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Selection of Superior Trees for Larger Fruit and High Productivity in *Sorbus commixta* Hedl.

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ABSTRACT

The objectives of this study, an analysis of the variation for leaf and fruit characteristics among the selected ten populations of *Sorbus commixta* Hedl. could be used for the conservation of gene resources and could provide information to superior trees selection. The results obtained from this study can be summarized as follows;

Approximately, the Mt. Sungin population at Ulleung island showed larger values in overall characteristics and populations. On the other hand, Mt. Halla population at Jeju island showed the smaller values of the overall characteristics and populations.

ANOVA tests showed that there were statistically significant differences in all leaf characteristics among the populations as well as individual trees within populations. But, for fruit characteristics, differences were statistically significant only among the populations.

Cluster analysis using single linkage method based on leaf and fruit characteristics showed that ten selected populations of *S. commixta* in Korea could be clustered into three groups. Group I is Mt. Sungin at Ulleung island, Group II is Mt. Halla at Jeju island, and Group III comprises Osan, Mt. Kaji, Mt. Duckyoo, Mt. Balwang, Mt. Sobaek, Mt. O-dae, Mt. Jiri, and Mt. Taebaek.

The selection level based on major agronomic traits, which are the Number of Fruit per Fruiting Lateral(NFL) over 50, and Fruit Length(FL) and Width(FW) over 10 mm, and Weight of 100 Fruit(WF100) over 66 g, was applied on 100 sample trees, and five trees were selected. The selection effects from selected trees in NFL, FL, FW, and WF100 were evaluated as 132%, 151%, 142%, and 264% compared to the mean of those 100 sample trees, respectively. Especially, Ulleung 2 showed excellent values that NFL and WF100 were 95, and 69 g, respectively, suggesting a promising new cultivar for larger fruit and high productivity.

Key words **:** *Sorbus commixta*, Superior tree selection, Selection effect, Agronomic traits, Larger fruit, High productivity

INTRODUCTION

S. commixta Hedl. is a deciduous and taller tree that is widespread in China, Japan, and Korea. In those countries, it has been used as medicinal resources for treating various ailments, as well as food, an industrial,

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and an ornamental tree(Lee, 1985). Analysis has been conducted on the nutrient content of seeds of rowanberry(*alias* Sorbus semen), stem and branches(*alias* Sorbus cortex), and bark of S. *commixta*, in which they have been known as a nourishment tonic, cough remedy, an expectorant, inflammation treatment, and other disease. Recently, researches reported that Flavonoid, Carotene, and acid proof materials were extracted from S. *commixta*(Kim, 1999; Na, 2000; Lee, 2003). Also, this species grows well at high elevations, over 500 m, and in a relatively low temperature zone. In addition to, it produces extremely large clusters of red berries, which make for an extremely decorative tree, especially during the winter months when berries hang from the branches after the leaves have dropped(Shin *et al.*, 1983).

In light of this new research and development, it can be stated that *S. commixta* is valuable for development of both edible and medicinal uses, and in fact, there is an even greater demand for these products. But, it has not been done many researches, for example, on the environment needed for the birth and breeding, and ecological and physiological, genetic variation of this species.

In general, there is the need for improvement of forest form and for selection of excellent individuals for management of genetic variation through the analysis of genetic variation within a forest that contains a variety of genetic variations. It is necessary to carry out research successively and continuously for developing a dominant population or mass selection, with tree selection and progeny testing from natural populations. To promote this research, systematic and basic researches are needed for understanding the level of variation within selected population and individual variation among populations.

This study, a variation survey and analysis of leaf and fruit characteristics among the selected populations of *S. commixta*, is more valuable in terms of a tree for a special use, such as food, medicine, or a cash tree for farmers. This study could be used for the selection of larger fruit and high productivity of the tree and will provide information on superior tree selection before the mass-rearing larger fruit and high productivity of the trees.

MATERIALS AND METHODS

1. Materials

The Division of Genetics and Resources, Korea Forest Research Institute selected specimens to produce larger fruit and high productivity of the *S. commixta* in 2002. Ten populations were selected and divided into two groups(nine natural populations and one planted population). The natural populations are A to E and G to J in Fig. 1. The planted population is located in Osan(F), which was planted in 1996(Fig. 1).

