Variation in Morphological Traits among *Loropetalum chinense* var. *rubrum* Accessions

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Abstract. *Loropetalum chinense* var. *rubrum* accessions in China have not been adequately characterized for their morphological traits. Such characterization would be helpful in the development of improved cultivars and in cultivar classification. In this study, the morphological traits of 23 accessions were evaluated in spring, summer, and autumn to determine their phenotypic diversity. Cluster analysis with average distance was performed for the main traits of leaf and flower using data processing system software. The morphological investigation indicated that the number of flowering accessions and the flower number of *L. chinense* var. *rubrum* in spring were more than those in autumn. Only one accession (no. 13) yielded several flowers in summer. Some accessions had the same or similar color of leaf or flower in spring and autumn. Two accessions had the same flower color in spring and autumn, whereas others showed slightly different colors in spring and autumn. The 23 entries were grouped into four clusters in spring and five clusters in autumn based on multivariate analysis of nine classification variables. Each cluster had some specific characteristics of its own. Generally, the cluster formed first because of the similarity in leaf color. The accessions with similar flower color formed subclusters within a cluster. These accessions are an important resource for the establishment of a core collection of *L. chinense* var. *rubrum* in the world. Several accessions with good qualities were selected and should be further tested for horticultural merit.

Loropetalum chinense var. *rubrum* is an evergreen, purple-leafed, medium-size shrub from Hunan Province, China (Hou et al., 2003). It is a member of the witch hazel family (Hamamelidaceae) and is defined as a variety of *L. chinense* (Creech, 1960). The gracefully layered branches are laden during spring and sporadically throughout the year with pendulous, bright-pink, spiderlike flowers. It is fast growing and tolerant to diseases and insects. *Loropetalum chinense* var. *rubrum* is versatile and can be grown in mild coastal climates in light shade to full sun, and can tolerate the more extreme winter and summer temperatures associated with other regions. As an important ornamental plant, *L. chinense* var. *rubrum* is very popular in Chinese cities and has been introduced into many foreign countries like America and Japan. For example, two selections of the hot-pink/purple-flowered *L. chinense* var. *rubrum* were introduced into the United States from Nihonkaki Nursery, Kawaguchi

City, Japan, by the former U.S. National Arboretum Director, John L. Creech, in September 1989 at the request of Sylvester G. March (Gawel et al., 1996). The plants rapidly entered the commercial market. In an attempt to give some order to the confusion of multiple accessions and clones, the U.S. National Arboretum named the purple-foliage form ‘Burgundy’, and the green-foliage form ‘Blush’. More than 15 different introductions of *L. chinense* var. *rubrum* have been established in North America since the late 1980s (Hou et al., 2004). Selection and registration of cultivars has been carried out since then.

In recent years, with rapid introduction and commercialization of *L. chinense* var. *rubrum*, much confusion concerning the identity of the cultivars has arisen. Although many investigations have been carried out by Chinese researchers (Hou et al., 2003; Huang et al., 2004; Liu and Zhang, 2001; Song et al., 1982; Tang and Zhou, 2001; Tang et al., 2003), the study of *L. chinense* var. *rubrum* in China is still in its primary stage, and accessions have not been adequately characterized for morphological traits. The extent of phenotypic diversity among *L. chinense* var. *rubrum* accessions throughout the world is

not known. Evaluation and comparison of accessions in different seasons will be helpful in developing improved cultivars and in cultivar identification.

The objectives of this study were to 1) compare leaf and flower traits of various accessions in spring, summer and autumn; 2) characterize phenotypic diversity among these accessions using cluster analysis; and 3) select some accessions with good characters to use in the landscape.

Materials and Methods

Seedlings were collected from Liuyang City, Hunan Province, China, and planted in the *L. chinense* var. *rubrum* Garden at the Academic Institution of Landscape Gardening of Changsha, the capital city of Hunan Province, in 1998. Field tests were established in spring 2001. Twenty-one accessions were selected from the garden according to their different appearances of flowers in spring, and were numbered from 1 to 21. There were two that flowered heavily in autumn of 2001, so they were added as nos. 26 and 27. The dates of investigation in spring, summer, and autumn were from 1 to 10 Apr., from 3 to 9 Aug., and from 2 to 6 Nov. respectively. Young leaf color, mature leaf color, underside color of young leaf, leaf shape, leaf length, leaf width, leaf length-to-width ratio, flower number, flower color, petal length, petal width, petal length-to-width ratio, floret number, and petal number were measured in every investigation. Also, spring shoot length and offshoot angle were measured in the summer investigation, and summer shoot length was measured in the autumn investigation. Ten observations were collected for each variable from each plant and means were calculated. The representative branches were cut from different parts of the plant and carried to the laboratory to determine leaf and flower color using the Royal Horticultural Society Color Chart under northward scattered light (Royal Horticultural Society and Flower Council of Holland, 1986).

