

## Breeding of mulberry variety “Shimgang” showing resistance to popcorn disease

Sung Gyoo Byung<sup>1\*</sup>, Seo Sang Deog<sup>2</sup>, Kim Yong Soon<sup>1</sup>, Ju Wan Taek<sup>1</sup>,  
Kim Hyun Bok<sup>1</sup>, and Kim Kee Young<sup>3</sup>

<sup>1</sup>Department of Agricultural Biology, National Institute of Agricultural Science, RDA, Wanju-gun, 55365, Korea

<sup>2</sup>Chungcheongnam-do Sericultural and Entomology Experiment Station, Gongju, 32528, Korea

<sup>3</sup>Rural Development Administration, 54875, Jeonju Korea

### Abstract

We bred a mulberry cultivar named Shimgang, through local adaptability test, which is under registration as a new cultivar for fruit production. Local adaptability test had been carried out at four local places (Suwon, Chuncheon, Buan and Jinju) for five years from 2011. This variety ‘Shimgang’ belongs to *Morus Microphylla* Buckl. selected from seedlings imported from USA. Shimgang was resistant to popcorn disease and high yielding variety in fruit productivity by 111% compared to control cultivar ‘Shimheung (*Morus alba* L.)’ for three years. Although fruits of ‘Shimgang’ was smaller in size and lower in sugar content of mulberry fruits, it showed stronger resistance than that of ‘Shimheung’. It is adaptable to every where except the places where cold and late frost damage happen frequently.

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### Introduction

Mulberry have been cultivated worldwide as a foliage crop for silkworm, and much research has been conducted on mulberry leaves.

Because mulberry fruit was considered of no use in silkworm rearing sericulture, mulberry varieties having a minimum of fruit are selected for breeding mulberry trees and little research has focused on the fruit.

Recently, mulberry fruit has been proved to have several functional ingredients (Kim and Kim 2003, Kim *et al.* 2005a, Kim *et al.* 1998, Kim *et al.* 1996, Lee *et al.* 2003) and increasingly evaluated as desirable food resources in fresh and

processed food and drink. With the increasing consumption of the mulberry fruits, it has also greatly increased the cultivated area. Popcorn disease of mulberry is caused by a fungus, thus it does no harm to the overall health of the trees for production of leaves, this disease is not considered economically important on cultivating mulberries for rearing silkworms.

But, it is a serious disease if the tree is being cultivated for commercial purposes of fruit production.

In addition, its fruits which are known to contain various beneficial substances for human health are commonly consumed in Asia. Annually, the productivity of mulberry fruits is greatly reduced by popcorn disease, also known as hypertrophy sorosis fruit

#### \*Corresponding author.

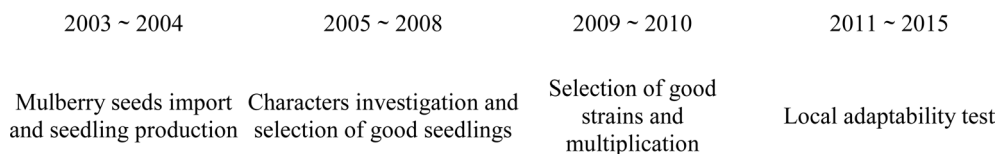
Sung Gyoo Byung

Department of Agricultural Biology, National Institute of Agricultural Science, RDA, Wanju-gun, 55365, Korea

Tel: +82-63-238-2844 / FAX: +82-63-238-3832

E-mail: truekbs@korea.kr

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**Fig. 1.** The pedigree of mulberry cultivar “Shimgang”, selection breeding from seedlings

scleroteniosis, swollen fruit disease, or shrunken fruit disease

Therefore, the needs for the breeding of resistant variety to popcorn disease has been increased.

The “Shimgang” was selected variety from imported mulberry seedlings showing resistance to popcorn disease, which was a serious when mulberry is being cultivated for producing fruits for commercial purposes.

We report briefly the major characteristics and breeding history of the new mulberry variety “Shimgang” showing significant resistance to popcorn disease.