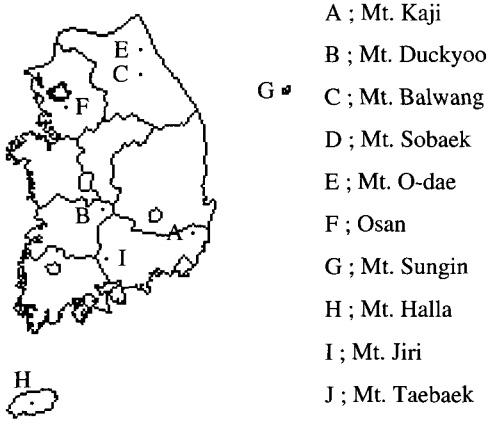

Fig. 1. Location of selected ten populations for *S. commixta.*

Mature leaves and fruits from normal branches and fruiting laterals were collected, because these are an excellent independent entity of the *S. commixta.* Ten leaves and twenty fruits per tree collected from each of ten trees per population were used to measure morphometric traits.

Table 1. Elements of leaf and fruit morphometric characteristics for *S. commixta*

Abbreviation	Leaf Characteristics	Abbreviation	Fruit Characteristics
LP	Length of Pinnate(cm)	FL	Fruit Length(mm)
WP	Width of Pinnate(cm)		
LR	Length of Rachis(cm)		
DR	Diameter of Rachis(mm)	FW	Fruit Width(mm)
LLR	Length of Lower Rachis(cm)		
LUR	Length of Upper Rachis(cm)		
LTL	Length of Terminal Leaflet(cm)	WF100	Weight of 100 Fruit(g)
WTL	Width of Terminal Leaflet(cm)		
NL	Number of Leaflet(Ea)		
PMI	Pinnate Morphological Index(WP/LP)	WPL	Weight per Liter(g/ *l*)
TLMI	Terminal Leaflet Morphological Index(WTL/LTL)		

2. Investigation and measurements

Leaf characteristics of *S. commixta* were measured with leaves without disease spots from mature and normal branches. Total 1,000 leaves, ten leaves from each of ten trees per population, were used to measurement of nine morphometric characteristics such as Length of Pinnate(LP), Width of Pinnate(WP), Length of Rachis(LR), Diameter of Rachis(DR), Length of Lower Rachis(LLR), Length of Upper Rachis(LUR), Length of Terminal Leaflet(LTL), Width of Terminal Leaflet(WTL), Number of Leaflet(NL) with a scale ruler and caliper(Table 1). The ratio of the WP and LP, WTL and LTL were used to determine Pinnate Morphological Index(PMI : WP/LP), and Terminal Leaflet Morphological Index(TLMI : WTL/LTL), respectively.

Also, four fruit characteristics of *S. commixta* that were assessed with total 2,000 fruits, twenty fruits per tree from each of ten trees per population. As can be seen in Table 1, four characteristics, Fruit Length(FL), Fruit Width(FW), Weight of 100 Fruit(WF100), and Weight per Liter(WPL) were measured with a scale ruler, caliper, and balance.

The selection level based on major agronomic traits, which are the Number of Fruit per Fruiting Lateral(NFL), FL and FW, and WF100 was applied on 100 sample trees and analyzed to the selection effects(Chung, 1994; Kim, 1998; Ahn *et al.*, 2002; Kim et al., 2002a, 2002b).

Based on these data, the ANOVA test and cluster analysis were carried out among the selected populations and the individual trees of the selected populations through the SAS(Statistical Analysis System, 1985) program.

RESULTS AND DISCUSSION

1. Leaf characteristics

Table 2 shows the results of analysis for the eleven leaf characteristics, such as the Lengths and Widths of Pinnate, Rachis, and Terminal Leaflet, and the Number of Leaflet of the *S. commixta* from the ten selected populations.