The representative traits were subjected to variance and cluster analyses with data processing system software (Tang and Feng, 2002). Multivariate analysis has been used in many plant species to group accessions and cultivars into clusters (Berdahl et al., 1999; Naghavi et al., 2005; Steiner et al., 1998). The main traits of leaf and flower—young leaf color, underside color of young leaf, mature leaf color, leaf length-to-width ratio, flower number, flower color, petal length-to-width ratio, floret number, and petal number—were used for classifying accessions into clusters in the current study. All qualitative data were transformed into numbers, and cluster analysis was performed using the following algorithm: 1) identify the minimum distance between any two taxa, 2) combine these two taxa as a single pair, 3) recalculate the average distance between this pair and all other taxa to form a new matrix, and 4) identify the closest pair in the new

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matrix and so on, until the last two clusters are joined.

Results and Discussion

Data from spring observations

Leaf color, size, and shape. New spring growth emerged crimson to light red. Most of the colors belonged to Greyed-Purple Group (183–187), with others in the Yellow-Green Group (144–154), Greyed-Orange Group (163–177), or Greyed-Red Group (178–182). The leaf underside colors ranged from red to gray-red to gray-purple. The mature leaf color, measured in spring, ranged from brown to gray-purple to green to yellow-green. Mature leaf length ranged from 2.06 to 5.52 cm, and leaf width ranged from 1.28 to 3.44 cm. The leaf length-to-width ratio ranged from 2.24 to 1.40 (Table 1).

Flower number and color. All accessions flowered in spring except nos. 16, 19, and 20. All flower colors were in the Red-Purple Group (57–74) with variation in the intensity (Table 1).

Petal size and number, and floret number. Petal length ranged from 1.34 to 2.40 cm, and petal width ranged from 0.13 to 0.22 cm. The petal length-to-width ratio ranged from 8.02 to 16.48. Most accessions had four petals per floret, with several accessions containing occasional five petals per floret. There were generally five to eight florets per inflorescence (Table 1).

Data from summer observations

The young leaf color of accession nos. 10, 11, and 12 was gray-purple (183A, 183A, and 183B respectively). The young leaf color of accessions nos. 5, 6, 7, 8, 9, 13, 14, 15, 16, 17, and 18 was gray-orange (163–177). The young leaf color of accession no. 1 was different from others, which turned green soon after new growth and was yellow-green (146A). The young leaves of accession no. 4 emerged earlier, some of which were bigger than mature leaves. Its color was green (137B). But its sprouts were still red, and turned green quickly under high temperatures in summer. All mature leaves in the investigation in summer emerged in spring, and turned green. Their colors were yellow-green (147A or 146A). Only one accession (no. 13) yielded several flowers in summer. There were four to five light-pink (62A) flowers at each branch tip.

Data from fall observations

Summer shoot length. Summer shoot length ranged from 8.48 to 18.48 cm (average, 10.0–16.0 cm; Table 2). Generally, the length of summer shoots was greater than that of spring shoots.

Leaf color, size, and shape. There were a few gray-purple young leaves at the branch tips of every plant. Fewer young leaves emerged in autumn than in spring. The color of new growth was not persistent, because all summer leaves had turned green by fall. Leaf length ranged from 2.06 to 5.60 cm, and leaf width ranged from 1.25 to 2.65 cm. The

Table 1. Origin and major attributes of 21 *Loropetalum chinense* var. *rubrum* accessions in spring evaluated at Changsha, Hunan, China.

