

A taxonomic study of *Camellia brevistyla* and *C. tenuiflora* (Theaceae) based on phenetic analyses

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ABSTRACT. *Camellia brevistyla* and *C. tenuiflora*, two ecologically and economically important species of Taiwan, have long been confused due to their morphological similarities. This paper aims to clarify their taxonomic relationship based on phenetic analyses of morphological data. We characterized the patterns of morphological variations of *C. brevistyla* and *C. tenuiflora*, along with *C. hengchunensis* and *C. kissi*, throughout their geographic ranges in Taiwan. The ordination plots obtained from non-linear principal analyses showed considerable overlap among the samples of *C. brevistyla* and *C. tenuiflora*, and none of the characters applied was able to distinguish the two species apart. Further assessment of morphological characters revealed considerable morphological variations across the entire geographic range. Pearson's correlation coefficients for the data suggested the occurrence of a continuum of morphological variation among the *C. brevistyla*-*C. tenuiflora* complex. It is concluded that *C. brevistyla* and *C. tenuiflora* belong to a single highly-variable species and the taxonomic treatment of *C. tenuiflora* as a synonym of *C. brevistyla* is supported.

Keywords: *Camellia brevistyla*; *Camellia tenuiflora*; Phenetics; Taiwan; Taxonomy.

INTRODUCTION

Camellia are the largest and the type genus of Theaceae, with the number of species varying from 110 to 300 depending on different taxonomic treatments (Chang and Ren, 1998; Ming, 2000; Ming and Bartholomew, 2007). In Taiwan, 12 native species of *Camellia* were described in the second edition of the *Flora of Taiwan* (Hsieh et al., 1996). Thereafter, *C. buisanensis* Sasaki was moved to the genus *Pyrenaria* based on its morphological characters (Su et al., 2004) and *C. kissi* Wallich was newly recorded (Su et al., 2008). Among these Taiwanese *Camellia* species, the taxonomic ambiguity on the highly similar *C. brevistyla* (Hayata) Cohen-Stuart and *C. tenuiflora* (Hayata) Cohen-Stuart appears as one of the major taxonomic problems.

The type specimen of *C. brevistyla* was sourced from Arizan and Tozan, Chiayi County, south-central Taiwan (Hayata, 1908; in TAIIF) and that of *C. tenuiflora* was from Wantan, Taipei County, northern Taiwan (Hayata, 1911; in TI) (Figure 1); but no comparison on the two taxa was provided in Hayata's publications. Due to their high similarities, the taxonomic treatments on *C. brevistyla* and *C. tenuiflora* have been controversial for a long time. Most studies accepted them as two independent species (see literature in Table 1), but Ming and Bartholomew (2007)

merged them under the name of *C. brevistyla*. Several features on distinguishing *C. brevistyla* from *C. tenuiflora* were proposed, with leaf morphology and style number as key criteria (Table 1); however, serious problems occur while applying these criteria in the identification in the field. For example, the most dominant *Camellia* species in Chatienshan Nature Reserve (northern Taiwan) has been identified as *C. brevistyla* (Su and Wang, 1988; Lu et al., 1998) and *C. tenuiflora* (Tsoong and Chang, 1954; Hsieh et al., 1987). The same problem exists in the identification of the most dominant *Camellia* species in Hoping Logging Road in eastern Taiwan (e.g., *C. brevistyla*, S. Y. Lu 12703, TAIIF; *C. tenuiflora*, M. F. Kao 260, TAIIF; *C. tenuiflora*, J. C. Wang et al. 8620, TNU; Appendix 1).