The coefficient of variation mean values for the Length of Pinnate and Width of Pinnate were diverse, and they were 21.4%, and 24.7%, respectively. The Mt. Sungin population at Ulleung island showed larger values with an average of 22.14 cm and 12.63 cm,

Table 2. Leaf characteristics of *S. commixta* by surveyed districts

Avg. / CV / Districts	Characteristics*										
	LP(cm)	WP(cm)	LR(cm)	DR(mm)	LLR(cm)	LUR(cm)	LTL(cm)	WTL(cm)	NL(Ea)	PMI	TLMI
Mt. Kaji	19.81 bc**	12.55 a	14.31 bc	2.38 b	4.07 b	1.50 a	5.46 b	2.08 b	11.10 f	0.63 ab	0.38 a
	16.1	20.5	17.2	13.8	14.7	29.2	21.3	21.3	5.4	9.0	12.7
Mt. Duckyoo	19.95 bc	12.34 ab	14.52 b	2.26 b	4.05 b	1.18 c	5.37 b	1.75 cd	11.94 cd	0.62 bc	0.33 de
	13.4	17.4	13.8	18.2	17.4	24.6	20.9	22.4	10.8	10.5	18.5
Mt. Balwang	20.07 b	11.92 b	14.63 b	2.30 b	3.54 d	0.91 e	5.44 b	1.69 d	13.26 a	0.60 cd	0.31 e
	20.2	16.8	21.8	18.1	23.2	31.7	22.5	25.6	10.7	12.4	18.9
Mt. Sobaek	19.59 bc	12.38 ab	13.79 cd	2.73 a	3.86 bc	1.41 b	5.79 a	2.21 a	11.20 f	0.63 ab	0.38 a
	15.8	16.3	19.3	16.2	17.7	29.1	19.8	26.5	10.6	8.8	16.6
Mt. O-dae	17.81 e	10.51 d	13.17 d	1.72 c	2.87 e	1.08 d	4.71 c	1.56 e	12.28 c	0.59 de	0.34 cd
	19.3	23.1	21.2	32.7	23.4	22.0	22.3	19.7	14.2	15.8	17.1
Osan	18.32 de	11.25 c	13.06 d	2.82 a	3.71 cd	1.08 d	5.28 b	1.86 c	11.98 cd	0.62 abc	0.36 bc
	15.3	16.1	17.7	17.2	24.9	27.0	21.1	23.2	12.0	17.1	19.3
Mt. Sungin	22.14 a	12.63 a	16.65 a	2.38 b	4.97 a	1.35 b	5.49 b	1.83 c	12.80 b	0.57 e	0.34 cd
	12.6	14.2	15.7	20.6	17.8	21.6	22.4	21.7	13.2	12.8	15.7
Mt. Halla	11.27 f	5.69 e	8.31 e	1.58 d	2.43 f	0.77 f	2.87 d	1.06 f	11.44 ef	0.51 f	0.38 a
	22.5	21.3	24.6	22.7	22.9	31.1	21.6	22.4	12.8	18.3	27.9
Mt. Jiri	19.15 cd	12.33 ab	13.69 cd	2.31 b	3.70 cd	1.15 cd	5.44 b	1.85 c	12.16 cd	0.65 a	0.35 bcd
	10.5	13.2	11.6	15.1	15.5	20.9	15.9	14.1	8.5	10.3	16.9
Mt. Taebaek	18.70 d	11.85 b	13.50 d	2.25 b	3.65 cd	1.14 cd	5.18 b	1.82 c	11.80 de	0.63 ab	0.36 b
	13.6	15.9	14.7	13.6	17.1	25.9	19.5	18.3	8.4	8.3	19.8
Mean	18.68	11.35	13.56	2.27	3.69	1.16	5.10	1.77	12.00	0.61	0.35
	21.4	24.7	23.0	24.4	26.1	32.3	26.0	27.7	12.2	13.9	19.9

* : Abbreviations of characteristics are the same as those of Table 1

** : Different letters indicate Duncan's multiple range tests(Significant at $p<0.05$)

which are 19% and 11% higher than total sampling mean of 18.68 cm and 11.35 cm for most characteristics in overall populations. On the other hand, Mt. Halla population at Jeju island showed the smaller values, with an average of the 11.27 cm and 5.69 cm, which are 40% and 50% lower than the total sampling mean of the overall characteristics and populations. This kind of population trend was almost the same as with other analyze of the leaf characteristics. Moreover, the range of average coefficient variation on the LP and WP were 10.5 to 23.1%, whereas, the Mt. Sungin population was in a narrow range of variation, and Mt. Halla population had the widest range of variation.

Also, the coefficient of variation mean values for the Length of Rachis and Diameter of Rachis were 23.0% and 24.4%, respectively. The average of LR was 13.56 cm, while on Mt. Sungin it was 16.65 cm and on Mt. Halla it was 8.31 cm. The total mean of DR was 2.27 mm. The Mt. Sobaek(2.73 mm), Osan(2.82 mm), and Mt. Sungin(2.38 mm) were higher than the mean, and Mt. Halla had the lowest value(1.58 mm) among the ten populations.

