Morphological Characteristics and Classification of Selected Populations of *Rubus coreanus* Miq

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Abstract: We surveyed 14 selected populations of *Rubus coreanus* Miq. that are indigenous to Korea, examining the leaves, fruiting laterals, and fruits, in order to develop superior cultivars of this species. Whereas most of the populations in the Songgye region had large leaf characteristics, populations in the Hannam, Sanghyo, Wonju, and Chiak regions generally had small leaf characteristics. The Songgye region plants also had longer leaves relative to their leaf widths. The number of flowers and number of fruits per fruiting lateral were 19.7 and 19.8, respectively, for the Gochang region, and 19.3 and 18.9, respectively, for the Hannam region. Both these regions exceeded the average numbers of flowers and fruits, which were 17.2 and 16.6, respectively. There were wide variations in fruit length, width, weight, and morphological characteristics. A principal components analysis (PCA) of 24 characteristics revealed that the first principal component value was 9.53 (or 39% of the total variance), the second principal component value was 5.85 (24.3% of the total), the third principal component value was 3.53 (14.7% of the total), the fourth principal component value was 2.00 (8.3% of the total), and the fifth principal component value was 1.20 (5.0% of the total). The proportions of the top five principal components accounted for a high percentage (92.2%) of the total variance.
[Sea-Hyun Kim, Moon-Sup Kim, Yong-Seok Jang, Hae-Su Kim, Do-Hyung Lee. **Morphological Characteristics and Classification of the Selected Populations of *Rubus coreanus* Miq**. *Life Sci J* 2013; 10(3): 144-151]. (ISSN: 1097-8135). http://www.lifesciencesite.com. 23

Keywords: Morphological characteristics; Classification; *Rubus coreanus* Miq.; Principal component analysis; UPGMA method

1. Introduction

Rubus coreanus Miq. is a vine belonging to the deciduous shrub rose family. It is distributed nationwide in Korea, Japan, and China, where it grows in sunny areas in valleys, foothills, abandoned fields, and burnt fields 50–1,000 m above sea level. It reaches about 3 m in height. As it is hardy and resistant to cold, dryness, and salt air, it grows well in dry areas and wetlands. Unlike other raspberry species, it requires a lot of sunlight, and if it does not get enough exposure, will not achieve normal flowering or fruiting. The leaves are alternate and usually leaflets contain seven strands. A white powder on the surface of the leaflets makes it easily distinguishable from other raspberry species. Petioles and branches bear thorns. The flowers are corymbs and pink in color; they bloom from the new branches in early June. Hemispherical-shaped fruit ripens July through August, initially red in color and then turning black.

The plant's Korean name, Bokbunja, means "immature or dried fruit" raspberry species. *Bokbunja* is collectively used to refer to medicinal herbs, and these plants are used widely for medicinal purposes. Among these species, *R. coreanus* Miq. is regarded as having the greatest medicinal effects. Research is ongoing on the pharmacological effects of *R. coreanus* Miq. with regard to the phenol materials, tannins, antioxidants, and antibacterial compounds that it contains, as well as physiological studies on its nutritional value and processing methods (Park and Ju, 1982; Hardori *et. al*., 1988; Kim, 1996; Oh *et. al*., 1996; Ha, 200; Lee *et al*., 2000; Cha *et al*., 2001; Jo *et. al*., 2001; Park and Chang, 2003; Yun, 2003; Choi, 2004; Yang *et al*., 2004; Kim *et al*., 2005).

However, despite its versatility and usefulness, locally grown *R. coreanus* Miq. are cultivated only in small quantities in Korea. Most of the cultivated species (*R. occidentalis*) are imported from North America. Approximately 3,500 ha were being cultivated in 2009 (Kang *et al*., 2009).

Because of advances in numerical taxonomy, species identification based on the external morphological characteristics of the plant uses not only quantity and quality characteristics related to leaves, fruits, and flowers but also differences in the composition of phenol and sugar compounds that exist in the plant body, the degree of growth response during processing, and the number of bands of proteins and isoenzymes revealed by electrophoresis. Using these data, various multivariate analyses have been conducted, including discriminant function analysis, factor analysis, principal component analysis, and cluster analysis. Recently, the data containing a number of correlated variables have been restructured to form a data set with fewer

variables. In principal component analysis, data are represented by principal factors, a linear combination of data displaying fewer than the initial number of variables by projecting the data to a lower dimension than a point in a multi-dimensional space. In cluster analysis, after combining the constituents inside a population into similar groups from the distribution of components in the multi-dimensional space without external standards or group numbers, the distances between clusters are calculated using Euclidean distance. Cluster analysis that defines the characteristics between species is being used extensively (Kim *et al*., 1992; Kim and Ko 1995; Ha, 2000; Cho *et al*., 2001; Yun *et al*., 2002; Kim and Chang, 2003; Choi, 2004; Kim *et al*., 2007; Kim *et al*., 2011).

