagnep.
S16534 (TNM)	5	○	Specimen of *A. callosa* Lindl. var. *formosana* Finet. & Gagnep.
S4902 (TNM)	2	○	Specimen of *A. callosa* Lindl. var. *formosana* Finet. & Gagnep.
S76931 (TNM)	1	○	Specimen of *Actinidia latifolia* (Gardn. & Champ.) Merr.
S085954 (TNM)	4	○	Specimen of *Actinidia chinensis* var. *setosa* Li
S072915 (TNM)	4	○	Specimen of *Actinidia chinensis* var. *setosa* Li
L0012511 (U)	2	×	Type specimen of *Kadsura pubescens* Miq.
L0012506 (U)	3	○	Type of *Trochostigma arguta* Siebold & Zucc.
L0012509 (U)	2	○	Type of *Trochostigma rufa* Siebold & Zucc.
L0012507 (U)	3	○	Type of *A. cordifolia* Miq.
1052327 (US)	4	○	Holotype of *A. chinensis* var. *setosa* Li
00458008 (US)	2	×	Isosyntype of *A. rubricaulis* Dunn

For the dichotomizers, a circle "○" indicates that the results match the polychotomizer and an "×" indicates that they do not match. An asterisk "*" indicates that no characters were selected by the model for the specimens. The list is arranged alphabetically by herbarium acronym.

to the placement of *A. latifolia* between *A. callosa* var. *callosa* and *A. rubricaulis* in the heat map. The irregular color gradations surrounding *A. callosa* on the heat map show its natural hybridization with *A. chinensis* var. *setosa*. Without the presence of hybrids, the map and the tree reflect comparable relationships.

As a result of this study, we divided *Actinidia* accessions into five groups in Taiwan: *A. latifolia, A. callosa* var. *callosa, A. arguta, A. chinensis* var. *setosa* and *A. rubricaulis*. We found no evidence of reproductive or geographical isolation between putative parents and the hybrids in the field.

Identification of *Actinidia* specimens and numerical nomenclature

From the results of classifier modeling, this study selected model variable combinations of X1, X2, X3, X5, X18, and X19 for the polychotomizer of *Actinidia*; then X1, X2, and X24 for the dichotomizer of *A. callosa*, X13 for *A. arguta*, X29 for *A. chinensis* var. *setosa*, X59 for *A. rubricaulis*, and X10 for the *A. latifolia* model. All the identification results of *Actinidia* specimens are shown in Table 2.

From Table 2, all *A. latifolia* specimens were identified as "1" by the polychotomizer and accepted by the dichotomizer of *A. latifolia*, including the types of *A. latifolia* and *A. gnaphalocarpa*. These results imply that the scientific name of *A. latifolia* in the FOT2 (Peng and Lu, 1996) is the correct name, and that *A. gnaphalocarpa* is a synonym of *A. latifolia* (used by the ICBN: McNeill et al., 2006).

The identification results of *A. callosa* specimens were very complex. The polychotomizer assigned the same group to the type specimens of *A. rufa*, *A. callosa*, and *A. rubricaulis* and the cited specimens of *A. callosa*, *A.*

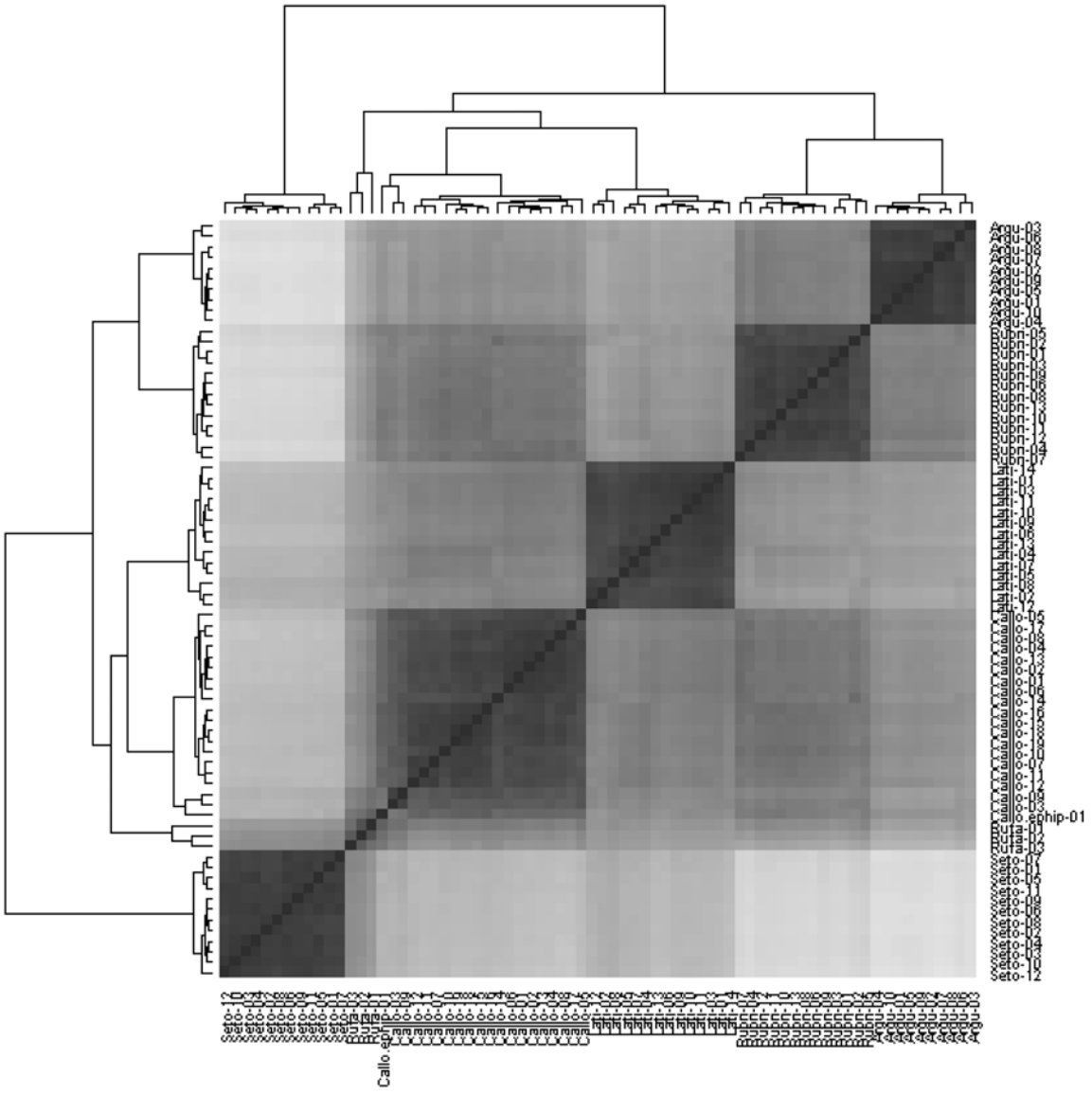

Figure 3. Seriated heat map of *Actinidia* accessions in this study. The codes are based on the abbreviations of specific epithets from the *Flora of Taiwan* 2nd ed.

callosa var. *ephippioidea,* and *A. rufa* in the FOT2; The exception being TNM S11128, a specimen of *A. callosa* cited by the FOT2. Moreover, we were not able to investigate character X24 (pith type of 1-year-old branch) on the types of *A. callosa* because we had only type images on hand. Other specimens, including the type of *A. rufa* and cited specimens of *A. callosa* var. *ephippioidea, A. rufa* and *A. callosa* var. *callosa* in the FOT2, were accepted by the dichotomizer, except the type of *A. rubricaulis*. The results suggest that the names *A. callosa* var. *callosa* and *A. callosa* var. *ephippioidea* in the FOT2 should be revised to *A. rufa*.

The type specimens of *A. arguta* and *A. cordifolia* and the cited specimens of *A. arguta* and *A. tetramera* in the FOT2 were placed into the same group, and all were accepted by the dichotomizer of *A. arguta*, except the type of *A. tetramera.* The results imply that the scientific name of *A. arguta* in the FOT2 is the correct name, and that *A. cordifolia* is a synonym of *A. arguta.* In addition, the cited specimen of *A. tetramera* in the FOT2 should be corrected as *A. arguta*.

The type specimens of *A. chinensis* var. *setosa* and *A. chinensis* var. *chinensis* were classified into the same group by the polychotomizer, but only the *A. chinensis* var. *setosa* holotype was accepted by the dichotomizer of *A. chinensis* var. *setosa*. These results imply that *A. chinensis* var. *setosa* should be elevated to the species rank, but that *A. setosa* may be close to *A. chinensis*.

The types of *A. callosa* var. *discolor*, *A. rankanensis, A. arisanensis, A. remoganensis,* and the cited specimens of *A. rubricaulis* in the FOT2 were classified into the same group by the polychotomizer and accepted by the dichotomizer, but the type of *A. rubricaulis* was classified into another group and rejected by its dichotomizer. These results imply that *A. rubricaulis* does not exist in Taiwan; all cited specimens of *A. rubricaulis* in the FOT2 fell into the same group with types of *A. callosa* var. *discolor*, *A. rankanensis*, *A. arisanensis* and *A. remoganensis*. Liang (1984) and Li et al. (2007) synonymized *A. rankanensis, A. arisanensis,* and *A. remoganensis* under *A. callosa* var. *discolor,* which was taken up in this study. All specimens not mentioned above are discussed in detail below.

