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Similarity Relationship and Intraspecific Variation in Pollen Morphology of Korean Subgenus *Lepidobalanus* ENDL.(Genus *Quercus* L.)[1]

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한국산 참나무아속 화분형태의 유사관계 및 종내변이에 관한 연구[1]

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ABSTRACT

This study was initiated to investigate similarity and intraspecific variation in pollen morphology of Korean subgenus. *Lepidobalanus* Endl. of the genus *Quercus* L. The parameters measured were polar axis length (PL), equatorial width (EW), colpus length (CL), and colpus width (CW), and PE (PL/EW) ratios were calculated. The cluster analysis based on these variables of this result showed that the similarity between *Q. acutissima* Carruther and *Q. variabilis* Blume was the highest. Wide variation in the pollen grain size of *Quercus dentata* Thunb. ex Murray might imply, the existence of polyploid and/or aneuploid forms. Studies of ploidy levels within species are recommended for *Lepidobalanus* species.

요 약

한국산 참나무아속 화분형태의 유사관계 및 종내변이를 조사하기 위하여 화분립의 극축길이, 적도면 폭, 구의 길이, 구의 폭을 측정하고 화분립의 극축길이에 대한 적도면 폭의 비율을 계산하였다 본 연구 결과를 근거로 하여 군집분석을 수행한 결과 상수리나무와 굴참나무의 화분형태가 가장 유사관계가 높은 것으로 나타났다. 조사된 수종 중 화분립의 크기에 있어서 폭 넓은 변이를 나타내는 떡갈나무의 경우에는 polyploid와 (또는) aneuploid의 형태가 존재하는 것으로 추정되었다. 참나무아속 수종들의 ploidy levels에 대한 연구가 수행되어야 할 것이다.

Key words : *Lepidobalanus*, pollen morphology, intraspecific variation

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INTRODUCTION

There are more than 200 *Quercus* spp. in the world and their major communities are spread over the temperate zone in the northern hemisphere, Colombia of South America in the southern hemisphere, and the Malay Archipelago in Asia. Most of *Quercus* spp. are deciduous or evergreen trees, rarely shrubs. The genus *Quercus* L. is divided into three subgenera; *Cyclobalanopsis* Prantl., *Erythrobalanus* Spach., and *Lepidobalanus* Endl.[23].

Though, in Korea, *Lepidobalanus* spp. have not been considered as economic planting species and replaced by other coniferous trees, they have kept their prosperity and occupied 27% of the total stock volume in the forest where they are the dominant species with pine trees[1,2,3]. This suggests that *Lepidobalanus* spp. play an important role in the forest ecosystem in Korea.

In Korea, *Lepidobalanus* spp. grow fast and produce heavy, hard, and fine woods which have been used to make various furniture and buttresses and to decorate buildings. *Quercus* biomass is used as an important source to bioenergy so that there are a great demand for their biomass[14]. Also, lateral branches or small trees produced during the thinning operation have been used as an excellent host to grow various mushrooms as a good forest byproduct. Their cork production adds to their high value. Their fruit (acorn) which contains carbohydrate and stored protein is important animal food and even to Koreans who take it as a tonic[9].

Pollen morphology can be applied to and useful for various research areas, such as taxonomy, genetic and evolutionary studies, allergy studies, melissopalynology, forensic science, tracing plant geography, geology (stratihraphy), climatic change studies and the study of past human impact on vegetation[15]. Most references on *Quercus* are about pollen surface patterns and grain types which might be used to classify the species.

Therefore, this study aimed to examine intraspecific variation in the pollen morphology of subgenus *Lepidobalanus* Endl.

MATERIALS AND METHODS

Pollen materials of the following six species of subgenus *Lepidobalanus* Endl. in Korea were studied: *Quercus acutissima* Carruther, *Q. aliena* Blume, *Q. dentata* Thunb. ex Murray, *Q. mongolica* Fischer ex Ledebour, *Q. serrata* Thunb. ex Murray, and *Q. variabilis* Blume (Table 1). Five populations were used. from representative and distant localities to record the highest possible variability. Fifteen different samples per each species were used, making a total of 90 samples, and the pollen materials of each samples were generally collected in the field. The origin of 90 samples from five populations studied is given in Table 1, where province and voucher specimens are indicated.