Camellia brevistyla and *C. tenuiflora* are widely distributed in Taiwan based on specimens from various herbaria (Figure 1) and form important components in those broadleaved forests (Hsieh et al., 1987; Yang, 1997; Chen, 2005). These two species are also cultivated for oil production and horticultural purposes (Wang and Lin, 1990; Wang et al., 1994; Ming, 2000). Therefore, detailed taxonomic studies are essential not only for the identification of these species in the field, but also for the conservation and management of natural resources (Meiri and Mace, 2007). In this study, the taxonomic clarity of *C. brevistyla* and *C. tenuiflora* is addressed and the patterns of morphological variation of *C. brevistyla*

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and *C. tenuiflora* throughout their geographic ranges in Taiwan are characterized. Two native sibling species, *C. hengchunensis* Chang and *C. kissi* from the section *Paracamellia* (Ming, 2000; Vijayan et al., 2009) which *C. brevistyla* and *C. tenuiflora* belong to, are also compared. Many previous studies show that plants usually exhibit a morphological plasticity in response to environmental

conditions (Thompson, 1991; Rôças et al., 1997) and that frequently causes taxonomic problems. Since *C. brevistyla* and *C. tenuiflora* are widely distributed, a test of the correlation between morphological variation and geographical location of the two taxa is also conducted in this study.

MATERIALS AND METHODS

Materials

For scoring morphological characters, specimens deposited in the herbaria were examined (Appendix 1). Each collection was designated as an operational taxonomic unit (OTU). Duplicate specimens were treated as the same OTU. Scientific names given on the labels of specimens were tentatively used. A total of 149 specimens were examined, but those without sufficient measurable or label information were excluded from the data analyses. Finally, 74 specimens (OTUs), including 24 specimens of *C. brevistyla*, six of *C. hengchunensis*, four of *C. kissi* and 40 of *C. tenuiflora*, were included (Appendix 1). The specimens of *C. brevistyla* and *C. tenuiflora* represent their distribution range in Taiwan (Figure 1). Although type specimens of *C. brevistyla* and *C. tenuiflora* were not included in the study because they did not provide enough measurable traits, specimens from the type locality were used (e.g. *C. brevistyla*, M. H. Su 679 and 681, TAI; *C. tenuiflora*, P. F. Lu 7175, TNU; Appendix 1). The small sample sizes of *C. hengchunensis* and *C. kissi* were due to their limited distribution and small population sizes in Taiwan (Figure 1).

Characters analysis

Thirty-three characters were chosen on the basis of the variation mentioned in the literature and our own judgement: 12 leaf characters, 16 floral characters and five fruit characters (Tables 2-4). For each specimen, five mature and healthy-looking leaves were scored and averaged. The measurements of floral and fruit characters were averaged from one to three replicates, depending on the condition of the specimen.

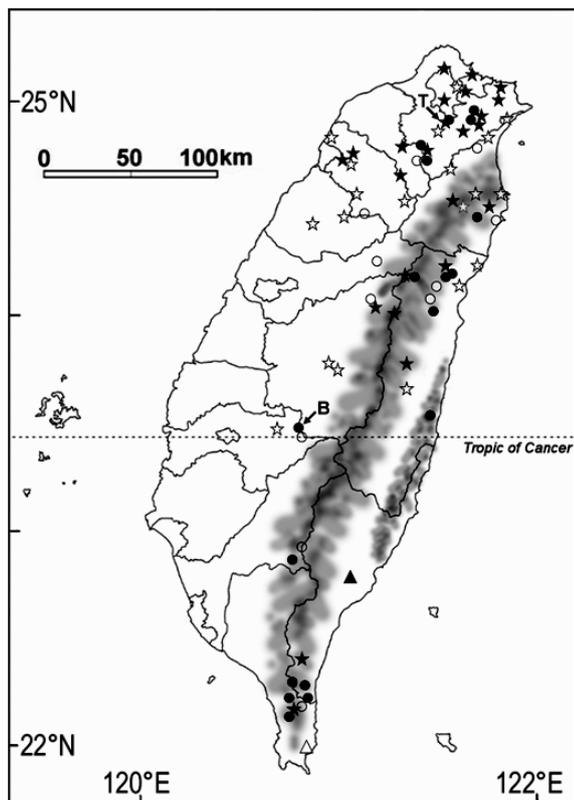


Figure 1. Distribution of the populations of *Camellia brevistyla* and *C. tenuiflora* in Taiwan. Solid circle, *C. brevistyla* sampled. Open circle, *C. brevistyla* not sampled. Solid star, *C. tenuiflora* sampled. Open star, *C. tenuiflora* not sampled. Solid triangle, *C. kissi*. Open triangle, *C. hengchunensis*. Arrow marked with B, collection site of type specimen of *C. brevistyla*. Arrow marked with T, collection site of type specimen of *C. tenuiflora*. Data were sourced from HAST, PPI, TAI, TAIF, TNM, and TNU.