DISCUSSION

Only two species of *Actinidia* were reported in Taiwan at the end of the nineteenth century: *A. championii* and the complex taxon *A. callosa* (Henry, 1895). Several years later, Dunn (1911) recorded a variety, *A. callosa* var. *formosana*, in Taiwan, which was originally published in *Bulletin de la Société Botanique de France* 52(4): 20 by Finet and Gagnepain in 1905(-1907). We were unable, however, to find the published protologue of this variety despite a thorough search of that journal from the year 1896 to 1911. Hayata (1911) recorded *A. championii* in Taiwan, which he later considered it a misapplied name for *A. callosa* var. *formosana* (Hayata, 1914). From the descriptions of Dunn and Hayata, *A. callosa* var. *formosana* may be any of the following taxa: *A. callosa* var. *discolor*, *A. rufa*, *A. arguta,* and *A. latifolia*. The major obstacle to the clarifying this issue is the unavailability of protologues and authentic specimens of *A. callosa* var. *formosana*. Hayata (1919) elevated *A. callosa* var. *formosana* to the species rank and designated a type with Latin diagnosis. The specimens of *A. formosana* cited therein by Hayata, however, were classified into *A. rufa* by the polychotomizer and accepted by the dichotomizer. As a result, we have synonymized *A. formosana* under *A. rufa* in this paper.

The result of applying classifiers to *A. setosa* showed that all specimens of *A. chinensis* (including the types) and *A. deliciosa* were rejected by the dichotomizer. Our field investigations indicated that the flowering and fruiting periods of *A. setosa* differ from those of *A. chinensis* and *A. deliciosa*, when they were cultivated at the same locations (Chou et al., 2008; Hsieh, 2011). The geographic and phenological isolations and morphological distinctions among them uphold Liang and Ferguson's (1985) ranking of *A. setosa* as a species and not variety.

There has been long-standing confusion regarding the classification and nomenclature of *A. rufa*, *A. callosa,* and *A. arguta*. *Actinidia callosa* is the type of the genus, but the brief description of this species made it difficult to distinguish from other members of *Actinidia*. *Actinidia arguta* and *A. rufa* were published by Siebold and Zuccarini in 1843, but their descriptions were also too brief to be useful. Furthermore, the authors mistakenly labeled their drawing of *A. arguta* fruit as that of *A. rufa*. Many botanists were thus even more confused about *A. rufa, A. arguta,* and *A. callosa*. Maximowicz advocated that *A. rufa* was a variety of *A. arguta* (Li et al., 2007). Makino (1901) treated *A. arguta* and *A. rufa* as varieties of *A. callosa*. In contrast, Dunn (1911) treated *A. arguta* as a variety of *A. rufa*. Such controversy on the classification and nomenclature of these species continued for a century. Taiwan has all three of these *Actinidia* species (Peng and Lu, 1996), thus providing an opportunity to clarify this issue. A cluster analysis conducted in the present study confirms that they belong in separate groups and the discriminant analysis clarified the correct names, resolving this long-standing issue.

What our results lack, however, is a model-selected character for type specimens and an investigation of accessions of *A. callosa*. Accepting the identification of foreign specimens without checking the dichotomizer is a highly risky matter (Hastie et al., 2001). Specimens labeled as *A. callosa* were a complex group that included some misidentifications. Further studies are needed to determine the proper rank and phylogenetic relationships of *A. callosa* and its varieties.

Specimens in Table 2 showed some interesting features. Specimen S10113 (TNM), the sole specimen labeled *A. chinensis* var. *setosa*, was determined as *A. arguta* by the polychotomizer but then rejected by the dichotomizer of *A. arguta*. After re-examining the specimen, we found it to

be *Schisandra arisanensis* (Schisandraceae). The classifiers of this study seem capable not only of identifying new species in *Actinidia* but also of picking out erroneously determined entities that do not belong to the genus.

Testolin et al. (1997) and Cipriani et al. (1998) studied some plastids and mitochondria sequences of 21 *Actinidia* taxa and pointed out that most *Actinidia* taxa, including *A. arguta*, *A. rufa*, *A. callosa*, and *A. latifolia*, can be separated by the chloroplast and mitochondrial DNA sequence. Subsequently, the phylogenetic study of Li et al. (2002) and Huang et al. (2002) based on nuclear ribosomal DNA internal transcribed spacers, chloroplast matK gene, and RAPD analysis showed that *A. arguta* are clearly distinguishable from the other species, including *A. callosa* var. *discolor*, *A. latifolia* and *A. rufa* inferred from either matK gene sequences, nrDNA ITS/5.8s region, or RAPD data. The latter three species appeared to be separable based on nrDNA ITS/5.8s region and RAPD data. Chat et al. (2004) studied the evolutionary relationships within *Actinidia* based on chloroplast, mitochondrial restriction site, and sequence data. Their study revealed reticulate evolution resulted from hybridization/introgression events and that *A. arguta*, *A. callosa* var. *discolor*, *A. setosa*, *A. latifolia*, and *A. rufa* can be separated based on 41 sequences (*rbcl* and *trnL-trnF*) and restriction sites (*matK* and *psbC-trnS*). We believe that introgression may have contributed to the morphological variation as observed in these studies. By comparison with previous phylogenetic studies, our work revealed the same results on the phylogenetic pattern and classification among all *Actinidia* at the species level. In comparison to the molecular methods, our methods are far more cost-efficient and simple. The heat map, a visual tools, is an ideal way to display introgressive hybridization. Most taxonomic studies of east Asian plants in recent years (e.g., Boyce and Wong, 2009; Chang et al., 2011; Chen and Chou, 2008; Chen et al., 2008, 2009; Chung et al., 2008, 2010; Cong et al., 2008; Dong, 2010; Gao and Yang, 2009; He and Zhang, 2010, 2011; Hou et al., 2009; Hsieh, 2002; Hsieh et al., 2002, 2007; Hsu et al., 2011; Hughes et al., 2011; Ku, 2006; Ku et al., 2008; Lammers and Klein, 2010; Lin et al., 2010; Liu et al., 2007, 2009, 2010, 2011; Liu and Yang, 2010, 2011a,b; Lu and Wang, 2009; Mou and Zhang, 2010; Peng et al., 2007a,b, 2008a,b, 2010; Sam et al., 2009; Sheue et al., 2009, 2010; Su et al., 2009; Tian et al., 2010; Tsai et al., 2003; Wang et al., 2010; Wong and Boyce, 2010a, b; Wu et al., 2009; Yang, 2009; Yu et al., 2009; Yuan and Yang, 2009; Yuan et al., 2011; Zhang and He, 2009a,b; Zhang et al., 2008, 2010) have not combined classification and nomenclature with statistics. Considering the diversity and complexity of plants, more models and methods should be developed and utilized for future studies of important and complex taxa (Cuerrier et al., 1998).

Taxonomic treatment of *Actinidia* in Taiwan

Key to the taxa of *Actinidia* in Taiwan (excluding natural hybrids).

1. Leaf abaxially glabrous, with hairy domatia in axils of lateral veins ..... 3. *A. arguta*
1. Leaf abaxially glabrous or hairy, axils of lateral veins without domatia.
   2. Pith of 1-year-old branchlets not lamellated ..... 5. *A. callosa* var. *discolor*
   2. Pith of 1-year-old branchlets lamellated.
      3. Branchlets densely hispid ..... 4. *A. setosa*
      3. Branchlets not hispid.
         4. Mature leaf densely stellate abaxially ..... 1. *A. latifolia*
         4. Mature leaf not or rarely stellate abaxially..... 2. *A. rufa*

1. Actinidia latifolia (Gardner & Champ.) Merr., J. Straits Branch Roy. Asiat. Soc. 86: 330. 1922; Li, J. Arnold Arbor. 33: 49. 1952; Li, Woody Fl. Taiwan 571. 1963; Li, Fl. Taiwan 2: 588. 1976; Liu et al., Tr. Taiwan (2nd ed.) 444. 1994; Peng & Lu, Fl. Taiwan (2nd ed.) 2: 659. 1996; Li et al., Fl. China 12: 343. 2007. Figure 4

Heptaca latifolia Gardner & Champ., Hooker's J. Bot. Kew Gard. Misc. 1: 243. 1849.

Actinidia championii Benth., Fl. Hongk. 26. 1861; Dunn., J. Linn. Soc., Bot. 39: 407. 1911.

Actinidia gnaphalocarpa Hayata, Icon. Pl. Formos. 9: 7. 1920.

Large climbing woody vine, deciduous to semi-evergreen. Branchlets glabrous, slightly puberulent or densely tomentose when young; pith white lamellate or hollow when old. Petiole 3-6 cm; leaf blade abaxially pale-green, adaxially green, usually broadly ovate to obovate, 7-14 × 4.5-9 cm, abaxially densely appressed stellate tomentose, glabrescent when old, base broadly cuneate to rounded or reniform, margin minutely and remotely callose-serrulate, apex acute to acuminate. Inflorescences 2-4 branched, 8 or more flowered, densely brownish tomentose. Flowers yellowish-brown. Sepals 3, ovate, 4-5 mm, reflexed after anthesis, both surfaces tomentose. Petals 5, oblong to obovate-oblong, 6-8 mm, reflexed after anthesis. Ovary globose, ca. 2 mm, densely pilose. Fruit brown, subglobose to ovoid, 1.2-2.1 × 0.7-1.5 cm with lenticels, glabrous when mature or sparse tomentose, especially both base and apex of fruit.

Specimens examined. TAIPEI COUNTY (CO.): Wulai Township, Uraisha, *B. Hayata s.n.* (TAIF 16697; TI). TAOYUAN CO.: Fuhsing Township, Lalashan, ca. 1,500 m elev., 19 June 1994, *Wen-Pen Leu 2045* (HAST 46836). ILAN CO.: Tatong Township, Mingchih, ca. 1,100-1,200 m elev., 22 June 1994, *Her-Long Chiang s.n.* (TAIF 101270). TAICHUNG CO.: Hoping Township, Tahsuehshan, ca. 1,675 m elev., 15 Aug 2001, *C. M. Wang 5234* (TNM S76931). NANTOU CO.: Yuchih Township, Lienhuachih, ca. 600 m elev., 10 Oct 1995, *Kuoh-Cheng Yang 4731* (TAIF 077374); Lienhuachih, ca. 650 m elev., 6 June 1985, *Sheng-You Lu 16482* (TAIF 096937); Suisha,

Hayata s.n. (TI). KAOHSIUNG CO.: Maolin Township, Fengkang logging road, ca. 1,600 m elev., 4 July 2000, *Her-Long Chiang 1299* (TAIF 117529). TAITUNG CO.: Taimali Township, Taimali working station, ca. 500-1,000 m elev., 15 Aug 1993, *Jenn-Che Wang et al. 8762* (TAIF 083643).