## Material and Methods

### Characteristics investigation

Morphological and agronomical characteristics were investigated following “Manual for the characterization and evaluation of mulberry genetic resources(Machii *et al.* 1997) from 2015 to 2016.

General characteristics such as leaves, buds, and fruits were carried out Shape of winter buds, shape of petiole scar, internodal distance were investigated at dormant stage and leaf shape, depth of leaf lobation, leaf tip shape were investigated at growing stage.

### Local adaptability test

Local adaptability test had been carried out for five years from 2011 to 2015 at 4 local places(Suwon, Chuncheon, Buan and Jinju) of Korea, following “Sericultural Experiment Guide” published by RDA using “Shimheung” as control varieties. Cultivation of mulberry was conducted following “Sericultural Experiment Guide (RDA, 2010).

Occurrence rate of popcorn disease was investigated the number of fruits and diseased fruits at longest fruiting branch and leaf shape was classified by the method proposed by Hotta(1951).

## Characteristics of mulberry fruits

Sugar content in a fruit was measured using a PR-32 $\alpha$  refractometer (Atago co. Ltd) and calculated as the mean of 30 ripe fruits. Acidity in a fruit was measured using a GMK-835 acidity meter(G won hitech co. Ltd) and calculated as the mean of 30 ripe fruits.

## Results and Discussion

### Breeding history

The “Shimgang” was selected variety from imported mulberry seedlings showing resistance to popcorn disease, which was a serious when mulberry is being cultivated for producing fruits for commercial purposes.

Sowing mulberry seeds imported from USA at 2003, we produced and transplanted seedlings. Then, we investigated and selected good seedling strain by characteristic investigation for 4 years from 2005 to 2008.

Local adaptability test had been carried out at four local places(Suwon, Chuncheon, Buan and Jinju) for five years from 2011.

### General characteristic

Newly bred mulberry variety “Shimgang” belong to *Morus Microphylla* Buckl. by the standard of Koidzumi (1917) who classified the genus *Morus* into 24 species and one subspecies. Fig. 2 is the shapes of "Shimgang" variety branch with leaf and



**Fig. 2.** Shapes of “Shimgang” branch with leaf and fruits.

**Table 1.** Characters of ‘Shimgang’ compared to control cultivar ‘Chungil’ in 2015

Characters	Expression	Grade	Shimgang		Chungil	
			Grade	Measurement	Grade	Measurement
Shapes of winter buds	Obtuse angled triangular	1				
	Triangular	2	3		2	
	Acute angled triangular	3				
	Spindle shaped	4				
Size of winter buds	Very small	3				
	Medium	5				
	Large	7				
Colour of winter buds	Light gray	1	5		4	
	Grayish brown	2				
	Light brown	3				
	Brown	4				
	Reddish brown	5				
	Dark brown	6				
Leaf angle	Obtuse	3	5		5	
	Horizontal	5				
	Acute	7				
Leaf shape	Orbicular	1	2		5	
	Elliptic	2				
	Ovate	3				
	Cordate	4				
	Pentagonal	5				
	Lanceolate	6				
	Pseudomorphic	7				
Depth of leaf lobation	Lobate	3	3		7	
	Medium	5				
	Cleft	7				
Leaf size	Small	3	3		5	
	Medium	5				
	Large	7				
Leaf tip shape	Emarginate	1	3		3	
	Obtuse	2				
	Acute	3				
	Acuminate	4				
	Caudate	5				
Leaf serration	Repand	1	3		4	
	Crenate	2				
	Mucronate	3				
	Serrulate	4				
	Dentate	5				
	Double serrate	6				
	Aristate	7				
Leaf bottom shape	Truncate	1	2		3	
	Retuse	2				
	Cordate	3				
	Closed	4				