Table 1. A comparison of the useful taxonomical features of *Camellia brevistyla* and *C. tenuiflora* cited in previous reports.

Source	<i>C. brevistyla</i>	<i>C. tenuiflora</i>
Yamamoto and Mori, 1934	Secondary veins inconspicuous.	Secondary veins flat or stressed above, conspicuous beneath.
Keng, 1950	Styles 4, 1 mm long, connate at base.	Styles 3, 3 mm long, free at upper portion or entirely connate at the base.
Liu and Lu, 1967	Secondary veins inconspicuous.	Secondary veins 5-8 pairs, conspicuous, slightly elevated on both surfaces.
Li, 1976	Styles 1-1.5 mm long, connate at base.	Styles 3 mm long, free at upper portion or entirely connate.
Ying, 1995	Leaf apex obtuse; styles 3-fid.	Leaf apex acute; styles shallowly 3-fid or entirely connate.
Hsieh et al., 1996	Styles 4, 1-1.5 mm long; leaves rhombic-oblong, midribs pubescent above.	Styles 3, more than 2.5 mm long; leaves obovate-elliptic, midribs almost glabrous above.

Table 2. Loadings of the 12 leaf characters on the first three axes of non-linear principal component analysis (NLPCA). Eigenvalues, Cronbach's α , percentage and cumulated percentage of variance accounted for are given for each axis.

Character	NLPCA axis		
	1	2	3
Leaf length	0.67	0.68	-0.06
Leaf width	0.61	0.48	0.12
Leaf thickness	0.83	-0.38	-0.05
Leaf shape	0.24	-0.53	0.59
Leaf apex shape	-0.10	-0.80	-0.03
Leaf serration	-0.85	0.37	0.12
Midrib pubescence	0.92	-0.32	-0.11
Pairs of secondary veins	0.36	0.36	0.34
Secondary vein angle	-0.62	-0.12	0.28
Secondary vein prominence	-0.46	-0.18	-0.69
Petiole length	0.62	0.39	-0.17
Petiole pubescence	0.92	-0.32	-0.11
Eigenvalue	5.09	2.43	1.10
Cronbach's α	0.88	0.64	0.10
Variance explained (%)	42.38	20.23	9.19
Cumulative variance explained (%)	42.38	62.61	71.80

Data analysis

To analyze the phenological features of the specimens, the data were rearranged into three combinations of leaf characters (74 OTUs \times 12 characters), floral characters (48 OTUs \times 16 characters) and fruit characters (34 OTUs \times 5 characters).

To group the OTUs and assess the pattern of morphological variation, nonlinear principal components analysis (NLPCA, de Leeuw, 1982) was performed. To assess the reliability of each component (NLPCA axis), Cronbach's α (Cronbach, 1951) was computed and a value of 0.70 or greater was considered to indicate the reliability (Bland and Altman, 1997). To investigate the relationship between geographic location and morphological variation among specimens of *C. brevistyla* and *C. tenuiflora*, an analysis of the Pearson correlation was conducted. Each geographic locality, obtained from the specimen labels, was defined by longitude, latitude and altitude. Total morphological variation was represented by the OTU scores on the first two NLPCA axes. All analyses in this study were performed using SPSS software v11.0 (SPSS Inc.).

RESULTS

The first three NLPCA axes generated in the analysis based on leaf characters accounted for 71.8% of the total variance; the first axis accounted for 42.38% of the total variance and was highly reliable (Cronbach's

$\alpha = 0.88$, Table 2). The second axis was close to the level of reliability of the first (Cronbach's $\alpha = 0.64$) and explained a further 20.23% of the variance. The ordination plot based on the first two axes showed three distinct groups, designated as Gr1-1, Gr1-2 and Gr1-3 (Figure 2a). Gr1-1 was composed of *C. kissi* and Gr1-2 of *C. hengchunensis*, while Gr1-3 was a mixture of *C. brevistyla* and *C. tenuiflora*. The leaf characters with high loadings on the first axis were length, width, thickness, serration, midrib pubescence, secondary vein angle, petiole length and petiole pubescence (Table 2), which separated *C. hengchunensis* (Gr1-2) from the other three taxa. The characters that contributed most to the second axis were leaf length and apex shape (Table 2). *Camellia kissi* (Gr1-1) can be distinguished easily from the *C. brevistyla*-*C. tenuiflora* mixture (Gr1-3) along this axis.