Etymology. The specific epithet '*latifolia*' means "broadly leaved".

Distribution and habitat. China, Taiwan, Cambodia, Laos, Thailand, and Vietnam. In Taiwan, occurs in forests and thickets, on slopes, and along roads throughout Taiwan at 300-2,200 m.

2. Actinidia rufa (Sieb. & Zucc.) Planch. ex Miquel, Ann. Mus. Bot. Lugduno-Batavi 3: 15. 1867; Dunn., J. Linn. Soc., Bot. 39: 402. 1911; Peng and Lu, Fl. Taiwan (2nd ed.) 2: 660. 1996; Li *et al.*, Fl. China 12: 337. 2007.

Figure 5

Trochostigma rufum Sieb. & Zucc., Abh. Math.-Phys. Cl. Königl. Bayer. Akad. Wiss. 3(2): 727. 1843.

Actinidia arguta var. *rufa* (Sieb. et Zucc.) Maxim., Bull. Acad. Sci. St. Pétersb. 31. 19. 1886; Li, J. Arnold Arbor. 33: 34. 1952.

Actinidia callosa var. *rufa* (Sieb. et Zucc.) Makino, Bot. Mag. (Tokyo) 15: 147. 1901.

Actinidia callosa auct. non Lindl.: Peng & Lu, Fl. Taiwan (2nd ed.) 2: 657. 1996.

Actinidia callosa var. *ephippioidea auct. non* C. F. Liang: Peng & Lu, Fl. Taiwan (2nd ed.) 657. 1996.

Actinidia formosana Hayata, Icon. Pl. Formos. 8: 12. 1919.

Deciduous to semi-evergreen climbing woody vine. Branches glabrous; pith brown lamellate; branchlets reddish, brownish puberulent. Petiole 2-7 cm, glabrous; leaf blade ovate to broadly ovate or orbicular, 4.5-13 × 3.3-8.5 cm, papery, lateral veins 5-8 pairs, base rounded to truncate or cordatulate, oblique or not, margin shallowly mucronate-serrate, sometimes glandular, apex obtuse to long acuminate. Inflorescences cymose, axillary, brownish velutinous. Male inflorescences multi-flowered. Female inflorescences with fewer flowers then male. Flowers white, often reddish at base. Sepals 4-5, ovate, ca. 4.8-5.7 mm, apex acute to round. Petals 5, obovate, ca. 1 cm. Ovary globose, ca. 4.5-5.7 mm, densely tomentose. Fruit oblong to ovoid, 2.3-4.5 cm, densely or sparsely tomentose to glabrous when mature, lenticels obscure.

Specimens examined. TAIPEI CO.: Kelung, *S. Soma s.n.* (TI); Daiton, 1903, *U. Faurie s.n.* (TI). TAIPEI CITY: Matsao, ca. 600-650 m elev., 6 Oct. 1985, *Ching-I Peng 8644* (HAST 758). ILAN CO.: Su-ao Town, Wushihpi, 17 Sept. 1992, *C. K. Lin s.n.* (TNM S10031); Ochobi, May 1916, *B. Hayata* s.n. (TI); Tatong Township, no. 100 logging road, ca. 1500 m elev., 17 Sept. 1996, *C. M. Wang 2219* (TAIF 099736). HUALIEN CO.: Sioulin Township, Hoping logging trail, ca. 1,200 m elev., 12 June 2001, *Yu-Pin Cheng s.n.* (TAIF 140149). TAICHUNG CO.: Hoping Township, Chingshan-Techi, ca. 1,320 m elev., 28 July 1997, *C. M. Wang 2749* (TNM S043479). KAOHSIUNG CO.: Liouguei Township, Shanping-Nanpengshan, 6 Apr. 1987, *C. H. Ou et al. s.n.* (TNM S5990). PINGTUNG CO.: Chunrih Township, Tahanlintao, 29 Sept. 1985, *C. H. Ou et al., s.n.* (TNM S4902). TAITUNG CO.: Tajen Township, Kueitien, 12 Aug 1994, *Sheng-You Lu s.n.* (TAIF 094740).

Etymology. The specific epithet '*rufa*' means "reddish".

Distribution and habitat. Japan and Taiwan. In Taiwan, occurs in forests and thickets, and along streams and roads throughout Taiwan at 150-2,200 m.

3. Actinidia arguta (Sieb. & Zucc.) Planch. ex Miquel, Ann. Mus. Bot. Lugduno-Batavi 3: 15. 1867; Li, J. Arnold Arbor. 33: 31. 1952; Liang, Fl. Reipubl. Popularis Sin. 49(2): 205. 1984; Peng and Lu, Fl. Taiwan (2nd ed.) 2: 657. 1996; Li *et al.*, Fl. China 12: 337. 2007.

Figure 6

Trochostigma argutum Sieb. & Zucc., Abh. Math.-Phys. Cl. Königl. Bayer. Akad. Wiss. 3(2): 727. 1843.

Actinidia cordifolia Miq., Ann. Mus. Bot. Lugduno-Batavi 3: 15. 1876.

Actinidia callosa var. *arguta* (Sieb. et Zucc.) Makino, Bot. Mag. (Tokyo) 15: 148. 1901.

Actinidia rufa var. *arguta* (Sieb. & Zucc.) Dunn, J. Linn. Soc., Bot. 39: 402. 1911.

Actinidia rufa var. *cordifolia* (Miq.) Dunn, J. Linn. Soc., Bot. 39: 403. 1911.

Actinidia arguta var. *cordifolia* (Miq.) Bean, Trees Shrubs Brit. Isles 1: 162. 1914.

Actinidia tetramera auct. non Maxim.: Peng & Lu, Fl. Taiwan (2nd ed.) 2: 660. 1996.

Deciduous woody twiner. One-year-old branchlets glabrous or puberulent when young; 2nd-year branches grayish-brown, glabrous; pith white to brown, 1-year shoot lamellate. Petiole green or sometimes pinkish-yellow when young, 2-5 cm, glabrous; leaf blade abaxially green, adaxially dark- or pale-green, ovate to broadly ovate, rarely ovate-oblong, 5-11 × 4-10 cm, papery, abaxially glabrous, with hairy domatia in axils of lateral veins, lateral veins 4-7 pairs, straight or arcuate-ascending, base rounded to cordate, symmetrical, margin with sharply serrate teeth, apex abruptly acuminate. Inflorescences cymose, axillary or lateral, 1-7-flowered. Flowers white, 1.4-2.3 cm in diam. Sepals 4-5, ovate to oblong, glandular-tomentose. Petals -5, obovate to orbicular, 7-9 mm. Ovary long bottle-shaped, 6-7 mm, glabrous. Fruit green when mature, globose to oblong, 1.6-2.7 cm, glabrous, without lenticels or persistent sepals.

Specimens examined. ILAN CO.: Yuanshan Township, Ayushan, 10 July 1996, *Yu-Pin Cheng s.n.* (TAIF 092148); Tatong Township, Taipingshan, ca. 1,950 m elev., 8 June 1985, *Ching-I Peng 7872* (HAST 759). TAOYUAN CO.:

Fusing Township, Lalashan, ca. 1,900-2,000 m elev., 5 Aug 1999, *Su-Wen Chung 2078* (TAIF 126875). TAICHUNG CO.: Hoping Township, Szuyuanyakou, ca. 1,900-2,200 m elev., 13 Aug 1993, *Chieh-Lin Huang et al. 36* (TAIF 080645); Szuyuanyakou, ca. 1,915 m elev., 27 July 1998, *Tsai-Wen Hsu 9094* (TAIE 12718); Jiayang, no. 810 logging road, ca. 1,900 m elev., 26 June 1998, *Ching-Kuoh Liou et al. 977* (TAIF 094191). CHIAYI CO.: Alishan Township, Tongpu, 26 May 1960, *T. I. Chuang et al. 4097* (HAST 760).