The materials were acetolysed for light microscopy according to Erdtman[6] with the modifications recommended by Livingstone[13]. Twenty randomly selected pollen grains from each of the 90 samples were measured with a Light Microscope (LM) (BHC, Olympus Optical Co., Ltd).

The parameters measured were polar axis length (PL), equatorial width (EW), colpus length (CL), and colpus width (CW) (Fig. 1), and P/E (PL/EW) ratios were calculated.

The terminology of pollen morphology used here follows that of Reitsma's[24].

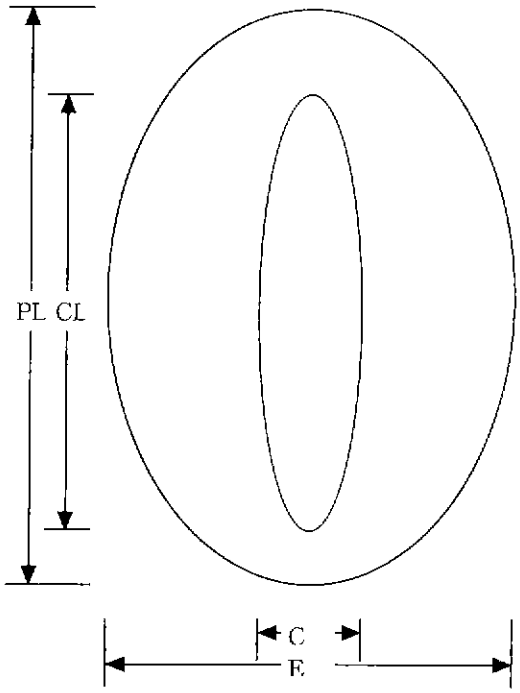

Fig. 1. Schematic representation of a *Lepidobalanus* pollen grain indicating the position of the four parameters measured (PL, polar axis length; EW, equatorial width; CL, colpus length; CW, colpus width).

All statistical procedures were carried out using SAS version 6.12 (SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

3.1 Pollen Morphology

The pollen morphological data for the six species studied are summarized in Table 2.

3.1.1 Pollen Grain Size

This LM study on *Lepidobalanus* species showed that polar axis length was 17.5-39.4 ㎛, and equatorial width was 16.7-34.2 ㎛.

In this study, the polar axis length of *Quercus dentata* Thunb. ex Murray, the only tetraploid (or diploid), was the longest (20.1 - 39.4 ㎛) and the length of *Q. serrata* Thunb. ex Murray was the shortest (17.5-31.6㎛) Also, when the polar axis length of pollen was considered with its pollination method, it is obvious that Korean *Lepidobalanus* spp. are anemophilous plants.

The equatorial width of *Quercus dentata* Thunb. ex Murray was the longest (18.6 - 34.2㎛) as its polar axis was the longest while the width of *Q. serrata* Thunb. ex Murray was the shortest (16.7 - 29.8 ㎛) as its polar axis length was the shortest.

The polar axis lengths of pollens were in the following decending order; *Quercus dentata* Thunb ex Murray > *Q. mongolica* Fischer ex Ledebour > *Q. acutissima* Carruther > *Q. variabilis* Blume > *Q. aliena* Blume > *Q. serrata* Thunb. ex Murray. The equatorial diameter of pollens showed the following decending order; *Quercus dentata* Thunb. ex Murray > *Q. acutissima* Carruther > *Q. variabilis* Blume > *Q. mongolica* Fischer ex Ledebour > *Q. aliena* Blume > *Q serrata* Thunb. ex Murray.

3.1.2 Aperture Size

The aperture of *Lepidobalanus* spp. was 13.0-32.7㎛ in the colpus length and 1.1-3.0 ㎛ in the colpus width. And the colpus length of *Quercus dentata* Thunb. ex Murray was the longest (16.7-32.7㎛) and the length of *Q. serrata* Thunb. ex Murray was the shortest(14.0-26.0㎛).

However, the colpus width of *Quercus acutissima* Carruther was the longest (1.5-2.6㎛) and the width of *Q. mongolica* Fischer ex Ledebour was the shortest (1.1-2.2㎛).