This study investigated and analyzed the relationships between populations, based on the morphological characteristics of the selected populations of *R. coreanus* Miq. that are indigenous to Korea. By conducting an in-depth examination of the selection factors that represent superior species, we attempted to provide basic data to guide the development and dissemination of superior cultivars for large fruit and high yield.

2. Material and Methods

2.1. Morphological characteristics investigation

The materials of this study are from the 220 clones, which displayed normal growth pattern, of the 227 clones belonging to the clone bank, which was formed by the Forest Resources Development Department within Korea Forest Research Institute in 1998 when it selected 14 regions throughout Korea for the purpose of breeding superior species of *R. coreanus* Miq. for large fruit and high yield. This study also studied and analyzed the morphological characteristics of leaves and fruit, by taking 20 mature leaves and 20 ripen fruits from 5 fruiting laterals (for each direction) for each sample category that displayed normal growth pattern.

The characteristics used for analysis were largely separated into the characteristics of leaves, fruit and fruiting laterals, as mentioned previously earlier in this study. The 16 characteristics of leaves studied were as follows: Length of compound leaf (LCL); Width of compound leaf (WCL); Length of rachis (LR); Length of terminal leaflet (LTL); Width of terminal leaflet (WTL); Length of terminal leaflet petiole (LTLP); Length of the first leaflet (LFL); Width of the first leaflet (WFL); Length of the first leaflet rachis (LFLR); Length of the second leaflet (LSL); Width of the second leaflet (WSL); Length of the second leaflet rachis (LSLR);Compound leaf morphological index, CLMI(WCL/LCL); Terminal leaflet morphological index, TLMI(WTL/LTL); First leaflet morphological index, FLMI(WFL/LFL); and Second leaflet morphological index, SLMI (WSL/LSL). The 8 characteristics of fruiting and fruits were as follows: Length of fruiting lateral (LFL); Number of flower per fruiting lateral (NFL); Number of fruit per fruiting lateral (NFFL); Percentage of fruiting (PF); Fruit length (FL); Fruit width (FW); Weight of fruit (WF); and Fruit morphological index, FMI(FW/FL). There were total of 24 characteristics (16 leaf characteristics and 8 fruiting and fruit characteristics).

2.2. Data analysis

All the data were processed, using the SAS (Statistical Analysis System, 1987 Ver 8.02) program, to obtain basic statistics and to compare and analyze morphological characteristics among the selected populations and among the individual; by conducting analysis of UPGMA (Unweighted pair-group method using arithmetic averages) that uses scoring value of each component as new variable and to comprehensively study the morphological characteristics and relationships of *R. coreanus* Miq. using multivariate analysis, the difference and relationship among the selected populations of *R. coreanus* Miq. and the individuals were thoroughly studied. In particular, through the analysis of the principal components, the contribution level of each primary component for the total variation and eigenvalues by calculating the distance between the selected populations from correlation matrix of the examined morphological characteristics; by synthesizing these principal components and listing component scores of principal components in an array on the axes, this study attempted to thoroughly study the relationships among the selected populations and among the individuals for the morphological characteristics of the selected objects of *R. coreanus* Miq.

3. Results and Discussion

3.1. Morphological characteristics of leaves

The results of the study which investigated and analyzed the 16 characteristics of leaves including compound leaf lengths and compound leaf widths to study the morphological characteristics and differences of the selected populations of the 220 clones of *R. coreanus* Miq. through Duncan's multiple tests of the significant differences are shown in Table 1.

The ranges of compound leaf lengths and widths were 106.4 mm - 133.0 mm and 63.9 mm - 84.2 mm, respectively, and the average coefficients of variation were 20.7% and 24.5%, respectively, and were showing various range of variations, and for the selected regions the compound leaf lengths and

compound leaf widths of the Songgye regions were 133.0 mm and 84.2 mm, respectively, and they were larger than the average lengths of 117.1 mm and widths of 74.9 mm by 13.6% and 12.4%, respectively, and they were of the longest lengths and the largest widths among the 14 selected populations.