**Table 1.** Continued

Characters	Expression	Grade	Shimgang		Chungil	
			Grade	Measurement	Grade	Measurement
Leaf color	Yellow	1				
	Yellowish green	3				
	Light green	5	7		7	
	Green	7				
	Dark green	9				
Leaf gross	None	1				
	Weak	3	3		5	
	Medium	5				
	Strong	7				
Leaf wrinkle	None	1				
	Few	3	3		3	
	Medium	5				
	Many	7				
Leaf thickness	Thin	3				
	Medium	5	5		5	
	Thick	7				
Petiole length	None	1				
	Short	3	5	34.1mm	5	50.0mm
	Medium	5				
	Long	7				
Phyllotaxis	1/2	1				
	1/3	2				
	2/5	3	3		3	
	3/8	4				
	5/13	5				
No. of shoots	Few	3				
	Medium	5	5		5	
	Many	7				
No. of lateral shoots	None	1				
	Few	3	3		3	
	Medium	5				
	Many	7				
Shoot length	Short	3				
	Medium	5	7		5	
	Long	7				
Shoot size	Thin	3				
	Medium	5	5		5	
	Thick	7				
Shoot color	Light gray	1				
	Grayish brown	2				
	Greenish brown	3				
	Light brown	4	6		2	
	Brown	5				
	Reddish brown	6				
	Dark brown	7				

**Table 1.** Continued

Characters	Expression	Grade	Shimgang		Chungil	
			Grade	Measurement	Grade	Measurement
Texture of shoot surface	Fine	1				
	Coarse	2	3		1	
	Scabrous	3				
Tree form	Erect	3				
	Procumbent	5	3		3	
	Drooping	7				
Internodal distance	Short	3				
	Medium	5	7	52.3mm	3	38.6mm
	Long	7				
Shape of petiole scar	Circular	1				
	Elliptic	2	4		4	
	Semiicircular	3				
	Triangular	4				
Lenticel size	Small	3				
	Medium	5	3	1.0mm	5	1.8mm
	Large	7				
Lenticel density	Low	3				
	Medium	5	5		5	
	High	7				
Sex expression	Staminate	1				
	Predominantly staminate	2				
	Hermaphrodite	3	3		5	
	Predominantly pistillate	4				
	Pistillate	5				
Number of flower clusters	Few	3				
	Medium	5	7		7	
	Many	7				
Fruit weight	Small	3				
	Medium	5	3	2.4g	3	2.3g
	Large	7				
Fruit shape	Cylindrical	3				
	Ellipsoidal	5	3		3	
	Globose	7				
Fruit color	Milk white	1				
	Yellow	2				
	Pink	3				
	Pale purple	4	6		6	
	Reddish purple	5				
	Dark purple	6				
	Dark	7				

**Table 2.** Development of winter buds and leaf expending in 2015

Cultivar	Area	Sprouting date	Leaf expending date				
			1st	2nd	3rd	4th	5th
Shimheung	Suwon	4.25	4.26	4.27	4.28	4.29	5.1
	Chuncheon	5.9	5.13	5.15	5.16	5.18	5.20
	Buan	4.24	4.26	4.28	5.1	5.4	5.6
	Jinju	4.22	4.24	4.24	5.9	5.10	5.11
Shimgang	Suwon	4.24	4.25	4.26	4.27	4.28	4.29
	Chuncheon	5.6	5.10	5.11	5.13	5.14	5.17
	Buan	4.22	4.24	4.26	4.28	5.1	5.4
	Jinju	4.13	4.14	4.15	5.7	5.8	5.9

fruits. Shape of petiole scar is triangular, leaf shape is elliptic, leaf tip shape is acute and leaf bottom shape is retuse.

Sex expression is hermaphrodite which has female and male flower on the same plant. Phyllotaxis is 2/5, tree form is erect, internodal distance is 52.3mm which is longer than control cultivar “chungil” 38.6mm and number of flower clusters is many, fruit shape of ‘Shimgang’ is cylindrical, ripe fruit color is dark purple.

For other characteristics, refer to Table 1.