The first three axes of NLPCA using floral characters explained less than half of the total variance (49.62%). The first axis was reliable (Cronbach's $\alpha = 0.81$, Table 3) but accounted for only 26.03% of the variance. The characters with high loadings on the first axis were petal length, petal width, sepal length, sepal width, style length and style pubescence (Table 3). However, variation of those characters was continuous and overlapped among OTUs from

Table 3. Loadings of the 16 floral characters on the first three axes of non-linear principal component analysis (NLPCA). Eigenvalues, Cronbach's α , percentage and cumulated percentage of variance accounted for are given for each axis.

Character	NLPCA axis		
	1	2	3
Petal number per flower	-0.06	-0.11	-0.13
Petal length	0.81	-0.03	0.03
Petal width	0.75	-0.16	-0.09
Petal pubescence	0.01	0.48	-0.74
Petal emargination	-0.06	-0.10	-0.23
Sepal number per flower	0.35	0.51	0.21
Sepal length	0.73	0.10	-0.07
Sepal width	0.78	0.04	-0.02
Sepal pubescence	-0.11	-0.47	0.77
Filament length	0.44	-0.52	-0.09
United filament tube length	-0.55	-0.43	0.06
Style length	0.81	-0.08	0.08
Style number per flower	0.03	0.62	0.59
United style length	0.13	-0.56	-0.38
Style pubescence	-0.64	0.16	-0.17
Ovary length	0.31	0.03	0.08
Eigenvalue	4.16	1.96	1.82
Cronbach's α	0.81	0.52	0.48
Variance explained (%)	26.03	12.23	11.36
Cumulative variance explained (%)	26.03	38.26	49.62