Table 1. Summary of leaf morphological characteristics of 14 *R. coreanus* Miq. populations

Populations	Characteristics [x]							
	LCL	WCL	CLMI	LR	LTL	WTL	TLMI	LTLP
Hoengseong	115.1±20.9[y]de[z]	75.1±24.1c	0.7±11.5b	37.3±23.5de	41.7±22.0cde	33.3±24.3cd	0.8±13.3fg	12.8±38.9cd
Wonju	111.2±16.9ef	73.9±19.5c	0.7±13.1b	36.0±22.0ef	42.0±16.9cd	32.8±23.3d	0.8±17.3g	11.6±35.6ef
Chiak	106.4±18.4g	69.5±21.6d	0.7±11.1b	35.7±22.2f	39.7±17.2f	33.6±26.0cd	0.8±12.6cd	11.1±40.4f
Chungju	115.5±19.0d	73.2±20.6c	0.6±12.6c	38.0±22.1cd	42.7±17.2c	34.5±24.6bc	0.8±15.1fg	12.1±43.2de
Songgye	133.0±20.5a	84.2±25.4a	0.6±18.0c	44.2±23.1a	47.2±20.3a	39.1±22.8a	0.8±11.8de	15.5±31.8a
Muju	121.2±22.0c	83.1±26.8a	0.7±13.6a	39.5±24.1bc	44.7±21.3b	35.8±28.1b	0.8±13.2fg	12.9±41.9bcd
Soyang	123.1±17.9c	78.4±22.6b	0.6±12.8c	39.7±21.5b	42.9±17.4c	38.0±26.0a	0.9±15.6b	15.2±33.4a
Gochang	124.6±20.3bc	82.8±22.1a	0.7±12.2b	39.9±24.8b	45.1±20.3b	38.6±29.5a	0.9±18.2cd	14.8±37.8a
Seungju	127.8±26.1b	78.7±31.4b	0.6±14.3de	40.7±27.6b	44.8±24.4b	38.0±27.7a	0.9±16.8c	15.4±33.3a
Machun	108.9±20.2fg	68.8±23.2d	0.6±15.6c	35.9±24.7ef	40.3±19.6ef	33.0±25.3cd	0.8±13.1ef	11.8±35.6ef
Hadong	114.7±20.1de	75.5±24.4c	0.7±15.2b	37.8±23.6d	41.3±20.6de	34.4±25.6bcd	0.8±16.5cde	13.7±55.4b
Uiryeong	112.3±16.2def	69.8±21.1d	0.6±12.9cd	35.5±20.1f	40.4±17.0ef	35.9±21.8b	0.9±12.4b	13.6±25.4bc
Sanghyo	115.6±18.6d	67.3±18.9d	0.6±13.7f	39.3±24.2bc	37.9±16.8g	33.5±19.6cd	0.9±11.1b	13.7±24.2b
Hannam	107.2±16.9g	63.9±17.4e	0.6±13.2ef	34.9±21.7f	36.0±15.1h	32.8±20.7d	0.9±12.1a	13.4±30.9bc
Mean	117.1±20.7	74.9±24.5	0.6±14.1	38.1±24.1	42.1±20.1	35.4±25.8	0.8±15.3	13.4±38.4