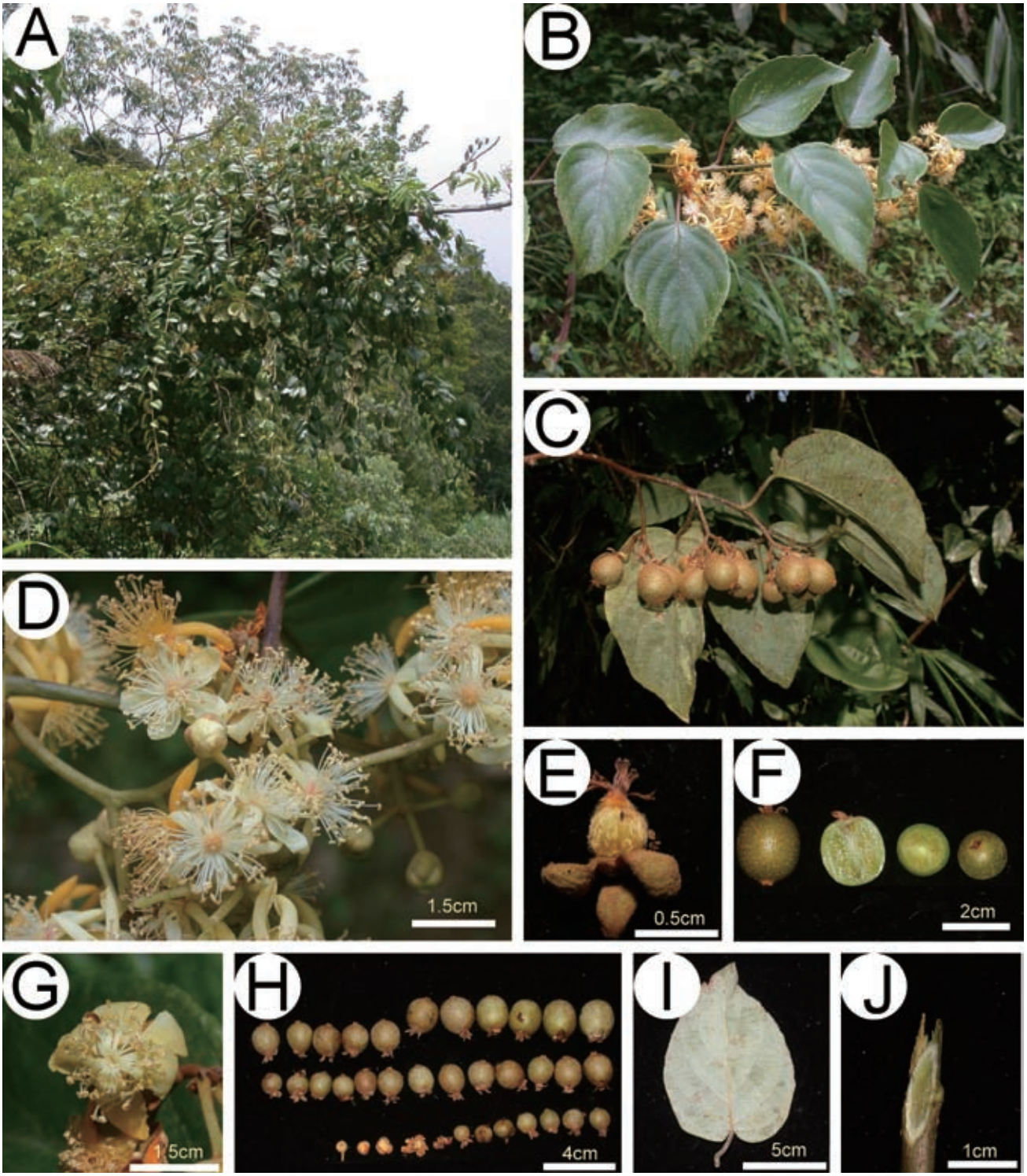

Figure 4. *Actinidia latifolia* (Gardner & Champ.) Merr. A, Habit (Tengchi, Kaohsiung County); B, Flowering branch; C, Fruiting branch; D, Male flowers; E, Overy; F, Fruits, showing cross sections; G, Female flower; H, Developmental stages from flower buds to mature fruits; I, Leaf, abaxial surface; J, Pith of one-year old shoot.

Etymology. The specific epithet '*arguta*' means "sharp teeth" in reference to the leaf blade margin.

Distribution and habitat. Siberia, Japan, Korea, China, and Taiwan. In Taiwan, occurs in mountain forests and along streams of the northern and central parts at 1,300-2,600 m.

4. Actinidia setosa (H. L. Li) C. F. Liang & A. R. Ferguson, Guihaia 5 (2): 72. 1985. *Actinidia chinensis auct. non* Planchon: Susuki in Masamune, Short Fl. Form.

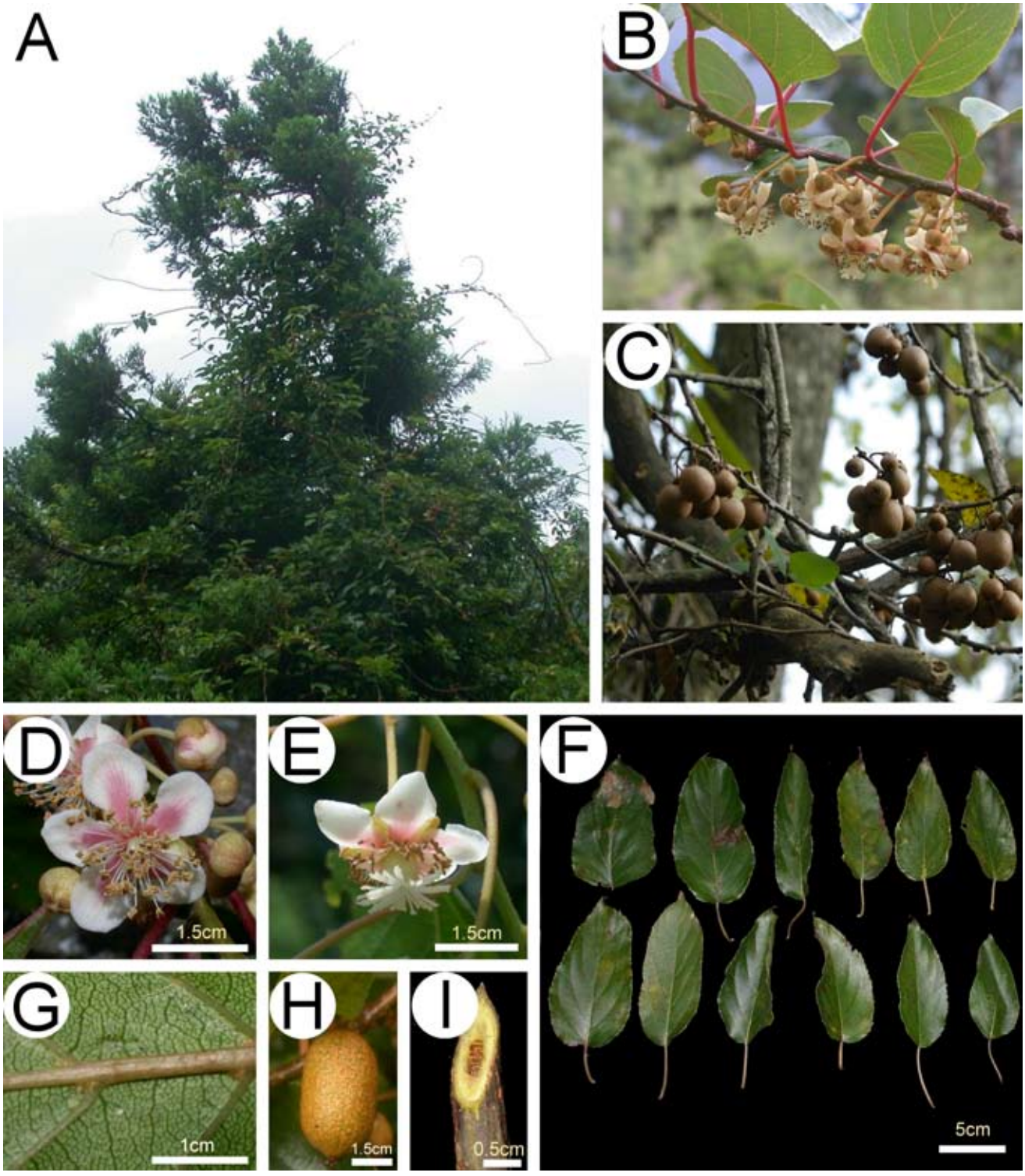

Figure 5. *Actinidia rufa* (Sieb. & Zucc.) Planch. ex Miquel. A, Habit (Yangmingshan, Taipei County; Callo-05); B, Flowering branch; C, Fruiting branch; D, Male flower; E, Female flower; F, Different shapes of leaves; G, Domatia in axils of lateral veins; H, Fruit; I, Pith of one-year old shoot.

137. 1936; Kanchira, Formos. Trees (rev. ed.) 449. pl. 406. 1936. Figure 7

Actinidia chinensis var. *setosa* H. L. Li, J. Arnold Arbor. 33: 56. 1952; Li, Woody Fl. Taiwan 573. 1963; Li, Fl. Taiwan 2: 588. 1976; Liang, Act. Phytotaxon. Sin. 13(4): 33. 1975; Liu et al., Tr. Taiwan (2nd ed.) 444. 1994; Peng & Lu, Fl. Taiwan (2nd ed.) 2: 659. 1996; Li et al., Fl. China 12: 350. 2007.

Large climbing vine, deciduous. Branchlets reddish, young branchlets densely hispid; pith lamellate, whit-