No.	Young leaf color	Mature leaf color	Underside color of young leaf ²	Leaf shape	Leaf length (cm)	Leaf width (cm)	Leaf length-to-width ratio ³	Flower no. ⁴	Flower color	Petal length (cm)	Petal width (cm)	Petal length-to-width ratio ⁵	Floret no.	Petal no.
1	144B	146B	145A	Elliptic	3.44	2.0	1.72 bc	++	57D	1.83	0.17	11.08 cd	6–8	4
2	152B	147A	145A	Elliptic	3.54	1.56	2.24 a	++	68B	1.44	0.13	10.74 cd	7–10	4
3	152B	147B	145A	Elliptic	3.05	1.91	1.60 cdef	++	62A	1.65	0.16	10.30 cd	6–8	4
4	184B	146A	185D	Elliptic	3.24	2.08	1.56 cdef	++	60B	1.34	0.17	8.02 e	5–7	4
5	183A	147A	182B	Elliptic	3.46	2.38	1.46 ef	++	63B	1.69	0.18	9.38 de	5–8	4
6	187A	146A	183C	Elliptic	5.52	3.2	1.72 bc	+	67B	2.00	0.14	13.94 b	4–8	4
7	183B	146A	183D	Broadly elliptic	2.94	1.76	1.66 cde	+++	68B	2.03	0.19	10.86 cd	6–7	4
8	187A	147A	183B	Elliptic	3.74	1.80	2.10 a	+++	61B	2.30	0.22	10.52 cd	5–8	4
9	183C	146A	183D	Ovate	2.56	1.84	1.40 f	++	67C	1.54	0.19	8.06 e	7–9	4
10	187A	200A	—	Ovate	4.74	3.44	1.40 f	+	59C	2.40	0.15	16.48 a	5–7	4
11	187A	147A	—	Elliptic	3.42	2.16	1.58 cdef	++	60A	1.76	0.16	11.30 c	5–7	4–5
12	187A	200A	—	Elliptic	3.66	2.1	1.70 bcd	+	67A	2.15	0.14	15.02 ab	5–7	4–5
13	187A	147A	—	Elliptic	3.54	2.44	1.46 ef	++	62A	2.30	0.20	11.76 c	4–7	4–5
14	183C	147A	—	Elliptic	3.44	2.14	1.62 cde	+	64D	1.61	0.14	11.74 c	7–8	4–5
15	187A	147A	—	Elliptic	3.70	1.94	1.88 b	++	64C	1.89	0.14	13.72 b	6–8	4–5
16	187A	147A	—	Elliptic	2.68	1.72	1.54 cdef	—	—	—	—	—	—	—
17	183C	147A	185D	Elliptic	3.46	2.18	1.60 cdef	++	60B	1.68	0.16	10.54 cd	4–6	4–5
18	176A	137A	—	Elliptic	2.72	1.88	1.48 ef	++	68A	2.13	0.19	11.32 c	5–7	4–5
19	187A	187A	185D	Elliptic	2.08	1.38	1.50 def	—	—	—	—	—	—	—
20	184B	187A	185C	Elliptic	2.06	1.28	1.62 cde	—	—	—	—	—	—	—
21	178A	137A	—	Elliptic	2.66	1.86	1.46 ef	++	68A	2.39	0.21	11.50 c	3–9	—

²“—” in the column of leaf color indicates the data cannot be measured because the leaf color is in red and green. “—” in the other columns indicates no data available.

³Different lowercase letters denote significant differences at the 0.05 level according to analysis of variance.

⁴+, ++, +++ denote “less,” “more,” or “many,” respectively.

Table 2. Origin and major attributes of 19 *Loropetalum chinense* var. *rubrum* accessions in autumn evaluated at Changsha, Hunan, China.

No.	Summer shoot length ^z	Young leaf color ^y	Mature leaf color	Under-side color of young leaf ^y	Leaf length (cm)	Leaf width (cm)	Length-to-width ratio of leaf ^z	Flower no. ^x	Flower color	Petal length (cm)	Petal width (cm)	Length-to-width ratio of petal ^z	Floret no.	Petal no.
1	11.38 ab	146C	147A	—	2.35	1.80	1.30 d	+	63A	0.87	0.20	4.40 f	4-6	4
3	—	146C	147B	—	—	—	—	—	—	—	—	—	—	—
4	11.65 ab	147A	147A	—	2.90	1.85	1.58 bc	+	60B	1.64	0.15	11.50 b	3-6	4
5	10.98 ab	—	146A	—	3.77	2.63	1.45 bcd	—	—	—	—	—	—	—
6	18.48 a	187A	147A	—	5.05	2.30	2.20 a	—	—	—	—	—	—	—
7	17.55 a	183A	146B	183D	3.21	2.06	1.55 bcd	+++	64C	1.84	0.20	10.20 bcd	6-7	4-5
8	11.93 ab	—	146A	—	2.74	1.74	1.60 bc	+++	60C	2.06	0.20	10.21 bcd	5-8	4-5
9	15.53 ab	183C	146A	—	3.07	2.20	1.39 cd	—	—	—	—	—	—	—
10	17.80 a	183C	146A	—	5.60	2.65	2.14 a	—	—	—	—	—	—	—
11	15.38 ab	187A	147A	—	3.67	2.43	1.51 bcd	—	—	—	—	—	—	—
12	11.95 ab	187A	147A	—	2.94	1.76	1.67 b	—	—	—	—	—	—	—
13	15.58 ab	183A	147B	186A	2.70	1.69	1.61 bc	++	62A	1.82	0.14	13.69 a	5-9	4-6
14	8.48 b	178A	147B	—	2.78	1.70	1.64 bc	+	60D	1.79	0.21	8.67 de	5-9	4-5
15	11.18 ab	200A	147A	—	3.92	1.72	2.29 a	+	64C	2.00	0.15	13.91 a	6-8	4-5
16	15.63 ab	187A	147A	183D	2.06	1.25	1.66 bc	—	—	—	—	—	—	—
17	10.55 ab	187A	147A	183D	2.30	1.55	1.50 bcd	+	60B	1.77	0.18	9.81 cd	4-6	4-5
18	12.63 ab	183A	146A	—	3.89	2.30	1.68 b	+	64C	1.65	0.23	7.11 e	6-9	4-5
26	10.38 ab	187A	147B	183D	2.30	1.66	1.39 cd	++	60B	1.93	0.19	10.22 bcd	6-7	4
27	11.25 ab	187A	147A	185D	2.95	1.90	1.55 bcd	+	61A	1.96	0.18	11.16 bc	8-10	4