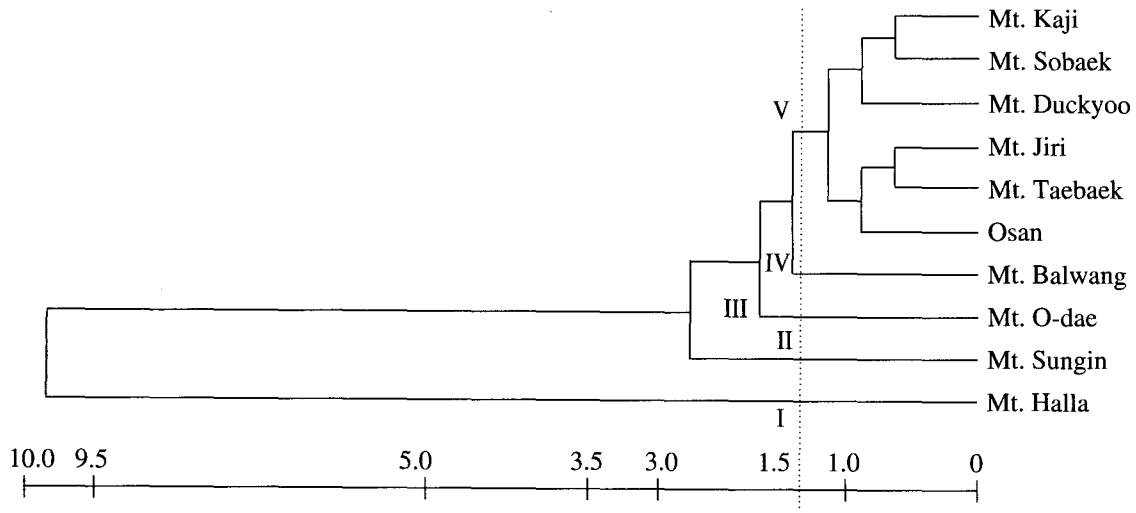

Fig. 2. Cluster dendrograms of *S. commixta* based on leaf characteristics.

The Length of Lower Rachis and Length of Upper Rachis were 26.1% and 32.2%, respectively, in the coefficient of variation mean values. For the LLR, Mt. Sungin population at Ulleung island showed excellent values with an average of 4.97 cm, which was 35% higher than the mean. The Mt. Halla population at Jeju island had the worst values, with an average of 2.43 cm among the ten selected populations. For the LUR, Mt. Kaji(1.50 cm), Mt. Sobaek(1.41 cm), and Mt. Sungin(1.35 cm) were higher than mean. The Mt. Halla had the lowest value as 0.77 cm.

However, both the Length of Terminal Leaflet and Width of Terminal Leaflet were highest on Mt. Sobaek, which was different trends than other characteristics. But, Mt. Halla had the lowest value in the two characteristics, which was the same as the above trends. The coefficient of variation mean values for the LTL and WTL were 26.0% and 27.7%, respectively. The two leaf characteristics on Mt. Sobaek showed excellent values with an average of 5.79 cm and 2.21 cm, which were 14% and 25% higher than the total sampling mean of 5.10 cm and 1.77 cm, respectively. On the other hand, Mt. Halla population at Jeju island showed the worst values, with an average of 2.87 cm and 1.06 cm, which were 44% and 40% lower than total sampling mean of the overall characteristics and populations.

In the Number of Leaflet analysis, the Mt. Balwang population was the most as 13.26, while the Mt. Kaji, Mt. Sobaek, and Mt. Halla populations demonstrated the lowest numbers of leaflets, 11.1, 11.2, and 11.4, respectively. Especially, for the Pinnate Morphological Index and Terminal Leaflet Morphological Index, the Mt. Kaji, Mt. Sobaek, and Mt. Halla populations scored 0.38 on the TLMI, which was a higher score than at the other populations.

Fig. 2 shows the dendrograms of cluster analysis that hired the single linkage method based on the eleven leaf characteristics of the selected ten populations of *S. commixta* in Korea.