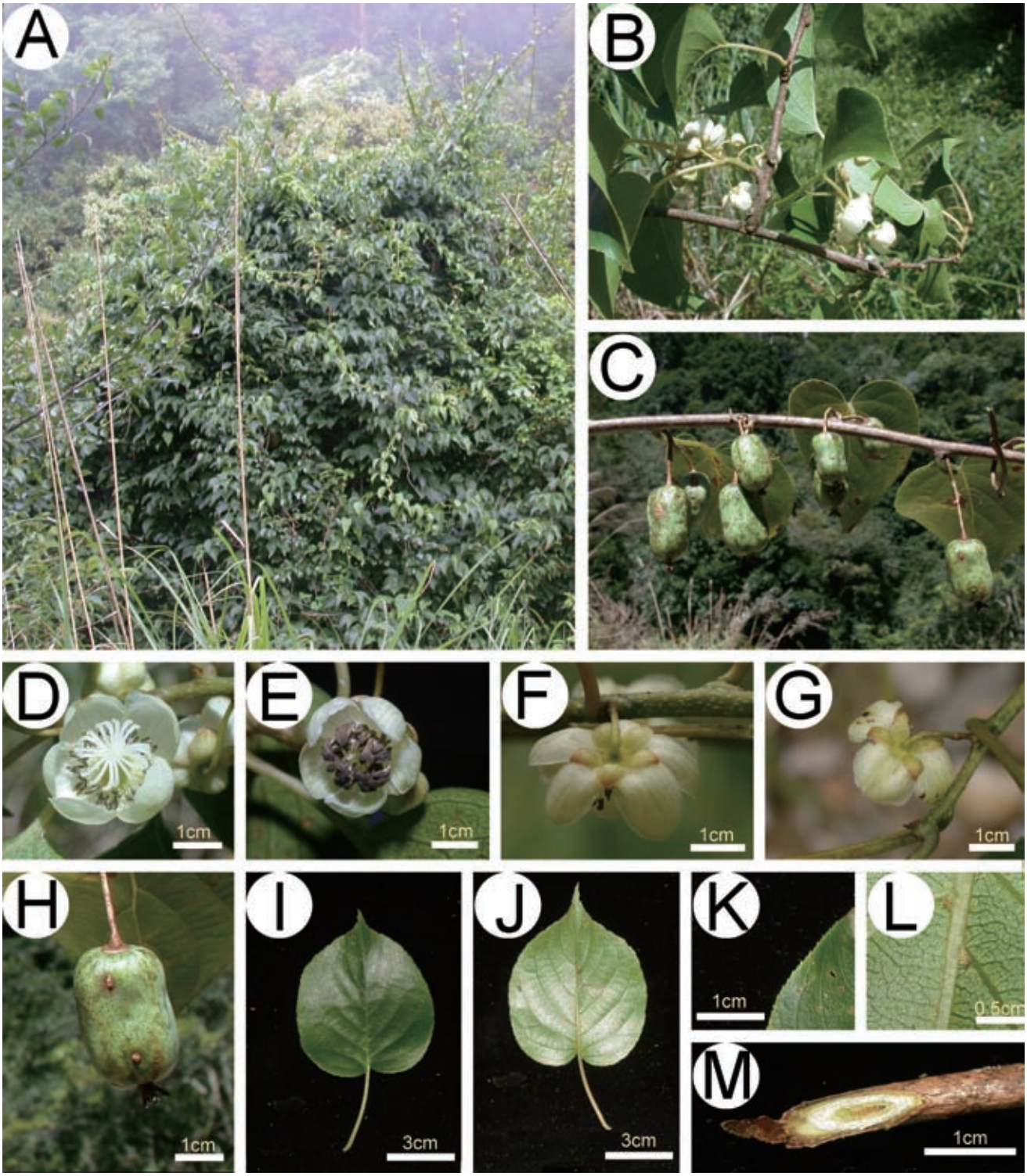

Figure 6. *Actinidia arguta* (Sieb. & Zucc.) Planch. ex Miquel. A, Habit (Szuyuanyakou, Taichung County; Argu-02); B, Flowering branch; C, Fruiting stem; D, Female flower; E, Male flower; F, Five-sepal flower; G, Four-sepal flower; H, Fruit; I, Leaf, adaxial surfae; J, Leaf, abaxial surface; K, Leaf margin; L, Domatia in axils of lateral veins; M, Pith of one-year old shoot.

ish to brown when mature. Petiole 3-5 cm, hispid; leaf blade abaxially pale-green, adaxially dark-green, broadly ovate to broadly obovate or suborbicular, 6-21 × 6-16 cm, chartaceous, abaxially brownish stellate tomentose, adaxially scabrid-hispid, lateral veins 5-8 pairs, base cordatulate, margin setose-serrulate with teeth, apex acute or shortly acuminate to acuminate. Inflorescences cymose, 1-4-flowered, white to yellowish-brown. Flowers white to orangish-yellow when mature. Sepals 5(-7), broadly ovate to oblong-ovate, 6-10 mm. Petals -5(-8), broadly obovate, 1-2 cm shortly clawed at base, apex rounded. Ovary globose, ca. 5 mm in diam. Fruit subglobose, cylindric to

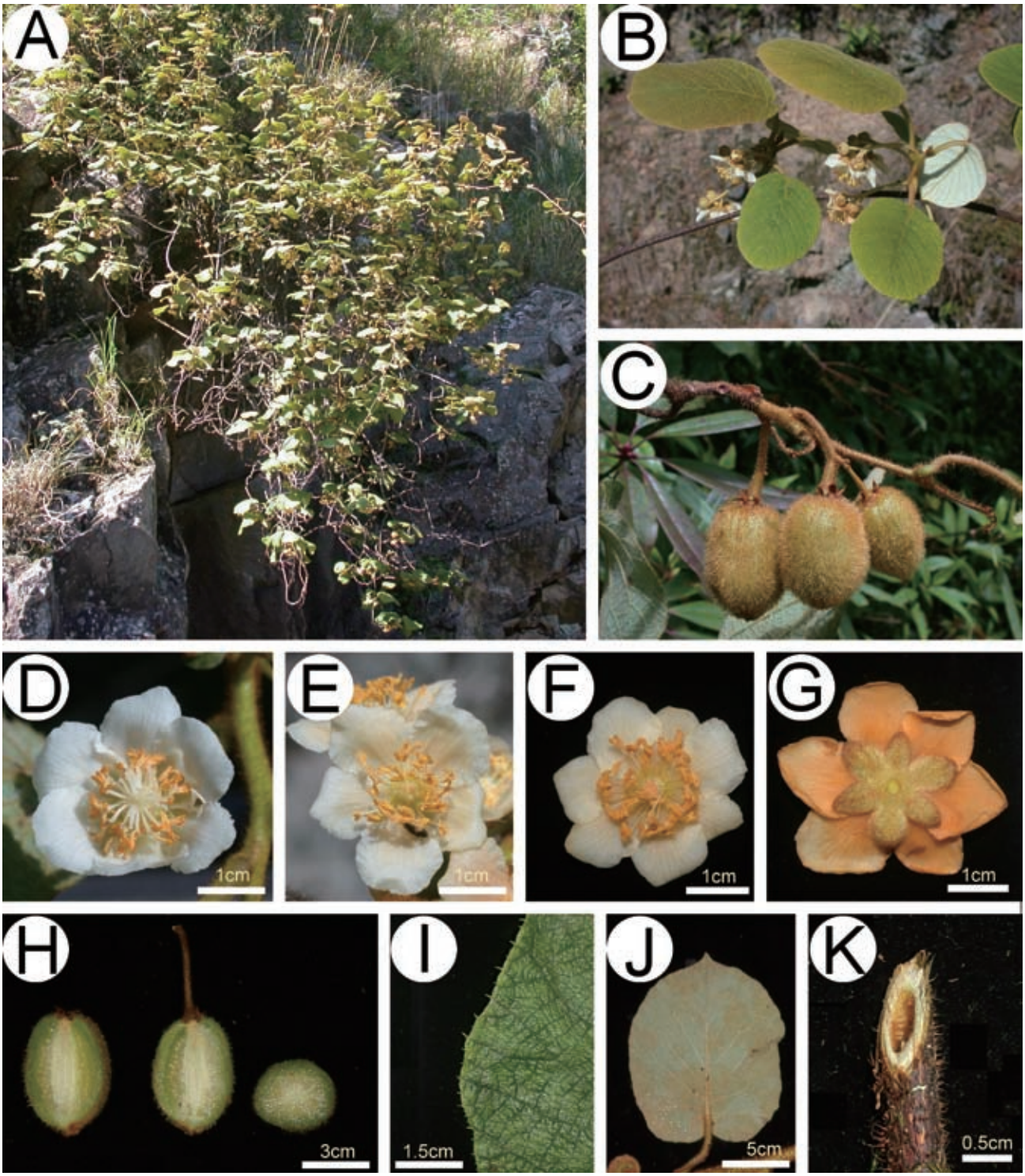

Figure 7. *Actinidia setosa* (H. L. Li) C. F. Liang & A. R. Ferguson. A, Habit (Hehuan river, Taichung County; Seto-04); B, Flowering branch; C, Fruiting branch; D, Female flower; E, Male flower; F, Seven-petal flower; G, Female flower with six petals and sepals; H, Sections of fruits; I, Leaf margin; J, Leaf, abaxial surface; K, Pith of one-year old shoot.

obovoid or ellipsoidal, 3.6-7.4 cm, densely hispid, with lenticels; persistent sepals reflexed.

Specimens examined. ILAN CO.: Tatong Township, Taipingshan, ca. 1,870 m elev., 14 May 1992, *S. F. Huang 4779* (TAI 222799). HSINCHU CO.: Wufeng Township, Kuanwu, ca. 2,000 m elev., 21 May 1994, *Jenn-Che Wang et al. 9224* (TAIF 075479). MIAOLI CO.: Taian Township, Kuanwu, ca. 2,350 m elev., 9 May 2003, *C. M. Wang et al. 6707* (TNM S085954). TAICHUNG CO.: Hoping Township, no. 710 logging track, ca. 1,800 m elev., 24 July 24, *Y. C. Lu 112* (HAST 23846). NANTOU CO.: Hsinyi Township, Yushankou, ca. 2,300 m elev., 6 May 2001, *C. M.*