The colpus lengths of pollens were in the following decending order; *Quercus dentata* Thunb. ex Murray > *Q. mongolica* Fischer ex Ledebour > *Q. acutissima* Carruther > *Q. variabilis* Blume > *Q. aliena* Blume > *Q. serrata* Thunb. ex Murray, while the colpus width of pollens showed the following decending order; *Q. acutissima* Carruther >

Table 1. *Lepidobalanus* samples investigated.

Sample No.	Origin	Chromosome number(2*n*)[a,b]
Q. acutissima Carruther[a]		24
ACU 11	Mt. Gwanak, Gyeonggi Prov.	
ACU 12	Mt. Gwanak, Gyeonggi Prov.	
ACU 13	Mt. Gwanak, Gyeonggi Prov.	
ACU 21	Mt. Gyeryong, Chungnam Prov.	
ACU 22	Mt. Gyeryong, Chungnam Prov.	
ACU 23	Mt. Gyeryong, Chungnam Prov.	
ACU 31	Mt Mudeung, Gwangju	
ACU 32	Mt. Mudeung. Gwangju	
ACU 33	Mt. Mudeung. Gwangju	
ACU 41	Mt. Seorak, Gangwon Prov.	
ACU 42	Mt. Seorak, Gangwon Prov.	
ACU 43	Mt. Seorak, Gangwon Prov.	
ACU 51	Mt. Palgong, Gyeongbuk Prov.	
ACU 52	Mt. Palgong, Gyeongbuk Prov.	
ACU 53	Mt. Palgong, Gyeongbuk Prov	
Q. aliena Blume[b]		?
ALI 11	Mt. Gwanak, Gyeonggi Prov.	
ALI 12	Mt. Gwanak, Gyeonggi Prov.	
ALI 13	Mt. Gwanak, Gyeonggi Prov.	
ALI 21	Mt. Gyeryong, Chungnam Prov.	
ALI 22	Mt. Gyeryong, Chungnam Prov.	
ALI 23	Mt. Gyeryong, Chungnam Prov.	
ALI 31	Mt. Mudeung. Gwangju	
ALI 32	Mt. Mudeung, Gwangju	
ALI 33	Mt. Mudeung, Gwangju	
ALI 41	Mt. Seorak, Gangwon Prov.	
ALI 42	Mt. Seorak, Gangwon Prov.	
ALI 43	Mt. Seorak, Gangwon Prov.	
ALI 51	Mt. Palgong, Gyeongbuk Prov.	
ALI 52	Mt. Palgong, Gyeongbuk Prov.	
ALI 53	Mt. Palgong, Gyeongbuk Prov.	
Q dentata Thunb. ex Murray[b]		24, 48
DEN 11	Mt Gwanak, Gyeonggi Prov.	
DEN 12	Mt. Gwanak, Gyeonggi Prov.	
DEN 13	Mt Gwanak, Gyeonggi Prov.	
DEN 21	Mt. Gyeryong, Chungnam Prov.	
DEN 22	Mt. Gyeryong, Chungnam Prov.	
DEN 23	Mt. Gyeryong, Chungnam Prov.	
DEN 31	Mt. Mudeung, Gwangju	
DEN 32	Mt. Mudeung, Gwangju	
DEN 33	Mt. Mudeung, Gwangju	
DEN 41	Mt. Seorak, Gangwon Prov.	
DEN 42	Mt. Seorak, Gangwon Prov.	
DEN 43	Mt. Seorak, Gangwon Prov.	
DEN 51	Mt. Palgong, Gyeongbuk Prov.	
DEN 52	Mt. Palgong, Gyeongbuk Prov.	
DEN 53	Mt. Palgong, Gyeongbuk Prov.	