There were five groups as to a distance level of 1.5. Group I is the Mt. Halla, Group II is the Mt. Sungin, Group III is the Mt. O-dae, Group IV is the Mt. Balwang, and Group V comprises Osan, Mt. Kaji, Mt. Duckyoo, Mt. Sobaek, Mt. Jiri, and Mt. Taebaek.

2. Fruit characteristics

Table 3 shows the results of analysis for the four fruit characteristics, such as the Fruit Length and Widths,

Table 3. Fruit characteristics of S. commixta by surveyed districts

Characteristics* \ Avg. / CV	Districts										
	Mt. Kaji	Mt. Duckyoo	Mt. Balwang	Mt. Sobaek	Mt. O-dae	Osan	Mt. Sungin	Mt. Halla	Mt. Jiri	Mt. Taebaek	Mean
FL(mm)	6.34 e**	6.95 cd	6.82 d	7.07 c	7.08 c	8.52 b	10.38 a	5.96 f	6.96 cd	7.05 c	7.31
	9.1	10.0	9.4	13.7	9.4	8.0	10.6	9.4	11.5	10.9	19.4
FW(mm)	6.73 e	6.76 e	6.57 f	6.49 f	7.35 c	9.04 b	9.79 a	5.68 g	6.78 e	6.98 d	7.22
	8.1	10.4	10.3	9.9	10.3	8.8	7.6	12.0	8.8	9.7	18.9
WF100(g)	19.06 cd	17.37 d	21.93 cd	19.03 cd	23.16 c	44.12 b	59.61 a	10.19 e	20.45 cd	19.60 cd	25.45
	10.3	15.1	21.2	29.8	26.0	25.0	12.7	24.0	19.5	21.0	59.4
WPL(g/ *l*)	424 c	398 c	418 c	418 c	487 c	925 b	1,292 a	243 d	458 c	457 c	552
	10.9	15.1	20.1	26.9	28.4	25.5	12.9	25.7	20.1	15.9	57.9

* : Abbreviations of characteristics were referred to Table 1

** : Different letters indicate Duncan's multiple range tests(Significant at $p<0.05$)

Weight of 100 Fruit, and Weight per Liter of the *S. commixta* from the ten selected populations.

The coefficient of variation mean values for the Fruit Length and Width were 19.4% and 18.9%, respectively. The Mt. Sungin population at Ulleung island showed larger values with an average of 10.38 mm and 9.79 mm, which are 42% and 36% higher than total sampling mean of 7.31 mm and 7.22 mm for most characteristics in overall populations. The next, Osan population showed larger values with an average of 8.52 mm and 9.04 mm. On the other hand, Mt. Halla population at Jeju island showed the smaller values, with an average of the 5.96 mm and 5.68 mm, which are 19% and 21% lower than the total sampling mean of the overall characteristics and populations.

This trend was almost the same as the result of the leaf characteristics. According to these results, it was assumed that there were a considerable differences between the populations and the various leaf and fruit characteristics of *S. commixta*(Fig. 3).

Total sampling means of the Weight of 100 Fruit and Weight per Liter were 25.45 g and 552 g/ *l* , respectively. The Mt. Sungin population at Ulleung island showed larger values with an average of 59.61 g and 1,292 g/ *l* for most characteristics in overall populations. The next, Osan population showed larger values with an average of 44.12 g and 925 g/ *l* . On the other hand, Mt. Halla population at Jeju island showed the smaller values, with an average of the 10.19 g and 243 g/ *l* of the overall characteristics and populations. Especially, the Mt. Sungin population at Ulleung island reveled the excellent values on the WF100 and WPL, and selection effect were evaluated as 134% compared to the mean of those 100 sample trees. Therefore, these results were applicable to the larger fruit and high productivity superior tree selection of *S. commixta* as major basis information in the near future.