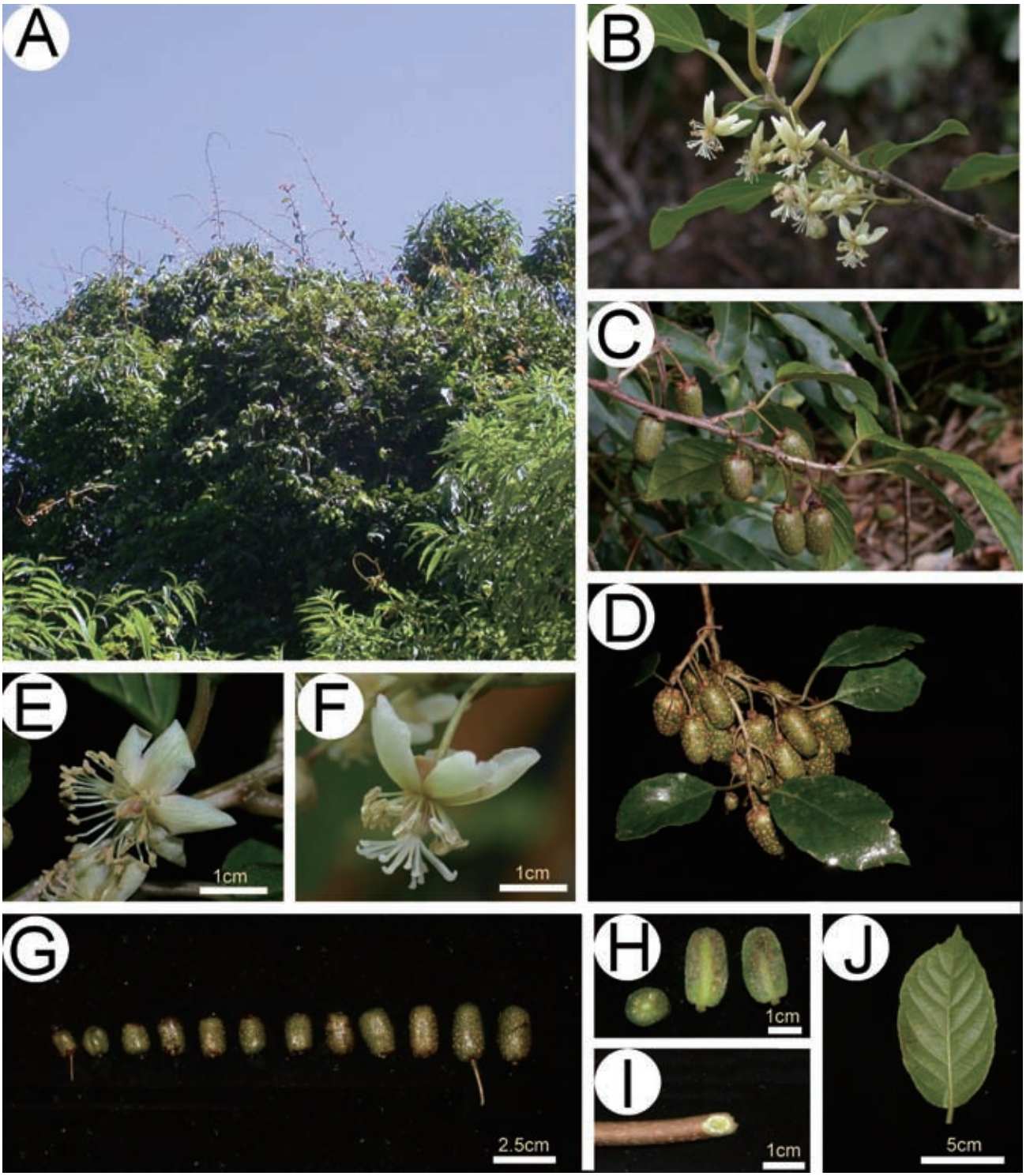

Figure 8. *Actinidia callosa* var. *discolor* C. F. Liang. A, Habit (Lixing industrial road, Nantou County; Rubri-03); B, Flowering branch; C-D, Fruiting branch; E, Male flower; F, Female flower; G, Different shapes of fruits; H, Sections of fruits; I, Pith of one-year old shoot; J, Leaf, abaxial surface.

Wang et al. 4974 (TNM S072915). CHIAYI CO.: Alishan Township, Alishan, 18 Oct 1918, *E. H. Wilson 10802* (US 1052327).

Etymology. The specific epithet '*setosa*' means "bristly hairy", based on this plant being bristly hairy throughout.

Distribution and habitat. Endemic to Taiwan, in mountain forests, on slopes, and along roads throughout Taiwan at (500-) 1,300-2,700 m.

5. Actinidia callosa var. discolor C. F. Liang in K. M. Feng, Fl. Reipubl. Popularis Sin. 49(2): 315. 1984; Li et al., Fl. China 12: 343. 2007. Figure 8

Actinidia callosa auct. non Lindl.: Peng & Lu, Fl. Taiwan (2nd ed.) 2: 657. 1996, pro part.

Actinidia arisanensis Hayata, Icon. Pl. Formos. 8: 11. 1919.

Actinidia rankanensis Hayata, Icon. Pl. Formos. 8: 13. 1919.

Actinidia remoganensis Hayata, Icon. Pl. Formos. 8: 13. 1919.

Actinidia rubricaulis auct. non Dunn: Peng & Lu, Fl. Taiwan (2nd ed.) 2: 660. 1996.

Deciduous to semi-evergreen twiner. Branchlets glabrous, lenticels conspicuous; pith of 1-year-old shoot solid, rarely lamellate; old branches grayish, pith solid or inconspicuously brown lamellate. Petiole glabrous; leaf blade abaxially pale-green, adaxially dark-green, elliptic or ovate to obovate, rarely elliptic, 3.6-10 × 3-6 cm, abaxially glabrous, lateral veins 4-7 pairs, base cuneate to obtuse, margin coarsely serrate or serrate to subentire, apex obtuse or acute. Inflorescences cymose, 1-5-flowered, glabrous; peduncles 0.7-1.5 cm; pedicels 1.1-1.7 cm. Flowers white. Sepals 5, ovate, 4-5 mm, glabrous. Petals 5, obovate, 8-10 mm. Ovary subglobose, densely pubescent; Fruit grayish-green, ovate to oblong, 1.2-2.7 cm, glabrous, lenticels white, conspicuous.

Specimens examined. TAIPEI CO.: Wulai Township, Kang-gu, 17 June 1955, *Hsuen Kao and Muh-Tsuen Kao 2904* (HAST 761); Houkengtzechi, 9 Nov. 1980, *H. N. Yang 3436* (TAI 183057); Remogan, 7 May 1916, *B. Hayata s.n.* (TI). ILAN CO.: Nan-ao Township, Rankanzan, 12 May 1916, *B. Hayata s.n.* (TAIF 16685, 16684; TI). NANTOU CO.: Ren-ai Township, Meifen, ca. 2,100 m elev., 13 July 1993, *C. M. Wang 80* (TNM S11128); Yuchih Township, Lienhuachih, ca. 576-925 m elev., 19 Sept. 1995, Liang Hung Wu 77 (TNM S17543); Luku Township, Fenghuangku, ca. 750-850 m elev., 11 Sept. 1994, *Kuang-Yuh Wang 168* (TNM S16534). HUALIEN CO.: Chohsi Township, Yamagon to Huangma, ca. 800-1300 m elev., 1 Aug. 1993, *Tseng-Pin Chiang 66* (TNM S13435). CHIAYI CO.: Alishan Township, Tatungshan, ca. 1,700 m, 6 Sept. 1993, *C. M. Wang 222* (TNM S12005); Alishan, inter Taroyen et Heishana, 26 April 1912, *B. Hayata s.n.* (TI).

Etymology. The specific epithet '*callosa*' refers to the leaf margin with callose teeth. The variety epithet '*discolor*' refers to the leaf blade with different colors on the two sides.

Distribution and habitat. China and Taiwan. In Taiwan, at forest margins, on slopes, in thickets and valleys, and along roads throughout Taiwan at 300-2,100 m.

Insufficiently known taxon:

Actinidia callosa var. formosana Finet & Gagnep., Bull. Soc. Bot. France, Mem. 4: 20. 1905.

Dunn (1911) referred to the variety, *A. callosa* var. *formosana* Finet & Gagnep., in Taiwan but the original description of *A. callosa* var. *formosana* in Bulletin de la Société botanique de France is not available. This entity is excluded in this treatment for lack of the protologue and type specimen.

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LITERATURE CITED

Albert, J. 2009. Bayesian computation with R, 2nd ed. Springer, New York, 298 pp.

Bentham, G. 1860. Notes on Ternstraemiaceae. J. Proc. Linn. Soc. Bot. **5:** 53-56.

Boyce, P.C. and S.Y. Wong. 2009. *Schottariella mirifica* P. C. Boyce & S. Y. Wong: a new name for *Schottarum sarikeense* (Araceae: Schismatoglottideae). Bot. Stud. **50:** 269-271.

Chang, K.C., C.C. Wang, S.L. Deng, Y. Kono, F.Y. Lu, and C.-I Peng. 2011. *Cotoneaster rosiflorus* (Rosaceae), a new species from Taiwan. Bot. Stud. **52:** 211-218.

Chat, J., B. Jáuregui, R.J. Petit, and S. Nadot. 2004. Reticulate evolution in kiwifruit (*Actinidia*, Actinidiaceae) identified by comparing their maternal and paternal phylogenies. Am. J. Bot. **91(5):** 736-747.

Chen, C.H., C.F. Chen, and S.Z. Yang. 2008. *Swertia changii* (Gentianaceae), a new species from southern Taiwan. Bot. Stud. **49:** 155-160.

Chen, T.T. and F.S. Chou. 2008. A new Taiwan species *Veronicastrum loshanense* (Scrophulariaceae). Bot. Stud. **49:** 281-285.

Chen, X.L., H. Liang, T.W. Hsieh, and S.H. Liu. 2008. Cluster analysis of fruit and leaf characters from 11 species of *Actinidia*. J. Anhui Agric. Sci. **35:** 15408-15410.

Chen, W.H., Y.M. Shui, Y.K. Sima, R.M. Zhang, and Z.D. Wei. 2009. *Pararuellia glomerata* (Acanthaceae), a new species from Yunnan, China. Bot. Stud. **50:** 261-267.

Chou, H.N., C.C. Nee, A.S. M. Ou, T.H. Chou, and C.C. Chien. 2008. Characterization of the physicochemical and antioxidant properties of Taiwanese kiwifruit (*Actinidia setosa*). Bot. Stud. **49:** 215-224.

Chung, K.F., Y. Kono, C.M. Wang, and C.-I Peng. 2008. Notes on *Acmella* (Asteraceae: *Heliantheae*) in Taiwan. Bot. Stud. **49:** 73-82.

Chung, S.W., T.C. Hsu, and C.-I Peng. 2010. *Phacellanthus* (Orobanchaceae), a newly recorded genus in Taiwan. Bot. Stud. **51:** 531-536.

Cipriani, G., R. Testolin, and R. Gardner. 1998. Restriction-size variation of PCR-amplified chloroplast DNA regions and its implication for the evolution and taxonomy of Actinidia. Theor. Appl. Genet. **96:** 389-396.

Claude, J. 2008. Morphometrics with R. Springer, New York, 316 pp.

Cong, Y.Y., K.M. Liu, X.Z. Cai, and S.Z. Tian. 2008. *Impatiens fugongensis* (Balsaminaceae), a new species from Yunnan, China. Bot. Stud. **49:** 161-165.

Cuerrier, A., L. Brouillet, and D. Barabé. 1998. Numerical and comparative analyses of the modern systems of classification of the flowering plants. Bot. Rev. **64:** 323-355.

Cuong, N.M., D.D. Soejarto, and J.Q. Li. 2007. A taxonomic revision of Actinidiaceae of Vietnam. Blumea **52:** 209-243.

Dong, S.Y. 2010. A new species of *Dryopteris* (Dryopteridaceae) from Hainan Island, China. Bot. Stud. **51:** 537-542.