Q. mongolica Fischer ex Ledebour[b]		24
MON 11	Mt. Gwanak, Gyeonggi Prov.	
MON 12	Mt. Gwanak, Gyeonggi Prov.	
MON 13	Mt. Gwanak, Gyeonggi Prov.	
MON 21	Mt. Gyeryong, Chungnam Prov.	
MON 22	Mt. Gyeryong, Chungnam Prov.	
MON 23	Mt. Gyeryong, Chungnam Prov.	
MON 31	Mt. Mudeung, Gwangju	
MON 32	Mt. Mudeung, Gwangju	
MON 33	Mt. Mudeung, Gwangju	
MON 41	Mt. Seorak, Gangwon Prov.	
MON 42	Mt. Seorak, Gangwon Prov.	
MON 43	Mt. Seorak, Gangwon Prov.	
MON 51	Mt. Palgong, Gyeongbuk Prov.	
MON 52	Mt. Palgong, Gyeongbuk Prov.	
MON 53	Mt. Palgong, Gyeongbuk Prov	
Q. serrata Thunb ex Murray[b]		24
SER 11	Mt. Gwanak, Gyeonggi Prov.	
SER 12	Mt. Gwanak, Gyeonggi Prov.	
SER 13	Mt. Gwanak, Gyeonggi Prov.	
SER 21	Mt. Gyeryong, Chungnam Prov.	
SER 22	Mt. Gyeryong, Chungnam Prov.	
SER 23	Mt. Gyeryong, Chungnam Prov.	
SER 31	Mt. Mudeung, Gwangju	
SER 32	Mt. Mudeung, Gwangju	
SER 33	Mt. Mudeung, Gwangju	
SER 41	Mt. Seorak, Gangwon Prov.	
SER 42	Mt. Seorak, Gangwon Prov.	
SER 43	Mt. Seorak, Gangwon Prov.	
SER 51	Mt Palgong, Gyeongbuk Prov	
SER 52	Mt. Palgong, Gyeongbuk Prov.	
SER 53	Mt. Palgong, Gyeongbuk Prov	
Q. variabilis Blume[a]		24
VAR 11	Mt. Gwanak, Gyeonggi Prov.	
VAR 12	Mt. Gwanak, Gyeonggi Prov.	
VAR 13	Mt. Gwanak, Gyeonggi Prov.	
VAR 21	Mt. Gyeryong, Chungnam Prov.	
VAR 22	Mt. Gyeryong, Chungnam Prov.	
VAR 23	Mt. Gyeryong, Chungnam Prov.	
VAR 31	Mt. Mudeung, Gwangju	
VAR 32	Mt. Mudeung, Gwangju	
VAR 33	Mt. Mudeung, Gwangju	
VAR 41	Mt. Seorak, Gangwon Prov	
VAR 42	Mt. Seorak, Gangwon Prov.	
VAR 43	Mt. Seorak, Gangwon Prov.	
VAR 51	Mt. Palgong, Gyeongbuk Prov.	
VAR 52	Mt. Palgong, Gyeongbuk Prov.	
VAR 53	Mt. Palgong, Gyeongbuk Prov.	

[a] Section Cerris Loud.
[b] Section Prinus Loud.
The voucher specimens are deposited at the herbarium of Faculty of Forest Science, Chonbuk National University.

Table 2. Pollen morphological data: polar axis length (PL), equatorial width (EW), colpus length (CL), colpus width (CW), and polar axis length/equatorial width (P/E); the range is given in parentheses.