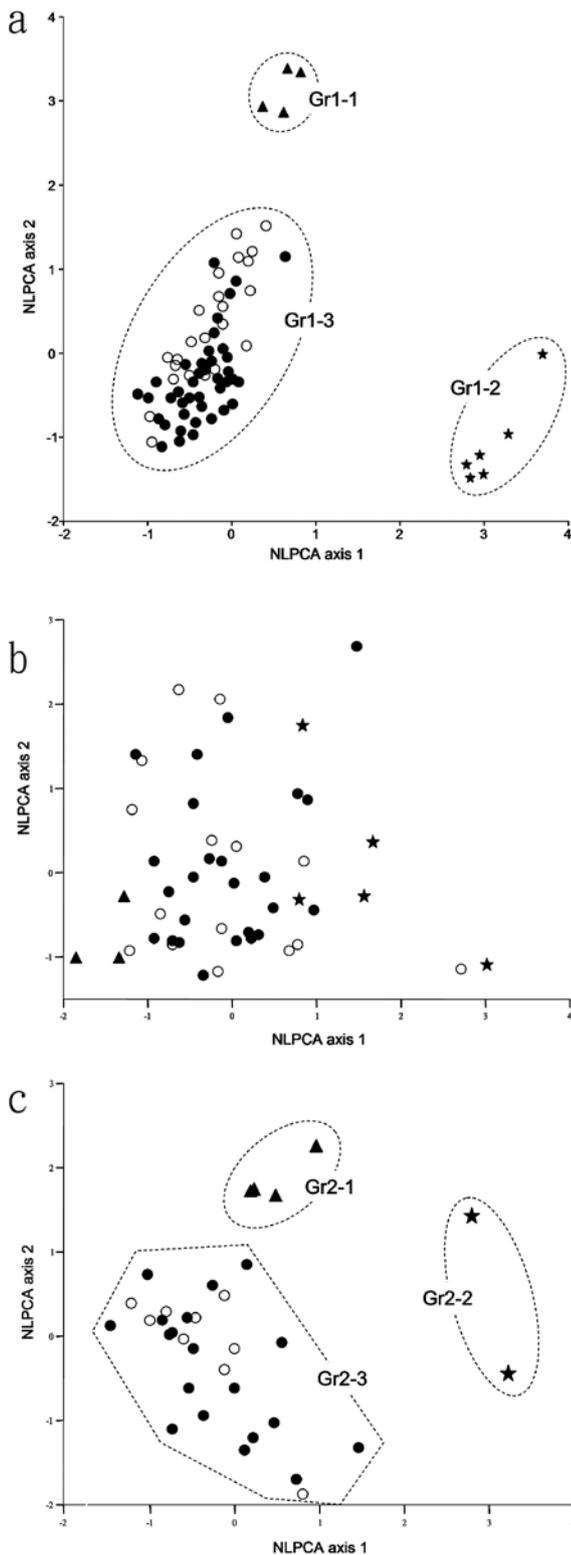


Figure 2. Ordination plots of the first two axes of NLPCA based on leaf (a), floral (b) and fruit (c) characters. Open circle, *Camellia brevistyla*. Solid circle, *C. tenuiflora*. Solid star, *C. hengchunensis*. Solid triangle, *C. kissi*.

Table 4. Loadings of the five fruit characters on the first three axes of non-linear principal component analysis (NLPCA). Eigenvalues, Cronbach's α , percentage and cumulated percentage of variance accounted for are given for each axis.

Character	NLPCA axis		
	1	2	3
Fruit shape	0.72	0.55	-0.02
Fruit length	0.95	-0.13	-0.23
Fruit width	0.67	-0.64	-0.32
Fruit pedicel length	0.58	0.62	0.31
Fruit pubescence	0.36	-0.58	0.72
Eigenvalue	2.33	1.44	0.77
Cronbach's α	0.71	0.39	-0.37
Variance explained (%)	46.59	28.89	15.44
Cumulative variance explained (%)	46.59	75.48	90.92

C. hengchunensis, *C. kissi* and the species complex of *C. brevistyla* and *C. tenuiflora*. No clear distinction could be found among the previously-recognized groups along the first axis (Figure 2b).

In NLPCA based on fruit characters (Table 4), the first axis accounted for nearly half of the total variance (46.59%) and was the only reliable axis (Cronbach's $\alpha = 0.71$). Three distinct groups, Gr2-1, Gr2-2 and Gr2-3, were recognized in the ordination plot based on the first two axes (Figure 2c). Gr2-1 was composed of *C. kissi* and Gr2-2 of *C. hengchunensis*, while Gr2-3 was a mixture of *C. brevistyla* and *C. tenuiflora*. Fruit shape, length, width and pedicel length were the most important for determining the scores of OTUs on the first axis, whereas fruit width, pedicel length and pubescence were the most important for determining the second axis (Table 4).

The test of correlations between geographic location and morphological variation among specimens of *C. brevistyla* and *C. tenuiflora* (Table 5) revealed that variation of leaf characters was significantly correlated with longitude (the first and second axes of NLPCA) and latitude (the second axis of NLPCA), but not correlated with altitude. Neither the test for floral characters nor that for fruit characters showed any significant correlation.

DISCUSSION

The phenetic analyses showed that samples of *C. brevistyla* and *C. tenuiflora* were mixed in a group in all the ordination plots. The morphological characters traditionally used to distinguish them apart include leaf shape, leaf apex shape, secondary vein prominence, style number and style length (Table 1). However, our analyses based on every single character and all kinds of combinations of multiple characters failed to show any discrete clusters within the *C. brevistyla*-*C. tenuiflora* complex.

Table 5. Pearson's correlation coefficients between geographic locations and scores of the first two NLPCA axes based on leaf, flower and fruit characters.

	Leaf (n=64)			Flower (n=40)			Fruit (n=28)		
	LG	LT	ALT	LG	LT	ALT	LG	LT	ALT
NLPCA axis 1	-0.26*	-0.23	0.07	0.22	0.15	0.12	-0.02	-0.03	0.05
NLPCA axis 2	-0.31*	-0.44**	0.11	0.12	0.20	0.12	0.04	-0.09	-0.05

LG: longitude; LT: latitude; ALT: altitude. Correlation is significant at the 0.05 (*) or 0.01 (**) level using a 2-tailed test.