Dunn, S.T. 1911. A revision of the genus *Actinidia* Lindl. J. Linn. Soc. Lond. Bot. **39:** 394-410.

Ferguson, A.R. 1984. Kiwifruit: a botanical review. Hort. Rev. **6:** 1-64.

Gower, J.C. 1971. A general coefficient of similarity and some of its properties. Biometrics **27:** 857-872.

Gao, Q. and Q.E. Yang. 2009. *Aconitum shennongjiaense* (Ranunculaceae), a new species from Hubei, China. Bot. Stud. **50:** 251-259.

Guo, H.L. and L.X. Zhang. 2006. Application of artificial neural network for classification of gooseberry species. J. Agric. Mech. Res. **12:** 195-198.

Hastie, T., R. Tibshirani, and J. Friedman. 2001. The elements of statistical learning data mining, inference, and prediction. Springer, New York, 533 pp.

Hayata, B. 1911. Icones Plantanum Formosanarum, Vol. I. Bureau of Forestry. Taihoku (Taipei). Taiwan, pp. 87-88.

Hayata, B. 1914. Icones Plantanum Formosanarum, Vol. IV. Bureau of Forestry. Taihoku (Taipei). Taiwan, p. 2.

Hayata, B. 1919. Icones Plantanum Formosanarum, Vol. VIII. Bureau of Forestry. Taihoku (Taipei). Taiwan, pp. 11-14.

Hayata, B. 1920. Icones Plantanum Formosanarum, Vol. IX. Bureau of Forestry. Taihoku (Taipei). Taiwan, pp. 7-8.

He, H. and L.B. Zhang. 2010. *Polystichum kungianum*, sp. nov. (sect. *Mastigopteris*, Dryopteridaceae) from Chongqing, China. Bot. Stud. **51:** 395- 401.

He, H. and L.B. Zhang. 2011. *Polystichum cavernicola*, sp. nov. (sect. *Haplopolystichum*, Dryopteridaceae) from a karst cave in Guizhou, China and its phylogenetic affinities. Bot. Stud. **52:** 121-127.

He, Z.C., Y. Zhong, H.T. Liu, X.H. Tang, Y. Li, D.S. Huang, and L.M. Xu, 2000a. Quantitative taxonomic analyses of *Actinidia* (Actinidiaceae) in China based on micromorphological characters of foliar trichomes. Acta Phytotax. Sin. **38:** 121-136.

He, Z.C., X.Y. Zhang, Y. Zhong, and Y. Li. 2000b. Phylogenetic relationships of *Actinidia* and related genera based on micromorphological characters of foliar trichomes. Genet. Resources Crop Evol. **47:** 627-639.

Henry, A. 1896. A list of plants from Formosa. Trans. Asia Soc. Jpn. **14:** 19-20.

Hou, M.F., Y. Liu, Y. Kono, and C.-I Peng. 2009. *Aspidistra daxinensis* (Ruscaceae), a new species from limestone areas in Guangxi, China. Bot. Stud. **50:** 371-378.

Hsieh, T.Y. 2002. A taxonomic study on the Ebenaceae of Taiwan. Master's thesis, Department of Horticulture, National Chung-Hsing University, Taichung, Taiwan.

Hsieh, T.Y., C.C. Nee, C.T. Chien, and H.F. Yen. 2002. A revision of the Ebebaceae in Taiwan. Hort. NCHU. **27:** 1-21.

Hsieh, T.Y., C.C. Nee, and C.T. Chien. 2004. Seed germination of Taiwanese *Actinidia latifolia* (Gardn. & Champ.) Merr. Taiwan J. For. Sci. **19:** 173-176.

Hsieh, T.Y., T.C. Hsu, Y. Kono, S.M. Ku, and C.-I Peng. 2007. *Gentiana bambuseti* (Gentianaceae), a new species from Taiwan. Bot. Stud. **48:** 349-355.

Hsieh, T.Y. 2011. Taxonomy and distribution of indigenous *Actinidia* in Taiwan. Ph.D. dissertation, Department of Horticulture, National Chung-Hsing University, Taichung, Taiwan.

Hsu, T.W., Y. Kono, T.Y. Chiang, and C.-I Peng. 2011. *Ypsilandra* (Melanthiaceae; Liliaceae sensu lato), a new generic record for Taiwan. Bot. Stud. **52:** 99-104.

Huang, H.W., Z.Z. Li, J.Q. Li, T.L. Kubisiak, and D.R. Layne. 2002. Phylogenetic relationships in *Actinidia* as revealed by RAPD analysis. J. Am. Soc. Hortic. Sci. **127:** 759-766.

Hughes, M., R.R. Rubite, Y. Kono, and C.-I Peng. 2011. *Begonia blancii* (sect. *Diploclinium*, Begoniaceae), a new species endemic to the Philippine island of Palawan. Bot. Stud. **52:** 203-209.

Ihaka, R. and R. Gentleman. 1996. R: a language for data analysis and graphics. J. Comput. Graph. Stat. **5:** 299-314.

Kanehira, R. 1936. Formosan trees. (rev. ed.) Dept. Forestry, Government Research Institute, pp. 754.

Korkovelos, A.E., A.G. Mavromatis, W.G. Huang, M. Hagidimitriou, A. Giakoundis, and C.K. Goulas. 2008. Effectiveness of SSR molecular markers in evaluating the phylogenetic relationships among eight *Actinidia* species. Sci. Hort. **116:** 305-310.

Ku, S.M. 2006. Systematics of *Begonia* sect. *Coelocentrum* (Begoniaceae) of China. Master's thesis, Department of Life Sciences, National Cheng-Kung University, Tainan, Taiwan.

Ku, S.M., Y. Kono, and Y. Liu. 2008. *Begonia pengii* (sect. Coelocentrum, Begoniaceae), a new species from limestone areas in Guangxi, China. Bot. Stud. **49:** 167-175.

Lammers, T.G. and L.L. Klein. 2010. A synopsis of *Codonopsis* subg. *Pseudocodonopsis* (Campanulaceae: Campanuloideae), with description of a new species of uncertain provenance. Bot. Stud. **51:** 553-561.

Li, H.L. 1952. The taxonomic review of the genus *Actinidia*. J. Arnold. Arb. **33:** 1-61.

Li, H.L. 1976. *Actinidia*. *In* H. L. Li et al. (eds.), Flora of Taiwan. Vol. 2. Taipei, Taiwan: Epoch Pub. Co., pp. 585-589.

Li, J.Q., Q. Cai, and H.W. Huang. 2000. On the phylogeny of the genus *Actinidia* Lindley. *In* H. W. Huang (ed.), Advance in *Actinidia* research, Science Press, Beijing, pp. 80-86.

Li, J.Q., H.W. Huang, and T. Sang. 2002. Molecular phylogeny and infrageneric classification of *Actinidia* (Actinidiaceae). Syst. Bot. **27:** 408-415.

Li, J.Q., X.W. Li, and D.D. Soejarto. 2007. Actinidiaceae. Fl. China **12:** 334-355.

Liang, C.F. 1984. *Actinidia*. *In* K. M. Fung (ed.), Flora Reipubliae Popularis Sinica, Vol. 49(2), Science Press, Beijing, pp. 196-324.

Liang, C.F. and A.R. Ferguson. 1985. Revision of infraspecific taxa of *Actinidia chinese* Planch. Guihaia. **5:** 71-72.

Lin, C.R., C.-I Peng, Y. Kono, and Y. Liu. 2010. *Aspidistra obconica*, Asparagaceae [Ruscaceae], a new species from limestone areas in Guangxi, China. Bot. Stud. **51:** 263-268.

Lindley, J. 1836. A Natural System of Botany. London: Longman, pp. 439.

Liu, Y., S.M. Ku, and C.-I Peng. 2007. *Begonia bamaensis* (sect. *Coelocentrum*, Begoniaceae), a new species from limestone areas in Guangxi, China. Bot. Stud. **48:** 465-473.

Liu, Y., G.X. Chen, and Q.E. Yang. 2009. *Sinosenecio baojingensis* (Asteraceae), a new species from Hunan, China. Bot. Stud. **50:** 107-113.

Liu, Y. and Q.E. Yang. 2010. *Sinosenecio yilingii* (Asteraceae), a new species from Sichuan, China. Bot. Stud. **51:** 269-275.

Liu, Y. and Q.E. Yang. 2011a. *Hainanecio*, a new genus of the Senecioneae, Asteraceae from China. Bot. Stud. **52:** 115-120.

Liu, Y. and Q.E. Yang. 2011b. *Sinosenecio sichuanicus* (Asteraceae), a new species from Sichuan, China. Bot. Stud. **52:** 219-223.

Liu, Y., D.G. Zhang, and Q.E. Yang. 2010. *Sinosenecio hupingshanensis* (Asteraceae), a new species from Hunan and Hubei, China. Bot. Stud. **51:** 387-394.

Liu, Z.Y., Y. Liu, and Q.E. Yang. 2011. *Sinosenecio nanchuanicus* (Asteraceae), a new species small in size yet high in chromosome number from Chongqing, China. Bot. Stud. **52:** 105-113.

Lu, C.T. and J.C. Wang. 2009. Three new species of *Asarum* (section Heterotropa) from Taiwan. Bot. Stud. **50:** 229-240.

Makino, T. 1901. Observations on the flora of Japan. Bot. Mag. Tokyo. **15:** 141-153.

Mallet, J. 2007. Hybrid speciation. Nature **446:** 279-283.

McNeill, J., F.R. Barrie, H.M. Burdet, V. Demoulin, D.L. Hawksworth, K. Marhold, D.H. Nicolson, J. Prado, P.C. Silva, J.E. Skog, J.H. Wiersema, and N.J. Turland (eds.). 2006. International Code of Botanical Nomenclature (Vienna Code). Ruggell, Vienna, A.R.G. Gantner Verlag.

Mou, F.J. and D.X. Zhang. 2010. *Rubovietnamia nonggangensis* (Rubiaceae), a new species from China. Bot. Stud. **51:** 119-126.