^zDifferent lowercase letters denote significant difference at the 0.05 level according to analysis of variance. ^y“—” in the column of leaf color indicates the data cannot be measured because the leaf color is in red and green. “—” in the other columns indicates no data available. ^x+, ++, +++ denote “less,” “more,” or “many,” respectively.

maximum leaf length-to-width ratio was 2.29 cm (Table 2).

Flower number and color. Only a part of the accessions flowered in autumn. The flower number of all flowered accessions in autumn was less than that in spring. Flower colors were in the Red-Purple Group (Table 2).

Petal size and number, and floret number. Petal length ranged from 0.87 to 2.06 cm, and petal width ranged from 0.14 to 0.23 cm. Most accessions had four to five petals per floret. There were generally four to seven florets per inflorescence, with some accessions containing occasional 9 to 10 florets per inflorescence (Table 2).

Cluster analysis

According to the data obtained in spring, the entries were grouped into four clusters at the threshold of 3.80 (Fig. 1). Cluster I included four subclusters. Subcluster I-1 included accession nos. 1, 3, 18, and 21. Subcluster I-2 included accession nos. 5, 7, 13, 14, and 15. Subcluster I-3 included accession nos. 4 and 17. Subcluster I-4 included accession nos. 6, 10, 11, 26, and 27. Cluster II included accession nos. 2, 8, and 9. Cluster III only included accession no. 12. Cluster IV included accession nos. 16, 19, and 20.

According to the data obtained in autumn, the entries were grouped into five clusters (Fig. 2). Cluster I included accession nos. 1, 3, 5, 8, 10, 11, 12, and 16. Cluster II included accession nos. 6, 14, 18, and 9. Cluster III only included accession no. 4. Cluster IV included accession nos. 7, 17, 26, and 27. Cluster V included accession nos. 13 and 15.

Results from this analysis showed that the cluster grouped first as a result of the similarity in leaf color. The accessions with

Fig. 1. Dendrogram of 21 *Loropetalum chinense* var. *rubrum* accessions in spring, with two additional accessions (nos. 26 and 27) in autumn obtained by analysis of nine morphological characterization variables.

Fig. 2. Dendrogram of 19 *Loropetalum chinense* var. *rubrum* accessions in autumn (accession nos. 2, 19, 20, and 21 were dead) obtained by analysis of nine morphological characterization variables.

similar flower color grouped into subclusters within a cluster; however, there were some exceptions. For example, the spring leaf colors of accession nos. 2 and 3, both in the Yellow-Green Group, and their flower colors are similar, belonging to the Red-Purple Group. However, in the cluster dendrogram, the two accessions were in fact far apart from each other.

Several accessions with good qualities

Results from this study have implications for future plant collection and application efforts with *L. chinense* var. *rubrum*. After comparing the morphological traits of all accessions in different seasons, four accessions with good qualities were selected and should be further tested in the landscape. Accession no. 8 had abundant, attractive flowers in spring and autumn. Its flowers were purplish red. Flowers of accession no. 11 were a vivid red. Leaf color of accession no. 12 was dark purple, and the leaf underside color was red. Its mature leaf color was long-lasting brownish black. Accession no. 13 yielded only several flowers in the summer in this study. The color and shape of its leaves were attractive. Its mature leaves were dark glossy green and ovate. The classification and nomenclature of these plants are currently in progress.

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