Taxa	Pollen grain size(μm)		Colpus(μm)		P/E
	PL	EW	CL	CW	
Q. acutissima					
Mt. Gwanak	27.3(22-33)	26.8(19-30)	21.6(13-28)	1.7(1.5-2.2)	1.02(0.90-1.32)
Mt. Gyeryong	29.6(26-34)	29.5(26-34)	23.2(20-28)	1.6(1.5-2.2)	1.01(0.88-1.21)
Mt. Mudeung	28.4(23-32)	26.3(22-31)	22.6(19-27)	1.8(1.5-2.2)	1.09(0.95-1.32)
Mt. Palgong	26.5(22-35)	26.2(20-31)	21.0(16-27)	1.8(1.5-2.6)	1.01(0.86-1.44)
Mt Seorak	27.8(23-32)	27.4(22-31)	22.1(17-26)	1.6(1.5-2.2)	1.02(0.88-1.23)
Mean(SE)	27.8(0.17)	27.2(0.16)	22.0(0.16)	1.7(0.02)	1.03(0.006)
Q. aliena					
Mt. Gwanak	25.5(21-32)	24.7(20-30)	20.3(15-27)	1.5(1.1-1.9)	1.04(0.88-1.38)
Mt. Gyeryong	26.2(23-32)	25.7(22-32)	20.2(17-26)	1.6(1.5-2.2)	1.02(0.86-1.13)
Mt. Mudeung	26.1(22-32)	23.5(19-28)	19.5(14-27)	1.6(1.1-2.2)	1.12(0.85-1.45)
Mt. Palgong	24.7(22-31)	24.3(18-28)	19.6(16-24)	1.5(1.5-2.2)	1.03(0.80-1.40)
Mt. Seorak	24.5(19-32)	23.6(19-26)	19.2(13-26)	1 5(1.5-1.9)	1.04(0.89-1.39)
Mean(SE)	25.4(0.15)	24.3(0 13)	19.8(0.15)	1.5(0.01)	1 05(0.007)
Q. dentata					
Mt. Gwanak	29.6(20-35)	26 3(19-33)	22.0(17-27)	1.5(1.1-1.9)	1.13(0 89-1.29)
Mt. Gyeryong	33.0(27-39)	29.5(25-33)	23.9(20-30)	1.6(1.5-3.0)	1.12(0.96-1.32)
Mt. Mudeung	32.0(23-38)	29.3(23-34)	25.0(18-33)	1.7(1.5-2.6)	1.09(0.93-1.28)
Mt. Palgong	31.5(23-34)	28.5(21-32)	23.8(18-28)	1.5(1.1-1.9)	1.11(0.95-1 36)
Mt Seorak	31.7(26-37)	27.6(24-31)	23.2(20-29)	1.6(1.1-1.9)	1.15(0.96-1.33)
Mean(SE)	31.6(0.21)	28.3(0.17)	23.6(0.19)	1.6(0.01)	1.12(0.006)
Q. mongolica					
Mt. Gwanak	29.3(24-35)	24.5(21-30)	21.4(16-25)	1.4(1.1-1.9)	1.20(0.99-1.44)
Mt. Gyeryong	28.4(23-32)	24.7(19-29)	22.9(19-26)	1.7(1.5-2.2)	1.16(0 94-1.42)
Mt. Mudeung	31.6(26-36)	26.2(18-30)	24.0(18-29)	1.4(1.1-1.9)	1.21(1.05-1.56)
Mt. Palgong	30.3(24-36)	25.1(22-27)	24.0(18-29)	1.5(1.1-1.9)	1.21(0.98-1.47)
Mt. Seorak	30.9(24-35)	24 9(22-30)	23.5(15-26)	1.4(1 1-1.9)	1.24(1.06-1.45)
Mean(SE)	30 2(0.16)	25.1(0.12)	23.2(0.15)	1.5(0.01)	1.21(0.007)
Q. serrata					
Mt. Gwanak	25.7(23-28)	22.8(20-30)	19.8(17-23)	1.6(1 5-1.9)	1.14(0.78-1.35)
Mt. Gyeryong	24.7(17-32)	21.7(17-26)	19.5(15-26)	1.6(1.5-1.9)	1.14(0.93-1.42)
Mt. Mudeung	26.6(23-30)	21.9(19-28)	20.1(17-23)	1.5(1.1-1.9)	1.22(1.06-1.38)
Mt. Palgong	24.8(20-28)	23.1(19-29)	19.5(16-26)	1.5(1.1-1.9)	1.08(0.91-1.39)
Mt. Seorak	23.7(20-27)	22.3(19-26)	18.8(16-21)	1.5(1.5-1.9)	1.07(0.86-1.28)
Mean(SE)	25.1(0.13)	22.3(0.14)	19.5(0.12)	1.5(0.01)	1.13(0.007)
Q. variabilis					
Mt. Gwanak	27.7(24-33)	25.5(22-29)	20.2(17-26)	1.5(1.1-1.9)	1.09(1 00-1.28)
Mt. Gyeryong	28.5(24-33)	25.7(21-30)	22.6(18-28)	1.6(1.5-1.9)	1.11(0.96-1.44)
Mt. Mudeung	25.7(18-34)	23.5(19-29)	20.0(14-28)	1.5(1.1-2.2)	1.09(0.87-1.42)
Mt. Palgong	27.8(26-32)	26.6(24-31)	20.8(18-24)	1.6(1.5-2.2)	1.05(0.92-1.22)
Mt. Seorak	27.5(24-30)	25 9(21-30)	21.0(17-25)	1.5(1.1-1.9)	1.06(0.95-1.32)
Mean(SE)	27.6(0.15)	25.6(0.13)	21.0(0.15)	1.5(0.01)	1.08(0.005)