Populations	Characteristics							
	LFL	WFL	FLMI	LFLR	LSL	WSL	SLMI	LSLR
Hoengseong	34.3±22.d	21.5±23.1d	0.6±11.7ef	0.3±53.3cd	37.2±24.0e	25.2±22.9cd	0.7±1.31bc	1.5±42.8a
Wonju	34.2±18.1de	19.5±21.1g	0.6±14.0j	0.2±220.2efg	36.6±19.5ef	22.0±20.5g	0.6±14.7g	1.0±65.3cd
Chiak	31.8±21.5f	19.8±23.7fg	0.6±11.3f	0.1±352.9i	34.0±21.8g	22.6±22.0fg	0.7±14.1cde	0.7±90.4f
Chungju	34.8±18.7cd	21.2±22.5e	0.6±13.0h	0.2±189.3eg	36.8±21.6ef	24.3±21.4de	0.7±13.8de	1.1±56.7c
Songgye	38.7±22.2a	24.9±26.5a	0.6±13.3de	0.2±261.8ghi	41.4±24.0a	28.1±26.5a	0.7±14.3bc	1.1±59.8c
Muju	37.0±24.6b	21.9±28.2d	0.6±13.1i	0.4±155.8c	40.2±27.4ab	25.5±29.3c	0.6±12.4f	1.4±74.8b
Soyang	36.8±19.6b	24.0±23.9b	0.7±11.4cd	0.3±189.3def	39.4±21.4bc	26.7±24.3b	0.7±13.1bcd	1.3±60.8b
Gochang	38.4±21.9a	22.9±25.4c	0.6±13.3hi	0.2±178.6def	40.9±22.7ab	26.0±24.0bc	0.6±14.2f	1.3±55.2b
Seungju	36.8±26.3b	23.1±26.1c	0.6±11.8ef	0.4±146.7c	38.7±28.8cd	26.1±26.8bc	0.7±14.9bc	1.3±67.9b
Machun	33.0±20.0ef	20.5±26.0ef	0.6±15.5fg	0.2±220.0fgh	35.5±21.8f	23.2±23.6f	0.7±15.5e	0.9±71.0de
Hadong	35.9±23.4bc	21.7±23.5d	0.6±13.6gh	0.1±282.4hi	37.6±24.8de	24.4±22.3d	0.7±15.5e	0.9±70.6e
Uiryeong	33.6±19.2de	22.0±19.9d	0.7±11.1c	0.3±191.6de	35.5±20.7f	24.3±20.0de	0.7±12.3b	1.1±62.8c
Sanghyo	30.3±19.2g	21.4±21.2d	0.7±16.4a	0.6±83.0a	32.5±19.9h	23.3±19.5ef	0.7±13.2a	1.6±39.0a
Hannam	29.0±16.3h	19.9±19.7fg	0.7±11.4b	0.5±115.6b	30.7±17.3i	22.0±18.8g	0.7±11.7a	1.5±52.0a
Mean	34.9±22.4	21.8±24.9	0.6±13.9	0.3±181.5	37.2±24.1	24.6±24.5	0.7±14.5	1.2±63.8

[x]; The abbreviations of traits are the same as these of materials and methods.
[y]; Average±C.V.,
[z]; Different letters indicate Duncan's multiple range tests(Significant at p=0.05).

On the other hand, the Hannam region showed compound leaf length of 107.2 mm and compound leaf width of 63.9 mm, and showed smaller compound leaf characteristics by 8.5% and 14.7%, respectively, compared to the average, and, along with the Cheonan region with 106.4 mm compound leaf length, showed the smallest and the narrowest compound leaf characteristics among the 14 selected populations. In particular, the leaf characteristics of the Songgye region were showing relatively longer and wider characteristics compared to the other selected regions.

Also, in the rachis length characteristics, the Songgye region was showing tendencies of longer rachis length with its 44.2 mm rachis length which was 16% longer than the average rachis length of 38.1 mm; the Hannam region were showing tendencies of shorter rachis length with its 34.9 mm rachis length which was 8.4% shorter than the average rachis length. At the same time, the analysis of the compound leaf morphological index (compound leaf width/compound leaf length), which was to study the morphological characteristics of compound leaves, was showing 0.6 average, i.e., the compound leaf length was longer than compound leaf width, therefore, it was possible to ascertain that the overall shape to be oval or oblong in shape.

Meanwhile, the ranges of the characteristics of the terminal leaflet length and terminal leaflet width and terminal leaflet petiole length were 36.0 mm - 47.2 mm, and 32.8 mm - 39.1mm, and 11.1 mm - 15.5 mm, respectively, and the average coefficients of variation were 20.1%, 25.8%, and 38.4%, respectively, thereby, were showing a variety of variations, and the Songgye region, with its terminal leaflet length of 47.2 mm and terminal leaflet width

of 39.1 mm and terminal leaflet petiole length of 15.5 mm, was showing, similar for the compound leaf characteristics, the longest and widest terminal leaflet characteristics among the 14 selected populations.