Nee, C.C. and T.T. Tsay. 1992. Kiwifruit in Taiwan. Acta Horticulturae **297:** 175-182.

Paradis, E. 2006. Analysis of Phylogenetics and Evolution with R. Springer, New York, 211 pp.

Peng, J.J. and F.Y. Lu. 1996. *Actinidia*. *In* T.C. Huang et al. (eds.), Flora of Taiwan 2nd ed. Vol. 2. Taipei, Taiwan; Editorial Committee, Department of Botany, National Taiwan University, pp. 656-661.

Peng, C.-I, T.Y. Hsieh, and N.Q. Ngyuen. 2007a. *Begonia kui* (sect. *Coelocentrum*, Begoniaceae), a new species from Vietnam. Bot. Stud. **48:** 127-132.

Peng, C.-I, C.L. Tiang, and T.W. Hsu. 2007b. *Tricyrtis ravenii* (Liliaceae), a new species from Taiwan. Bot. Stud. **48:** 357-364.

Peng, C.-I, Y. Liu, and S.M. Ku. 2008a. *Begonia aurantiflora* (sect. *Coelocentrum*, Begoniaceae), a new species from limestone areas in Guangxi, China. Bot. Stud. **49:** 83-92.

Peng, C.-I, S. M. Ku, Y. Kono, K.F. Chung, and Y. Liu. 2008b. Two new species of *Begonia* (sect. Coelocentrum, Begoniaceae) from limestone areas in Guangxi, China: *B. arachnoidea* and *B. subcoriacea*. Bot. Stud. **49:** 405-416.

Peng, C.-I and S.M. Ku. 2009. *Begonia* × *chungii* (Begoniaceae), a new natural hybrid in Taiwan. Bot. Stud. **50:** 241-250.

Peng, C.-I, Y. Liu, S.M. Ku, Y. Kono, and K.F. Chung. 2010. *Begonia* ×*breviscapa* (Begoniaceae), a new intersectional natural hybrid from limestone areas in Guangxi, China. Bot. Stud. **51:** 107-117.

Planchon, J.E. 1847. Sur la nouvelle famille des cochlospermres. Lond. J. Bot. **6:** 303.

Sam, Y.Y., A. Julius, and M.Y. Chew. 2009. *Haniffia flavescens* (Zingiberaceae): a new species from Peninsular Malaysia. Bot. Stud. **50:** 359-364.

Sheue, C.R., Y.P. Yang, H.Y. Liu, F.S. Chou, H.C. Chang, P. Saenger, C.P. Mangion, G. Wightman, J.W.H. Yong, and C. C. Tsai. 2009. Reevaluating the taxonomic status of *Ceriops australis* (Rhizophoraceae) based on morphological and molecular evidence. Bot. Stud. **50:** 89-100.

Sheue, C.R., H.Y. Liu, C.C. Tsai, and Y.P. Yang. 2010. Comparison of *Ceriops pseudodecanda* sp. nov. (Rhizophoraceae), a new mangrove species in Australasia, with related species. Bot. Stud. **51:** 237-248.

Siebold, P.F.B.V. and J.G. Zuccarini. 1843. Plantarum, quas in Japonica collegit Dr. Ph. Fr. de Siebold: genera nova, notis characteristicis delineationibusque illustrata. proponunt Ph. Fr. de Siebold et J. G. Zuccarini. Abhand, Math. Phys. Classe Konigl. Bayerischen Akad. Wissenschaften. **3:** 719-749.

Su, M.H., C.F. Hsieh, and C.H. Tsou. 2009. The confirmation of *Camellia formosensis* (Theaceae) as an independent species based on DNA sequence analyses. Bot. Stud. **50:** 477- 485.

Suezawa, K. 1989. Morphological variation on interspecies hybrid of *Actinidia*. Bull. Kagawa Agric. Exp. Stat. **40:** 36-42.

Tang, Y.C. and Q.Y. Xiang. 1989. A reclassification of the genus *Clematoclethra* (Actinidiaceae) and further note on the methodology of plant taxonomy. Acta Phytotax. Sin. **27:** 81-95.

Testolin, R., G. Cipriani, A.R. Ferguson, and R.C. Gardner. 1997. Molecular approaches to systematics of Actinidia. Acta Horticulturae **444:** 97-102.

Tian, B., T.L. Liu, and J.Q. Liu. 2010. *Ostryopsis intermedia*, a new species of Betulaceae from Yunnan, China. Bot. Stud. **51:** 257-262.

Tsai, C.H., T.Y. Hsieh, and C.C. Nee. 2003. Taxonomy and investigating of native species of *Pyrus* in Taiwan. Hort. NCHU. **28:** 19-42.

Wang, F.G., D.M. Liu, and F.W. Xing. 2010. Two new species of *Hypodematium* (Hypodematiaceae) from limestone areas in Guangdong, China. Bot. Stud. **51:** 99-106.

Warrington, I.J. and G.C. Weston. 1990. Kiwifruit: science and management. Ray Richards in association with the New Zealand Society for Horticultural Science Auckland, NZ., pp. 576.

Wiens, J.J. 2000. Phylogenetic analysis of morphological data. Smithsonian Institution, London, pp. 20-165.

Wong, S.Y. and P.C. Boyce. 2010a. Studies on Schismatoglottideae (Araceae) of Borneo IX: A new genus, *Hestia*, and resurrection of *Apoballis*. Bot. Stud. **51:** 249-255.

Wong, S.Y. and P.C. Boyce. 2010b. Studies on Schismatoglottideae (Araceae) of Borneo XI: *Ooia*, a new genus, and a new generic delimitation for *Piptospatha*. Bot. Stud. **51:** 543-552.

Wu, J.Y., M. Ogisu, H.N. Qin, and S.N. Lu. 2009. A new species of *Mahonia* Nutt. (Berberidaceae) from China. Bot. Stud. **50:** 487-492.

Xu, D.S., G.A. Hua, S. Liu, and S.W. Li. 1998. Multicomponent statistical analysis of sexual discrimination on *Actinidia* Lindl. J. Wuhan Bot. Res. **16:** 283-284.

Yang, A.T.Y. 2009. Additional remarks on Ranunculaceae in Taiwan (7)--Two new taxa and a new distributional record of *Clematis* in Taiwan. Bot. Stud. **50:** 499-510.

Yang, C.P. 2001. Numerical taxonomy of *Actinidia* species. Guangxi Hort. **2:** 6-7.

Yu, S.X., Y.T. Hou, Y.L. Chen, and H.N. Qin. 2009. *Impatiens lobulifera* (Balsaminaceae), a new species from limestone areas in Guangxi, China. Bot. Stud. **50:** 365-370.

Yuan, Q. and Q.E. Yang. 2009. *Anemone xingyiensis* (Ranunculaceae), a new species from Guizhou, China. Bot. Stud. **50:** 493- 498.

Yuan, Y.M., Y. Song, and X.J. Ge. 2011. *Impatiens qingchengshanica* (Balsaminaceae), a unique new species from China and its phylogenetic position. Bot. Stud. **52:** 225-230.

Zhang, D.G., Y. Liu, and Q.E. Yang. 2008. *Sinosenecio jishouensis* (Compositae), a new species from north-west Hunan, China. Bot. Stud. **49:** 287-294.

Zhang, L.B. and H. He. 2009a. *Polystichum peishanii* (sect. *Haplopolystichum*, Dryopteridaceae): a new fern species from a limestone area in Guizhou, China. Bot. Stud. **50:** 101-106.

Zhang, L.B. and H. He. 2009b. *Polystichum minutissimum* sp. nov. (sect. *Haplopolystichum*, Dryopteridaceae): the smallest *Polystichum* found in a karst cave in China. Bot. Stud. **50:** 353-356.

Zhang, L.B., H. He, and Q. Luo. 2010. *Polystichum puteicola*, sp. nov. (sect. *Haplopolystichum*, Dryopteridaceae) from a karst sinkhole in Guizhou, China based on molecular, palynological, and morphological evidences. Bot. Stud. **51:** 127- 136.

Zhao, Y.P., Y.X. Qiu, W. Gong, J.H. Li, and C.X. Fu. 2007. Authentication of *Actinidia macrosperma* using PCR-RFLP based on *trn*K sequences. Bot. Stud. **48:** 239-242.

台灣原生獼猴桃數值分類與分類定模之研究

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獼猴桃爲世界重要原生果樹之一，然而其形態性狀極爲複雜，長期以來造成分類、命名混亂與鑑定上的困難。本研究使用 60 個形態性狀，調查 72 個包含成熟雌、雄株在內的台灣野生獼猴桃族群，作爲分類運算單元。以高爾相似性係數計算族群間相似度，進行親緣分析，並將熱量圖排序後，得出五個明顯的類群斑塊，並發現介於台灣羊桃與硬齒獼猴桃之間的駝齒獼猴桃與腺齒獼猴桃漸滲雜交族群。依此結果進行指示反應矩陣編碼，再進行各種分類模型的性狀選擇與定模，以邏輯式迴歸模型作爲二類分類模型，貝氏判別模型作爲多類分類模型，並用這些分類模型對國內外各標本館的重要獼猴桃標本進行結合性判別分析，以確認各分類群學名使用之適確性。分析結果顯示，台灣共有四種一變種之原生獼猴桃，因此將台灣植物誌第二版中記載的硬齒獼猴桃（*Actinidia callosa*）訂正爲腺齒獼猴桃（*A. rufa*），駝齒獼猴桃（*A. callosa* var. *ephippioidea*）併入腺齒獼猴桃中，而紅莖獼猴桃（*A. rubricaulis*）則訂正爲異色獼猴桃（*A. callosa* var. *discolor*），台灣羊桃（*A. chinensis* var. *setosa*）提升爲台灣特有種；另台灣產四萼獼猴桃（*A. tetramera*）之紀錄，則爲軟棗獼猴桃（*A. arguta*）鑑定之誤，應予以更正。

關鍵詞：貝氏判別分析；台灣植物誌；熱量圖；邏輯式迴歸分類法；漸滲雜交；親緣分析。