Q. dentata Thunb. ex Murray > *Q. serrata* Thunb. ex Murray > *Q. aliena* Blume > *Q. variabilis* Blume > *Q. mongolica* Fischer ex Ledebour.

3.1.3 Pollen Shape at the Equatorial View

The ratio of polar axis length to equatorial width (P/E) of *Lepidobalanus* spp. was about 1.10 which classifies the pollen shape to prolate-spheroidal at the equatorial view. However, *Quercus mongolica* Fischer ex Ledebour itself was subprolate.

Concerning the pollen shape at the equatorial view, Cho et al.[3] stated *Quercus acutissima* Carruther was prolate-spheroidal and supported this study result.

In addition, Lee[18] pointed that the pollen grain of anemophilous flowers is 1.10 in its P/E and prolate-spheroidal and the grain of entomophilous flowers is 0.98 in its P/E and oblate-spheroidal. Therefore, this result tended to be in accord with his study.

Shape in equatorial longitudinal view is not significantly modified with the ploidy level.

3.1.4 Morphological similarity of pollen

The dendrogram (Fig. 2) resulting from a cluster analysis based on the mean values of the parameters of pollen grains demonstrated that the four species (*Quercus acutissima* Carruther, *Q. variabilis* Blume, *Q. mongolica* Fischer ex Ledebour, and *Q. dentata* Thunb. ex Murray) could fall into one group and the last two spp. (*Q aliena* Blume and *Q. serrata* Thunb. ex Murray) into another group.

In classification, *Q. acutissima* Carruther and *Q. variabilis* Blume fall into the section Cerris Loud., *Q. aliena* Blume *Q. mongolica* Fischer ex Ledebour, *Q. dentata* Thunb. ex Murray and *Q. dentata* Thunb ex Murray into the section Prinus Loud[23]. This result based on the pollen morphology showed that

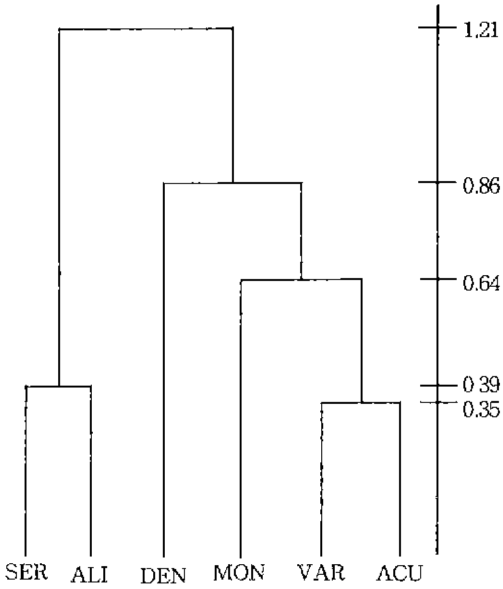

Fig. 2. Average linkage cluster dendrogram presenting the pollen morphological similarity relationship among six species of Korean subgenus *Lepidobalanus* Endl. based on the mean values of five pollen morphological traits.
Note : See Table 1 for abbreviations.

the similarity between *Q. acutissima* Carruther and *Q. variabilis* Blume, belonging to the same section, was the closest. However, the pollen morphological similarity among six species in this study is somewhat different when it is compared with other systematic study results[10,19,21,22,3,16].

In Korean subgenus *Lepidobalanus* Endl. the pollen grains are very uniform among the species when symmetry, shape, apertural system, and exine thickness are taken into consideration. These characters are not influenced by variation in ploidy levels. However, we can hypothesize that there are significant differences in pollen size, specially in PL and EW, in relation to changes in ploidy level.