In the case of the Hannam region, similar to the trend seen in the compound leaf characteristics, characteristics of 36.0 mm in terminal leaflet length, 32.8 mm in terminal leaflet width, respectively, were observed, which were 14.5% and 7.4% less than the average sizes, respectively, thereby, showing a shorter and narrower terminal leaflet characteristics; regarding the length of terminal leaflet petiole, the Chiak region showed the shortest tendencies with 11.1 mm. In the mean time, the analysis of terminal leaflet morphological index (terminal leaflet width/ terminal leaflet length) conducted to study the morphological characteristics of terminal leaflets showed 0.8, which was similar to compound leaf morphological index, and this ascertained that terminal leaflets too were longer in length than width and the overall shape oval or oblong.

The first leaflet length and width characteristics showed on average the Songgye region's length and width of 38.7 mm and 24.9 mm, respectively, which were 10.9% longer and 14.2% wider than the average first leaflet length of 34.9 mm and width of 21.8 mm, respectively; the Sanghyo and Hannam regions showed 30.3 mm and 29.0 mm, respectively, to have the shortest first leaflet length characteristics. On the other hand, the Wonju region's 19.5 mm showed the narrowest first leaflet width characteristics.

The range of first leaflet rachis length was 0.1 mm – 0.6 mm, average coefficient of variation was 181.5% which was a much larger variation compared to the other leaf characteristics; the Sanghyo region was the longest with 0.7 mm and the Chiak region was the shortest with 0.1 mm. Meanwhile, the analysis of the first leaflet morphological index (first leaflet width / first leaflet length) to study the morphological characteristics of first leaflet rachis showed 0.6, which was similar to the compound leaf morphological index previously mentioned in this report, thereby, the first leaflets were overall oval or oblong in shape as well.

The ranges for second leaflet length and width were 30.7 mm - 41.4 mm and 22.0 mm - 28.1 mm, respectively, the average coefficients of variation were 24.1% and 24.5%, respectively, thereby, showing a pretty wide range of variations; with respect to the selected populations, the Songgye region showed 41.4 mm in length and 28.1 mm in width, which were 10.6% longer and 13.8% wider than the average second leaflet length of 37.2 mm and width of 24.6 mm, respectively. In addition, similar to the other leaf characteristics, the Hannam region showed characteristics of having the shortest second leaflet length and narrowest width by showing 30.7 mm and 22.0 mm, respectively.

However, regarding the characteristics of second leaflet rachis length, the Hannam and Sanghyo regions showed 1.5 mm and 1.6 mm, respectively, thereby, showing the longest leaflet rachis length among the 14 selected populations. Meanwhile, the analysis of the second leaflets morphological index (second leaflet width / second leaflet length) to study the morphological characteristics of second leaflet showed 0.7, which was similar to the compound leaf morphological index previously mentioned in this report, thereby, the second leaflets were overall oval or oblong in shape as well.

These whole research results reflected, most of the Songgye region showed tendencies of being large in the most leaf characteristics, and the Hannam, Sanghyo, Wonju and Chiak regions showed tendencies of being small in leaf characteristics. Additionally, the characteristics related to the morphological characteristics length of leaf showed somewhat larger tendencies than those related to morphological characteristics width.

3.2. Fruiting laterals and fruit characteristics

The results of the study which investigated and analyzed the 8 characteristics of fruiting laterals and fruits to study the morphological characteristics and differences of the selected populations of the 220 clones of *R. coreanus* Miq. through Duncan's multiple tests of the significant differences are shown in Table 2.

The range of the characteristics of fruiting lateral length was 11.8 cm – 20.1 cm, the average coefficient of variation showed a wide range of variations with 34.4%; while the Sanghyo region was the longest with its 20.1 cm average length, the Chiak region showed the shortest tendencies with its 11.8 cm average length. Regarding the flowering number and fruiting number for each fruiting lateral, the Gochang and Hannam regions showed 19.7 and 19.8, and 19.3 and 18.9, respectively, thereby, showed larger flowering number and fruiting number characteristics than the average flowering number and fruiting number; The Chiak region with its the worst value showed of the characteristics of fruiting lateral length also showed the worst tendencies for flowering number and fruiting number with 13.0 and 12.5, respectively. Meanwhile, the average fruiting percentage was 96.3% from which it was ascertained that almost all fruiting laterals that had flowered resulted in fruiting.