ANOVA tests showed that there were statistically

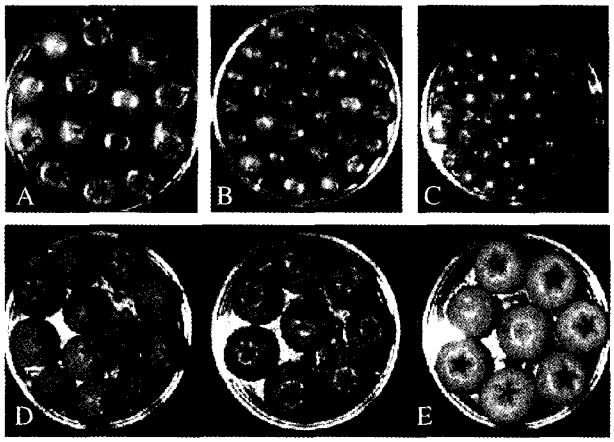

Fig. 3. Diversity of variation for fruit characteristics by selected populations of *S. commixta*.
A · B : Mt. O-dae, C : Mt. Halla,
D : Osan, E : Mt. Sungin

Table 4. Analysis of variance for fruit characteristics of *S. commixta*

Characteristics	Among populations		Among individuals within populations	
	MS	F-value	MS	F-value
FL	318.45	546.82**	3.02	1.50^{NS}
FW	309.95	658.85**	1.84	0.99^{NS}
WF100	2192.29	68.99**	20.17	0.08^{NS}
WPL	9779.83	67.10**	60.82	0.05^{NS}

**, NS : Significant at $p<0.01$, Non-significant, respectively

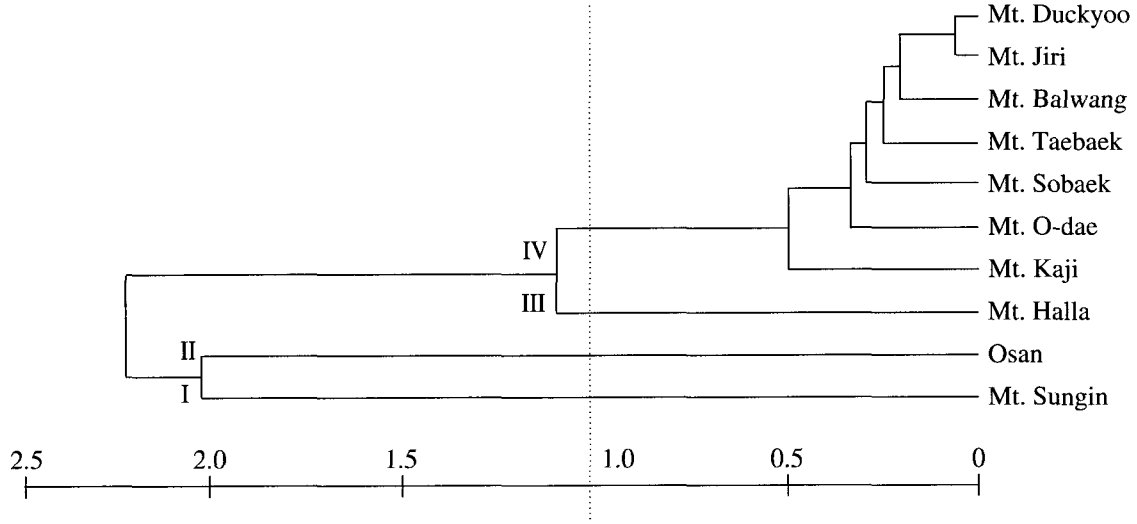

Fig. 4. Cluster dendrograms of *S. commixta* based on fruit characteristics.

significant differences in all fruit characteristics among the populations at 1% level. But, there were statistically non-significant differences among individual trees within the populations(Table 4).

Fig. 4 shows the dendrograms result of the cluster analysis that hired the single linkage method based on the fruit characteristics of the selected ten populations of *S. commixta* in Korea.

There were four groups as to a distance level of 1.0. Group I is the Mt. Sungin, Group II is the Osan, Group III is the Mt. Halla, and Group IV comprises Osan, Mt. Kaji, Mt. Duckyoo, Mt. Balwang, Mt. Sobaek, Mt. O-dae, Mt. Jiri, and Mt. Taebaek.

In conclusion, the leaf and fruit characteristics among the selected ten populations of *S. commixta* in Korea could be clustered into three groups. Group I is Mt. Sungin at Ulleung island, Group II is Mt. Halla at Jeju island, and Group III comprises Osan, Mt. Kaji, Mt. Duckyoo, Mt. Balwang, Mt. Sobaek, Mt. O-dae, Mt. Jiri, and Mt. Taebaek.