According to Keng (1950) and Hsieh et al. (1996), *C. brevistyla* has a style less than 1.5 mm long, whereas *C. tenuiflora* has a style longer than 2.5 mm; however, half (20/40) of the specimens examined have a style between 1.5 and 2.5 mm long. The four-styled feature was also used as a diagnostic character for *C. brevistyla* when the species was firstly described (Hayata, 1908); but in fact, the number of styles of the specimens scored in this study ranged from one to four: 28 out of 40 specimens with three styles, and only one specimen (A. T. Hsieh and M. T. Kao 2, Appendix 1) with four styles. A flower with three styles is a common character of species in section *Paracamellia* (Sealy, 1958); thus the four-styled state seems to be a rare case and unsuitable for distinguishing *C. brevistyla* from *C. tenuiflora*. The taxonomic importance of secondary vein prominence, which was emphasized in some literatures (Yamamoto and Mori, 1934; Liu and Lu, 1967) and adopted by some field investigators, displayed only a low loading in the NLPCA results (Table 2). Leaf shape and leaf apex shape displayed higher loadings on the second NLPCA axis; however, these characters are effective for the identification of *C. kissi* rather than for resolving the *C. brevistyla*-*C. tenuiflora* complex.

The correlation test showed that leaf variation in the *C. brevistyla*-*C. tenuiflora* complex is associated with geographic location (Table 5). Many studies have revealed such a relationship, which has been interpreted as a phenotypic response (adaptation) to the environmental gradient (Jonas and Geber, 1999; Santamaria et al., 2003; Herrera, 2005) and claimed to cause taxonomic confusions (Ellison et al., 2004). *C. brevistyla* was first described based on a specimen from Chiayi County (south-central Taiwan) and *C. tenuiflora* based on a specimen from Taipei County (near northern tip of Taiwan). Since type specimens of these two species were obtained from two extremes of the geographical range in Taiwan, our analyses suggest that it could be one of the reasons why *C. brevistyla* and *C. tenuiflora* have long been treated as two species. However, the patterns of morphological variations were found to be continuous along the geographical gradient. While the variation throughout the range of the complex has been considered, no proper delimitation of *C. brevistyla* and *C. tenuiflora* could be made.

Based on leaf and fruit characters, samples of *C. hengchunensis* and *C. kissi* were clearly separated from each other in the ordination plots, and both were also clearly distinct from the *C. brevistyla*-*C. tenuiflora*

complex. The results suggest that *C. hengchunensis* and *C. kissi* should be treated as distinct species, respectively, and thus are not in agreement with the view that *C. hengchunensis* should be reduced to a synonym of *C. brevistyla* (Ming and Bartholomew, 2007). Useful characters to identify *C. hengchunensis* are the glabrous midrib, acute or obtuse leaf apex, thick leaf blades, nearly entire margins, glabrous petioles, and oblong capsules. *Camellia kissi* can be identified by its caudate leaf apex, longer leaf blades (> 5.5 cm), villose midrib and pyriform capsules, as mentioned by Su et al. (2008).

In conclusion, the present phenetic study does not support the treatment of *C. tenuiflora* and *C. brevistyla* as two distinct species. The treatment of *C. tenuiflora* as a synonym of *C. brevistyla* as earlier proposed by Ming and Bartholomew (2007) is supported.

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Appendix 1. List of voucher specimens used in the phenetic analyses. Counts of specimens collected in the same county are included in parentheses.