### Budding and leaf expanding

Budding and leaf expanding is related to late frost damage (Kim 1990), early budding varieties are likely to be a late frost damage. Table 2 denotes the development of winter buds and leaf expending in 2015. Shimgang variety showed no significant difference in development of winter buds and leaf expending.

In general, we distinguish the four~five days earlier variety early budding variety, the four~five days later variety later budding variety than middle budding variety “Chungil”. Because ‘Shimheung’ variety is middle budding like Chungil variety(Sung et al 2013), ‘Shimgang’ variety can be described as late frost damage is small variety.

### Characteristics of mulberry fruits

Table 3 shows single weight, sugar content, acidity and harvest periods.

Mean weight of ‘Shimgang’ fruits was 2.42g, which was less than control variety ‘Shimheung’ 2.8g. Sugar content and acidity

of ‘Shimgang’ fruits were 13.8 °Brix and 0.3% respectively, which were lower than that of control variety ‘Shimheung’.

The bigger and more °Brix the fruits are, the better quality of fruits. Therefore, it is necessary to improve Shimgang variety fructify a bigger sweet fruits.

Mulberry fruits harvest periods at Suwon began at June 3 and ended at June 16, which was later 2~4 days than that of ‘Shimheung’ variety.

In mulberry cultivation for the production of the mulberry fruits, harvest ends in a short period of 15 to 20 days, and harvest labor is concentrated a short period. This concentration of harvest labor lead to employment labor. Harvest period of Shimgang variety is no significant difference with Shimheung variety.

### Fruits productivity

Mulberry begins fruiting from threes after planting. Table 4 shows average productivity of ‘Shimgang’ variety for 3 years(3rd ~ 5<sup>th</sup> years after planting) at four local places.

At first harvesting year(third year after planting), average productivity of ‘Shimgang’ variety at four local places was high by 119% compared to control variety ‘Shimheung(*Morus alba* L.)’.

Average productivity of ‘Shimgang’ variety for 3 years(3rd ~ 5<sup>th</sup> years after planting) at four local places was high by 111% compared to control variety ‘Shimheung’

### Resistance to sclerotial disease

Sclerotial disease known as popcorn disease on mulberry fruits

**Table 3.** Characteristics of mulberry fruits and harvesting period (’13~’15, Average of 3 years except harvesting period)

Cultivar	Single fruit weight(g)	Sugar content(°Brix)	Acidity(%)	Harvesting period*	
Shimheung	Suwon	3.3	14.5	0.52	May 30~June 14
	Chuncheon	2.0	13.9	-	June 6~June 24
	Buan	2.8	16.0	-	May 29~June 19
	Jinju	2.7	14.5	-	May 25~June 14
	Average	2.7	14.7	0.52	-
Shimgang	Suwon	2.8	14.1	0.36	June 3~June 16
	Chuncheon	2.1	14.2	-	June 11~June 26
	Buan	2.4	13.9	-	May 26~June 17
	Jinju	2.4	12.8	-	May 24~June 15
	Average	2.42	13.8	0.36	-

\* Harvesting period denote data in ’15

**Table 4.** Yield of mulberry fruits (’13~’15, Average of 4 places)

Cultivar		Yield(kg/10a)				Average(Index)
		Suwon	Chuncheon	Buan	Jinju	
Shimheung	’13	109	57	117	40	78(100)
	’14	307	136	263	23	182(100)
	’15	435	166	154	401	289(100)
	Average	284	120	178	155	130(100)
Shimgang	’13	248	104	117	216	171(219)
	’14	374	209	335	585	376(207)
	’15	524	284	173	538	380(132)
	Average	382	199	208	446	274(211)

is a serious disease for the production of mulberry fruits, if the tree is being cropped for commercial purposes; however, it does no harm to the overall health of the trees

Table 5 shows the occurrence of sclerotial disease known on mulberry fruits during local adaptability test at four local places. The mean occurrence of popcorn disease of ‘Shimgang’ variety was 2.1%, which was 66.7% decreased compared to control variety ‘Shimheung’ 6.3%. Therefore, it is obvious that ‘Shimgang’ variety has resistance to sclerotial disease.