Table 2. Summary of fruiting and fruit morphological characteristics of 14 *R. coreanus* Miq. populations

Populations	Characteristics [x]							
	LFL	NFL	NFFL	PF	FL	FW	FMI	WF
Hoengseong	15.7±33.2[y]def[z]	14.6±31.5f	13.8±32.7gh	94.7±4.4ab	10.0±10.6bc	13.8±9.0d	1.4±10.4f	1.1±23.0f
Wonju	15.7±23.1def	17.5±36.7bcd	17.0±36.9cde	97.0±3.3a	10.0±10.8cde	14.4±9.3b	1.5±10.6d	1.3±25.5bc
Chiak	11.8±32.6h	13.0±42.0g	12.5±43.2h	96.2±2.8a	9.4±9.6g	14.2±9.3c	1.5±9.8b	1.3±25.5b
Chungju	15.2±28.6ef	15.4±32.1ef	14.8±34.0fg	96.3±3.2a	9.9±12.8cde	14.5±10.0b	1.5±11.0c	1.2±25.9bc
Songgye	16.7±40.1cd	15.5±28.9ef	14.7±30.6fg	97.1±1.7a	9.8±11.9ef	14.7±9.9a	1.5±11.5b	1.4±24.7a
Muju	15.4±28.8def	18.0±38.2bcd	17.4±38.3bcde	96.9±2.4a	9.8±10.3def	14.4±8.3b	1.5±10.8c	1.2±21.8bcd
Soyang	16.5±33.3cde	16.5±33.7de	16.1±34.6ef	96.6±3.6a	9.7±15.8f	14.6±10.2ab	1.5±12.4ab	1.3±25.5b
Gochang	17.5±31.3bc	19.7±39.2a	19.3±39.4a	98.0±1.3a	10.4±11.6a	14.1±10.4c	1.4±11.1f	1.2±27.0de
Seungju	18.5±49.8b	17.2±35.7cd	16.5±36.7de	92.9±9.2b	9.4±11.6g	14.4±10.6b	1.5±9.3a	1.2±29.8cd
Machun	13.3±35.8g	17.7±38.6bcd	16.9±38.8cde	95.8±3.3ab	10.0±10.3cde	14.1±7.8c	1.4±11.6e	1.1±19.2ef
Hadong	14.5±34.4fg	18.5±39.4abc	18.0±40.4abcd	97.2±2.7a	10.2±9.3ab	14.5±9.3b	1.4±9.9e	1.2±22.4cd
Uiryeong	15.1±30.2ef	18.3±34.2abc	17.8±35.8abcde	96.6±3.8a	10.3±11.8a	14.5±8.6ab	1.4±11.7e	1.3±22.5a
Sanghyo	20.1±23.9a	18.9±26.5ab	18.7±26.8abc	97.7±1.2a	9.9±9.9cde	14.5±8.6ab	1.5±13.1c	1.3±18.0bc
Hannam	16.8±21.7cd	19.8±28.1a	18.9±29.8ab	95.5±5.0ab	10.0±13.1ab	13.6±9.0e	1.4±13.5f	1.1±23.9f
Mean	15.8±34.4	17.2±36.6	16.6±37.7	96.3±3.9	9.9±12.0	14.3±9.6	1.5±11.8	1.2±24.8

[x]; The abbreviations of traits are the same as these of materials and methods.
[y]; Average±C.V.,
[z]; Different letters indicate Duncan's multiple range tests(Significant at p=0.05).

In looking at fruit length, fruit width, weight of fruit and fruit morphological index (fruit width / fruit length) to study the morphological characteristics of fruits, it can be learned that the average coefficient of variation had a wide range of variations with 12.0% and 9.6%, and 11.8% and 24.8%, respectively. The ranges of fruit length and fruit width were 9.4 mm – 104 mm and 13.6 mm – 14.7 mm, respectively, and regarding fruit length the Gochang and Uiryeong regions showed 10.4 mm and 10.3 mm, respectively, thereby, showing tendencies of having larger fruit lengths than the average fruit length of 9.9 mm with their 10.4 mm (5.1% longer) and 10.3 mm (5.0% longer), and the Chiak and Seungju regions showed the shortest fruit length of 9.4 mm. The Songgye region showed the longest tendencies with its 14.7 mm; the Hannam region showed the shortest tendencies with its 13.6 mm. In looking at the fruit weight characteristics, the average fruit weight was 1.2g, and the average coefficient of variation was 24.8%, which showed a wide range of variations. The Songgye and Uiryeong regions showed the most outstanding weight characteristics with their 1.4g and 1.3g, respectively; the Hoengseong and Hannam regions showed the worst fruit weight with 1.1g. On the other hand, the result of analysis of fruit morphological index (fruit width / fruit length) showed 1.5, thereby, showing that the shape of fruit was oval in shape with the length being shorter than the width, which was wider in width than height, thereby, making a wide oval in shape.