3.2 Intraspecific Variation

Different intraspecific variation in each index value was found in the pollen parameters; PL, EW, CL, CW and P/E of 6 spp. (Table 3).

Table 3. The coefficients of variation for five pollen parameters.

Taxa	PL	EW	CL	CW	P/E
Q. acutissima	9.59	9.53	11.57	16.76	9.46
Gwanak	11.00	9.89	13.93	15.05	8.29
Gyeryong	6.69	6.00	8.34	12.21	9.07
Mudeung	6.90	8.82	10.35	15.15	8.70
Palgong	11.50	9.73	13.06	20.41	10.72
Seorak	6.52	7.56	8.79	14.39	7.89
Q. aliena	9.41	8.72	12.22	10.16	11.09
Gwanak	10.08	7.11	13.79	6.68	11.06
Gyeryong	8.44	9.03	9.41	12.82	6.09
Mudeung	7.05	8.96	11.73	13.06	10.36
Palgong	8.17	7.98	9.98	7.38	13.50
Seorak	11.38	7.49	14.71	4.81	10.29
Q. dentata	10.55	9.57	12.84	14.75	7.95
Gwanak	13.70	15.68	13.65	10.65	8.25
Gyeryong	9.66	6.64	10.75	17.18	7.70
Mudeung	11.64	7.64	16.78	17.57	8.45
Palgong	5.33	6.61	9.63	9.89	6.93
Seorak	9.02	5.88	8.92	12.09	7.74
Q. mongolica	8.53	7.41	10.08	15.12	9.34
Gwanak	7.65	8.19	9.45	18.90	8.90
Gyeryong	7.89	8.91	8.07	13.37	11.20
Mudeung	8.98	7.17	11.91	16.35	9.94
Palgong	8.06	5.43	8.76	10.25	9.36
Seorak	6.45	6.13	7.71	11.13	6.87
Q. serrata	8.32	9.88	10.33	10.88	10.24
Gwanak	5.34	9.52	7.63	9.98	10.99
Gyeryong	9.91	9.06	11.44	11.20	9.02
Mudeung	5.18	8.23	7.72	11.68	7.35
Palgong	8.54	11.46	14.32	10.78	10.47
Seorak	6.66	10.19	8.24	3.75	8.66
Q. variabilis	8.44	7.90	11.48	9.44	7.50
Gwanak	7.86	5.90	9.70	7.56	6.08
Gyeryong	7.20	7.97	10.58	9.62	7.88
Mudeung	16.81	11.45	19.08	13.62	11.56
Palgong	4.76	5.28	8.63	10.18	5.31
Seorak	4.63	6.84	8.00	6.35	6.06

Note : See Table 2 for abbreviations.

In *Q. serrata* Thunb. ex Murray, five parameter value over each variation index was below 10.88 and relatively low. It suggests that this is more stable than the other five spp. The variation value, 8.32, in PL was the least and the variation value, 10.88, in CW was the highest.

Q. variabilis Blume had the highest value, 11.48, in CL variation index and the lowest value, 7.50, in P/E variation value. And the five parameter value of Mt. Mudeung population was higher than the other populations in variation index. It seems that this was resulted from the regional and forest stand character of Mt. Mudeung.

The majority of the variation index values of pollen parameters fell into the range of 7-17 and this result is comparable to the work of Cho *et al.*[2] who examined the pollen character variation of *Q. acutissima* Carruther. There are differences in the values for coefficients of variation among populations within species.

The mean value for coefficients of variation in PL was higher for *Q. dentata* Thunb. ex Murray than for the other five species studied. Various degrees of intraspecific variation in measured pollen parameters could reflect the genetic variation in the species. We may also hypothesize about environmental effects, such as temperature and drought, causing such variation. While we can only speculate on such effects, it has been observed in taxa other than *Quercus L.* that variation in chromosome numbers (and ploidy levels) was related to the size of pollen grains[8,11]. Especially, Diaz Lifante stated that *Asphodelus* pollen size (PL) differences were in most cases statistically significant among populations with different chromosome numbers. In *Quercus L.*, there are several examples of polyploidy not only between species, but also within species[4,7]. While the species studied here are noted for diploid and tetraploid numbers of chromosomes (Table 1), the occurrence of different polidy levels within species has been recorded only for *Q. dentata* Thunb. ex Murray. Therefore, we can hypothesize that the larger degree of variation in PL observed in this study for *Q. dentata* Thunb. ex Murray, as compared with the other five species studied, indicate the existence of polyploid (and probably aneuploid) types in *Q. dentata* Thunb. ex Murray.