The disease is known to be caused by sclerotial fungal pathogens such as *Ciboria shiraiana* (Hong *et al.*, 2007b; Liang, 2009), *Scleromitruula shiraiana* (Kishi, 1998), and *Ciboria carunculoides* (Hong *et al.*, 2007a; Hu *et al.*, 2011; Siegler & Jenkins, 1923; Sultana *et al.*, 2013). In particular, C.

*shiraiana* was reported as the causative sclerotial pathogen most abundantly detected in Asia (Ahn *et al.*, 2013; Liang, 2009; Zhang & An, 2012). Symptoms of the disease were characterised by iscolouration and hypertrophied drupelets, which resulted in a popcorn-like appearance in fruits (Hong *et al.*, 2007b).

The occurrence and severity of popcorn disease varied depending on temperature, moisture (Yang, 1959), geographical location, and mulberry plant variety (Hong *et al.*, 2007b). Typically, disease symptoms start in late April and are ceased by July. Infected fallen fruits turn into mummified black sclerotia, a compact mass of hardened fungal mycelia, that can remain dormant for at least two years in the soil. Overwintered sclerotia germinated in the soil and induced apothecia to form encased ascospores within the ascus (Hong *et al.*, 2007a; Hu *et al.*, 2011).

**Table 5.** Occurrence of sclerotic disease (’10~’14, Average of 3 places)

Cultivar	Area	Sclerotic disease(%)			Average(Index)
		’13	’14	’15	
Chungil	Suwon	3.5	2.7	10.2	5.5
	Chuncheon	0.0	2.3	3.6	2.0
	Buan	16.3	6.8	18.5	13.9
	Jinju	1.6	0.2	8.9	3.6
	Average	2.8	3.0	10.3	6.3(100)
Shimgang	Suwon	0.0	0.0	4.1	1.4
	Chuncheon	0.0	0.4	1.2	0.5
	Buan	2.1	7.2	7.4	5.6
	Jinju	0.7	0.0	1.8	0.8
	Average	0.7	1.9	3.6	2.1(33)

These ascospores were dispersed to infect the floral stigma, leading to enlargement of ovaries and succulent calyx-lobes (Gray & Gray, 1987). It is noteworthy that, although the flowers remain infected, the symptoms of the disease are not expressed on the flowers but only appear on the fruits.

## Summary

Mulberry have been cultivated worldwide as a foliage crop for silkworm, and much research has been conducted on mulberry leaves.

With the increase of cultivating area, the damage of sclerotic disease known as popcorn disease.

It is a serious disease if mulberry is being cultivated for commercial purposes of fruit production. Therefore, the needs for the breeding of resistant variety to popcorn disease has been increased.

To meet these needs, the “Shimgang” showing resistance to popcorn disease, was bred in 2015.

The “Shimgang” was selected variety from imported mulberry seedlings showing resistance to popcorn disease, which was a serious when mulberry is being cultivated for producing fruits for commercial purposes.

The major characteristics of mulberry variety ‘Shimgang’ are as below.

1. Newly bred mulberry variety “Shimgang” belong to *Morus Microphylla* Buckl. by the standard of Koidzumi (1917) who classified the genus *Morus* into 24 species and one subspecies.

2. Mean weight of ‘Shimgang’ fruits was 2.42g, which was less than control variety ‘Shimheung’ 2.8g. Sugar content and acidity of ‘Shimgang’ fruits were 13.8 °Brix and 0.3% respectively, which were lower than that of control variety ‘Shimheung’.

3. Average productivity of ‘Shimgang’ variety for 3 years(3rd ~ 5<sup>th</sup> years after planting) at four local places was high by 111% compared to control variety ‘Shimheung’

4. The mean occurrence of popcorn disease of ‘Shimgang’ variety was 2.1%, which was 66.7% decreased compared to control variety ‘Shimheung’ 6.3%. Therefore, it is obvious that ‘Shimgang’ variety has resistance to sclerotial disease.

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