3.3. Relationship Analysis

The results of the study which investigated and analyzed the 24 characteristics of leaves and fruits to study the morphological characteristics and differences of the selected populations of the 220 clones of *R. coreanus* Miq. through UPGMA (Unweighted pair-group method using arithmetic averages) that uses scoring value of each component as new variable are shown in Table 3 and Figure 1.

Based on the analysis of the unique values for each traits of the principal components of 24 kinds of characteristics, the 1st principal component value was 9.53 (or 39.7% of the total variance), the 2nd principal component value was 5.85 (or 24.3% of the total variance), the 3rd principal component value was 3.53 (or 14.7% of the total variance), the 4th and 5th principal component value were 2.00 and 1.20, thereby, accounting for 8.3% and 5.0%, respectively, of the total variance; the top 5 principal components accounted for a high percentage (92.2%) of the total variance. The 6th and lower principal component values less than 1.0 or accounting for less than 5% contribution were disregarded as being insignificant.

Meanwhile, looking at the results shown in terms of the correlation coefficient of the analysis of the eigenvalues for each principal component and morphological traits, the 1st principal component among the 24 types of characteristics studied all showed positive values (except for the morphological indices, leaflet rachis lengths and fruit lengths of the first leaflet and second leaflet, and the characteristics of flowering number and fruiting number), and the range for the correlation coefficients was -0.1157 ~ 0.3104. In particular, the characteristics of terminal leaflet length showed the highest correlation with its 0.3104 correlation coefficient; this was followed by, in the order decreasing correlation coefficients, the first leaflet length, the second leaflet length and

compound leaf width, the second leaflet width, compound leaf length, terminal leaflet width, all showing high levels of correlation. These results would indicate that the characteristics of leaf length and leaf width have high levels of contribution among the 24 characteristics studied. The range of correlation coefficients for the 2nd principal component was analyzed to be -0.3070 ~ 0.3465, and its characteristics of fruiting lateral showed the highest correlation with 0.3465 correlation coefficient. The characteristics of the first leaflet morphological index and leaf length that showed negative values in the characteristics of the 1st principal component showed high level of correlation with their respective correlation coefficients of 0.3280 and 0.3188; this was followed by, in the order decreasing correlation coefficients, the terminal leaflet morphological index, length of second leaflet rachis, and second leaflet morphological index, all showing high levels of correlation.

Table 3. Results of principal component analysis and eigenvector associating to eigenvalue obtained from principal component of 14 *R. coreanus* Miq. populations

Characteristics [x]	Prin. 1	Prin. 2	Prin. 3	Prin. 4	Prin. 5
LCL	0.2991	0.1424	0.0061	-0.0839	0.0504
WCL	0.3064	-0.0430	0.1149	-0.1038	0.0405
CLMI	0.1296	-0.3070	0.2291	-0.0283	0.0473
LR	0.2822	0.1398	-0.0490	-0.0314	0.1135
LTL	0.3104	-0.0724	0.0467	-0.0910	0.0395
WTL	0.2859	0.1259	-0.0032	0.0421	-0.1993
TLMI	-0.0869	0.3143	-0.0780	0.1953	-0.3367
LTLP	0.2070	0.2891	0.0304	-0.0065	-0.1889
LFL	0.3087	-0.0631	0.1118	-0.0483	-0.0701
WFL	0.2796	0.1735	-0.0389	0.0111	-0.2112
FLMI	-0.1255	0.3280	-0.1898	0.0985	-0.1613
LFLR	-0.1037	0.3188	0.0700	-0.1440	0.3986
LSL	0.3072	-0.0744	0.1160	-0.0715	-0.0396
WSL	0.2955	0.1034	-0.0174	-0.1001	-0.2083
SLMI	-0.1157	0.3056	-0.2201	-0.0551	-0.2490
LSLR	-0.0150	0.3124	0.1482	-0.2718	0.2207
LFL	0.0689	0.3465	0.0920	-0.0665	0.3393
NFL	-0.0564	0.2129	0.3775	0.1658	0.0977
NFFL	-0.0545	0.2086	0.3781	0.1960	0.1307
PF	0.0345	-0.0308	0.2277	0.5232	0.0496
FL	-0.0491	0.0127	0.4380	0.1745	-0.2647
FW	0.1981	0.0139	-0.1497	0.4187	0.2769
FMI	0.1471	0.0016	-0.4098	0.0961	0.3215
WF	0.1453	0.0040	-0.2360	0.4982	0.0779
Eigenvalue	9.5305	5.8528	3.5318	2.0064	1.2017
Difference	3.6777	2.3209	1.5254	0.8048	0.3616
Proportion	0.3971	0.2439	0.1472	0.0836	0.0501
Cumulative(%)	39.71	64.10	78.82	87.18	92.19

[x]; The abbreviations of traits are the same as these of materials and methods.