County	Collection information
<i>C. brevistyla</i>	
Taipei (4)	Erhkoshan , 8 Nov. 1998, <i>S. S. Li 174</i> (TAIF). Lopeishan , 1,500 m, 27 Aug. 1935, <i>T. Suzuki ST18965</i> (TAI). Peichatienshan , 600-1,400 m, 28 Sep. 1984, <i>R. T. Li 3535</i> (TAI). Sintien Stream , 23 Nov. 1932, <i>T. Suzuki 7829</i> (TAI).
Ilan (2)	Songluo Lake , 1240 m, 20, Jul. 2000, <i>S. W. Chung 2677</i> (TAIF); same date, <i>C. C. Chen 7460</i> (TAIF).
Chiayi (3)	Menyue , 2,300 m, 1 Nov. 1918, <i>E. H. Wilson s. n.</i> (TAIF). Tozan , 2,100 m, 26 Oct. 2005, <i>M. H. Su 679, 681</i> (TAI).
Hualien (7)	Hopping Logging Road , 57 km, 2,100 m, 3 Aug. 1983, <i>S. Y. Lu 12703</i> (TAIF). Lainshan , 1,850-1,900 m, 10 Aug. 1956, <i>Liu et al. 150</i> (TAI); 2100-2330 m, 15 Aug. 1956, <i>Liu et al. 242</i> (TAI). Paliwanshan , 900 m, 21 Dec. 2004, <i>M. H. Su 587, 588, 589</i> (TAI). Pilu , 2300 m, 20 Sep. 1985, <i>S. Y. Lu 17013</i> (TAIF).
Kaohsiung (1)	Sasi Logging Road , 1,640 m, 19 Nov. 1983, <i>S. Y. Lu s. n.</i> (TAIF).
Pingtung (4)	Fanshan , 31 Jan. 1997, <i>S. Y. Lu 25226</i> (TAIF). Chachayalaishan , 900 m, 27 Dec. 1995, <i>S. Y. Lu 24940</i> (TAIF). Lilongshan , 1,000 m, date unknown, <i>H. M. Chang s. n.</i> (TAI); 12 Jul. 1993, <i>T. T. Chen et al. 1544</i> (TAIF).
Taitung (3)	Kwetien , 560 m, 11 Nov. 2003, <i>M. H. Su 439, 441</i> (TAI). Tawu , 28 Sep. 1997, <i>K. C. Yang 5106</i> (TAIF).
<i>C. tenuiflora</i>	
Keelung (2)	Chingjen Lake , 200 m, 30 Oct. 2003, <i>Y. P. Cheng 4232</i> (TAIF); 150 m, 28 Aug. 1993, <i>W. P. Leu et al. 1988</i> (TNU).
Taipei (17)	Chaitsushan , 18 Oct. 1938, <i>T. Nakamura 2217</i> (TAI). Erhkoshan , 600 m, 23 Nov. 1996, <i>C. H. Chen 1878</i> (TNU). Houtung , 2 Jan. 1996, <i>S. Y. Lu 24944</i> (TAIF). Huangtieten , 10 Sep. 1985, <i>K. C. Yang 1612</i> (TAI); 500-550 m, 22 Aug. 1996, <i>C. K. Liou et al. 355</i> (TNU); 300-500 m, 22 Dec. 1995, <i>J. C. Wang 9726</i> (TNU); 500-570 m, 4 Oct. 1996, <i>J. C. Wang et al. 10196</i> (TNU); 450-500 m, 16 Aug. 2003, <i>S. C. Liu & H. M. Chang 1450</i> (TNU). Kuolai , 25 Dec. 1988, <i>Y. P. Chiang s. n.</i> (TNU). Lusytarn , 21 Feb. 1983, <i>S. Y. Lu 12521</i> (TAIF). Mon Lake , 600 m, 23 Dec. 2003, <i>M. H. Su 488</i> (TAI). NTU campus , 1939 (date unknown), <i>K. Mori s. n.</i> (TAI). Panpinshan , 510-550 m, 11 Aug. 1996, <i>C. K. Liou et al. 281</i> (TNU). Peichatienshan , date unknown, <i>H. M. Chang s. n.</i> (TAI). Taipei , 9 Dec. 1927, <i>Sasaki s. n.</i> (TAI). Tongho , 23 Sep. 1979, <i>C. L. Huang 834</i> (TAI). Tsankuangliaoshan , 738 m, 3 Jun. 1998, <i>Y. P. Cheng 2290</i> (TAIF).
<i>C. tenuiflora</i>	
Taipei (5)	Wantan , 450 m, 31 Dec. 2003, <i>P. F. Lu 7175</i> (TNU). Wu-er-cha-hu-shan , 300 m, 7 Nov. 2005, <i>M. H. Su 682</i> (TAI) Yangmingshan , 13 Nov. 1924, <i>Sasaki s. n.</i> (TAI); 2 Nov. 1928, <i>Sasaki s. n.</i> (TAI); 15 Dec. 1934, <i>Sasaki s. n.</i> (TAI).
Ilan (2)	Taipingshan , date unknown, <i>C. T. Huang s. n.</i> (TAI) Yu-en-shan , 700 m, 8 Oct. 2003, <i>M. H. Su 326</i> (TAI)