Concerning to the pollen grain size, PL× EW, in the spp. among the populations, *Q. acutissima* Carruther, *Q. aliena* Blume, and *Q. dentata* Thunb. ex Murray were the biggest at Mt. Gyeryong, and *Q. mongolica* Fischer ex Ledebour at Mt. Mudeung, *Q. serrata* Thunb. ex Murray at Mt. Gwanak, and *Q. variabilis* Blume at Mt. Palgong were the biggest. The mean value of the pollen size was in the following decending order; Mt. Gyeryong > Mt. Mudeung > Mt. Palgong > Mt. Seorak > Mt. Gwanak. Kim *et al.*[12] examined the leaf character variation of 10 *Q. mongolica* Fischer ex Ledebour native populations and 9 *Q. serrata* Thunb. ex Murray native populations and reported both spp. at Mt. Gyeryong were big which agrees to this study.

The increase of cell volume and all parts of a plant as a consequence of an increase in ploidy level is a well established fact[5,20,25]. On the other hand, Acacia pollen diameter as well as pore number and diameter varied according to a geographical pattern of variation both between species and topoclines within species[17] And this variation seems to be resulted from environmental factors such as climate, drought, and soil condition.

Based on the pollen morphological data, the similarity between Mt. Seorak population and Mt. Palgong population was the closest and Mt. Mudeung and Gyeryong populations were classified into the other group (Fig. 3).

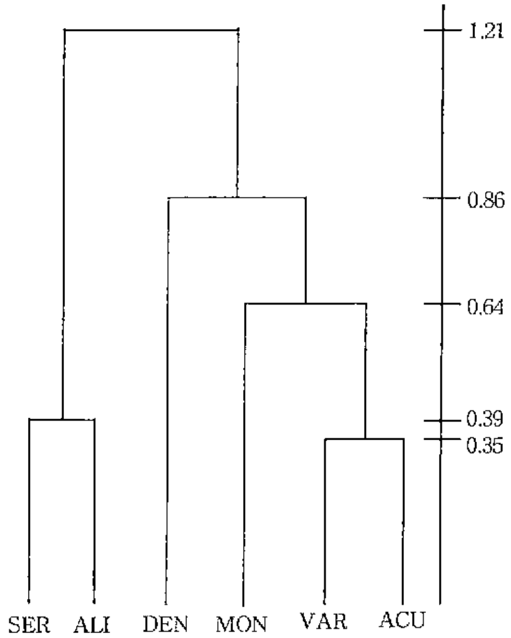

Fig. 3. Average linkage cluster dendrogram presenting the pollen morphological similarity relationship among five populations in Korean subgenus *Lepidobalanus* Endl. from five pollen morphological traits.

Note: KW, Mt. Gwanak population; KY, Mt. Gyeryong population, MU, Mt. Mudeung population, PA, Mt. Palgong population; SO, Mt. Seorak population

CONCLUSIONS

In this study, pollen morphological similarity relationship among Korean Lepidobalanus species was somewhat incongruent with other systematic study results.

The values for coefficients of variation in PL were higher for *Q. dentata* Thunb. ex Murray than for the other five species studied. In the case of *Quercus dentata* Thunb. ex Murray showing wide variation in the size of pollen grain, the existence of polyploid and (or) aneuploid forms was hypothesized.

The mean value of the pollen size of Mt. Gyeryong population was the largest and the cluster analysis carried out on the basis of this result showed that the pollen morphological similarity relationship between Mt. Seorak population and Mt. Palgong population was the closest one.

Therefore, studies on ploidy levels within species and on the environmental factors such as soil condition and microclimate are recommended to cause pollen size and character variation.

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