3. Selection effect

As referred to above, *S. commixta* has been used as medicinal resources for treating various ailments, as well as food, an industrial, and an ornamental tree. Also, recently researches reported that it has been some kinds of useful materials, such as Flavonoid, Carotene, and acid proof materials. Therefore, it is necessary to

Table 5. Selection effects for agronomic traits of *S. commixta*

Selection level	NFL	FL	FW	WF100	No. of selected tree
· NFL ≥ 50 & FL · FW ≥ 10 ㎜ & · WF100 ≥ 66 g	50	11.03	10.25	67.18	5 trees
Selected effect(%)	**132**	**151**	**142**	**264**	
Mean of 100 sample trees	38	7.31	7.22	25.5	

analyze the selection effect for agronomic trait among the selected populations of *S. commixta*, which is more valuable in terms of a tree for a special use, such as food, medicine or a cash tree for farmers(Kim *et al.*, 2002a).

The selection level based on major agronomic traits, which are the Number of Fruit per Fruiting Lateral over 50, and Fruit Length and Width over 10 mm, and Weight of 100 Fruit over 66 g, was applied on 100 sample trees and five trees were selected(Table 5).

The selection effects from selected trees in NFL, FL, FW, and WF100 were evaluated as 132%, 151%, 142%, and 264% compared to the mean of those 100 sample trees, respectively. Especially, Ulleung 2 showed excellent values that NFL and WF100 were 95 and 69 g, respectively, suggesting a promising new cultivar for larger fruit and high productivity(Table 6).

Therefore, additional research is required through genetic analysis such as, the RAPD method, corresponding enzyme, and fruit coloring analysis by populations for discovering the differences for the quantitative and qualitative characteristics of genus sorbus regarding environmental factors or genetic differences between the populations and species.

REFERENCES

Ahn, Y.S., S.H. Kim, H.G. Chung, Y.S. Jang, Y.C. Choi and K.I. Oh. 2002. The variation of leaf characters among natural populations of *Kalopanax septemlobus Koidz.* Journal of Korean Forestry Society. 91(6) : 755-764.

Chung, J.M. 1994. Taxonomic characteristics of Korean-native Anacardiaceae. Ph. D. Thesis, Gyeongsang National University, Chinju, Korea. pp. 101.

Kim, H.U. 1999. Screening of antioxidants from *Sorbus commixta* Hedl. and determination of its antioxidant activity. MS. Thesis, University of Konkuk, Seoul, Korea. pp. 62.

Kim, M.J., S.H. Kim and U. Lee. 2002a. Selection of Korean Black Raspberry(*Rubus coreanus* Miq.) for larger fruit and high productivity. Journal of Korean Forestry Society. 91(1) : 96-101.

Table 6. Characteristics of selected superior trees for larger fruit and high productivity

Characteristics / Selected trees	FL(㎜)	FW(㎜)	WF100(g)
Ulleung 2	10.04	10.77	69.00
Ulleung 5	11.87	9.56	66.17
Ulleung 10	10.19	9.88	67.12
Ulleung 1	11.30	10.39	66.64
Osan 5	11.87	10.56	67.77
Mean of 100 sample trees	7.3±0.03	7.2±0.03	25.5±1.51

Kim, M.J., U. Lee, S.H. Kim and H.G. Chung. 2002b. Variation of leaf, fruiting and fruit characteristics in *Rubus coreanus* Miq.. Korean Journal of Breeding. 34(1) : 50-56.

Kim, S.H. 1998. Ecology and superior tree selection of *Dendropanax morbifera* Lev.. Ph. D. Thesis, Gyeongsang National University, Chinju, Korea. pp. 135.

Lee, C.B. 1985. Illustrated flora of Korea. Hangmun Pub. Co., Seoul. pp. 990.

Lee, S.O. 2003. Effects of Sorbus *commixta* extract on alcohol metabolism and detoxification system. MS. Thesis, University of Keimyung, Daegu, Korea. pp. 64.

Na, M.K. 2000. Antioxidative compounds from the bark of Sorbus *commixta* Hedl.. MS. Thesis, Chungnam National University, Daejeon, Korea. pp. 77.

Shin, J.M., T.S. Kim and S.S. Han. 1983. A study on the ecological habitat and protection of natural Sorbus *commixta* forest at Mt. Seorak. Bulletin of the Forest Science, Kangwon National University. 3 : 1-9.

SAS Institute Inc. 1985. SAS user's guide : Statistics Version 5th ed. SAS Institute Inc, Cary, NC, U.S.A. pp. 956.

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