In the case of the 3rd principal component, the correlation coefficient range was -0.4098 ~ 0.4380, and the characteristics of fruit length and flowering number and fruiting number were showing relatively high levels of correlation. The correlation coefficient ranges for the 4th and 5th principal components were showing -0.2718 ~ 0.5232 and -0.3367 ~ 0.3986, respectively; in the case of the former, the percentage of fruiting, fruiting leaf weight, and fruit width characteristics, and, in the case of the latter, the length of second leaflet rachis, fruiting lateral, and fruit width characteristics were showing high levels of correlation. As mentioned so far, comprehensively looking at the results from analyses of the principal components, the morphological characteristics of leaves, fruits, and fruiting of the selected populations from 14 regions in Korea of the 220 clones of *R. coreanus* Miq. showed, through the characteristics related to leaf length, leaf width and the morphological characteristics of fruits and fruiting, relatively evenly high levels of contribution.

Figure 1 shows the resulting dendrogram of each of the distances calculated using UPGMA that uses component scores of principal components of the *R. coreanus* Miq. of the 14 selected regions as new variables by summarizing the analyses results so far.

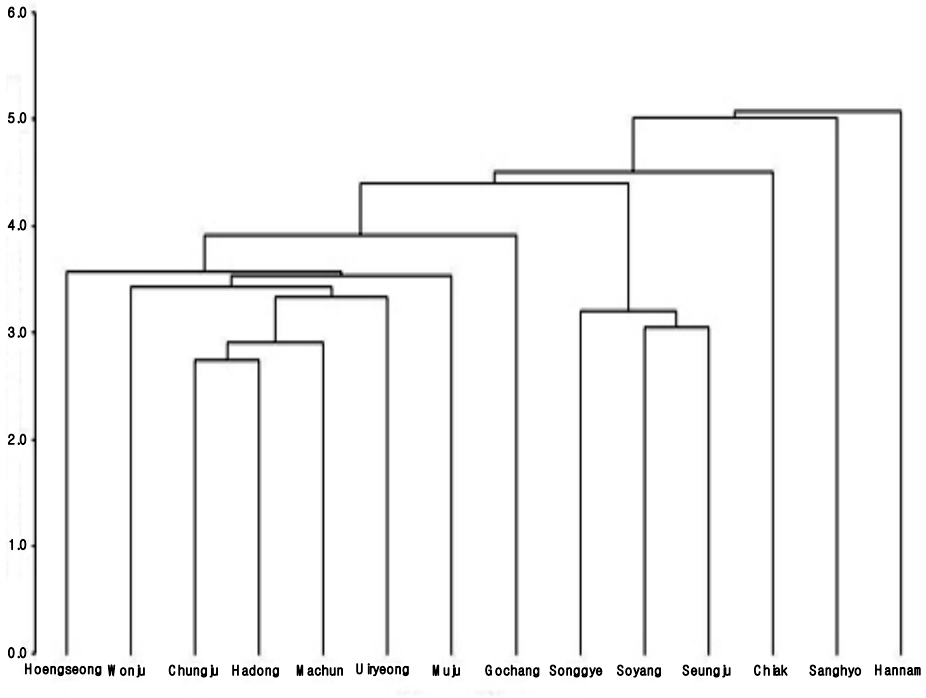

Figure 1. Cluster dendrogram of 14 *R. coreanus* Miq. populations based on 24 morphological characteristics

The cluster analysis results were divided largely into two groups, based on distance-level 4.5 as norm: Group I which included Chiak, and Sanghyo and Hannam; and the Group II showed two subgroups: Subgroup #1 which included Hoengseong, Wonju, Chungju, Muju, Macheon, Hadong; and Uiryeong regions, and Subgroup #2 which included Gochang, Songgye, Soyang, Seungju regions.

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7/8/2013