Appendix 1. (Continued)

County	Collection information
Taoyuan (1)	Wutukushan , 100-300 m, 11 Sep. 2002, <i>C. C. Chen s. n.</i> (TNU).
Hsinchu (5)	Hsinchu , Oct. 1913, <i>S. Sasaki 19699</i> (TAI), Litungshan , 1,940 m, 19 Sep. 2000, <i>S. W. Chung 3077</i> (TAIF); 1,914 m, 7 Dec. 2002, <i>Y. Y. Huang 1261</i> (TAI); 1,540-1,913 m, 28 Aug. 2003, <i>S. C. Liu 1512</i> (TNU). Peipu , Dec. 1910, <i>Kawakami s. n.</i> (TAIF)
Hualien (4)	Ertzishan , 2,100 m, 28 Jul. 1984, <i>S. Y. Lu 15010</i> (TAIF). Hoping Logging Road , 1,800-2,100 m, 21 Sep. 1991, <i>M. F. Kao 260</i> (TAIF); 1,800 m, 28 Jul. 1993, <i>J. C. Wang et al. 8620</i> (TNU). Tayulin , 2,047 m, 4 Dec. 1997, <i>C. K. Liou et al. 918</i> (TAIF).
Nantou (2)	Noko , 11 Dec. 1930, <i>Sasaki s. n.</i> (TAI) Weisun , 27 Feb. 1955, <i>A. T. Hsieh & M. T. Kao 2</i> (TAI)
Pingtung (1)	Peililongshan , 800 m, 27 Jan. 1994, <i>T. T. Chen et al. 3062</i> (TAIF).
Taitung (1)	Tuyayuanshan , 1,230 m, 30 Apr. 2005, <i>M. H. Su 619</i> (TAI).
<i>C. hengchunensis</i>	
Pingtung (6)	Nanjen Lake , 100 m, 30 May 1991, <i>C. H. Tsou & K. H. Wang 482</i> (PPI). Nanjenshan , Oct. 1919, <i>E. Matuda s. n.</i> (TAI); 15 Dec. 1977, <i>C. I. Peng 3464</i> (TAI); 320 m, 5 Jan. 1984, <i>S. Y. Lu 13900</i> (TAIF); 11 Jan. 1980, <i>C. E. Chang s. n.</i> (PPI). Tsufonbi , 370 m, 6 Jan. 1984, <i>S. Y. Lu 13877</i> (TAIF).
<i>C. kissi</i>	
Taitung (4)	Chuifenshan , 1,200 m, 29 Sep. 2005, <i>M. H. Su 662, 663, 664, 665</i> (TAI).

使用數值分類方法探討短柱山茶與細葉山茶之分類問題

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短柱山茶與細葉山茶是兩個在生態與經濟上都佔有重要地位的原生山茶屬植物，但因為形態上的近似度高而經常有難以區分的情況。本研究旨在使用以形態特徵為基礎的數值分類方法來探討兩者之間的關係。我們測量了短柱山茶、細葉山茶、恆春山茶與落瓣油茶的標本，標本來源涵蓋了台灣全島。非線性主成份分析結果指出，短柱山茶與細葉山茶形成一個無法分割的混合群，顯示兩者的形態變異極大且有所重疊。對此混合群，進一步以 Pearson 相關係數進行分析，發現其形態變異與地理位置呈現顯著相關。綜合上述，本研究認為短柱山茶與細葉山茶並無法以形態進行確切的分類，本結果支持先前將細葉山茶併入短柱山茶之分類處理。

關鍵詞：短柱山茶；細葉山茶；數值分類；台灣。