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Breeding of a New Silkworm Variety, Kumhwangjam, with a Sex-Limited Cocoon Color for Spring Rearing Season

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A new silkworm variety, Kumhwangjam, with a sex-limited cocoon color for spring rearing season is F_1 hybrid between Jam 309, a Japanese race bred from Y1/9153, and Jam 310, a Chinese race from Y1/8586. In the local adaptability test performed at 8 local areas in spring rearing season of 2003, major characteristics of Kumhwangjam were mainly similar to those of the check variety Kumokjam. The new silkworm variety, Kumhwangjam, showed a sex-limited cocoon color: yellow for female and white for male with elliptical cocoon shape. This sex-limited cocoon color can be used as a valuable marker for discrimination between female and male for various purposes.

Key words: *Bombyx mori*, Breeding, Combining ability, Kumhwangjam, Sex-limited cocoon color, Silkworm

Introduction

The breeding technology to produce new silkworm variety has been optimized over hundreds of years. Because of economic importance for silk yarn, an effort to breed new silkworm variety with high silk yielding has been focused. By relying on know-how accumulated for long periods of rearing silkworms, silk yielding is dramatically increased. Today, several hundred varieties have been bred accordingly various interests and purposes (Sohn *et al.*, 1987; Lee and Kim 2000; Kang *et al.*, 2001, 2002, 2003). In general, the main goal in traditional sericulture is to breed a new silkworm variety with high silk yielding. High cocoon yielding due to high resistance, high silk reeling ability and productivity, and better silk quality in neatness and lousiness is essential for new silkworm variety to increase silk productivity. Pupation rate, single cocoon weight, cocoon shell weight and cocoon shell percentage are the main factors affecting the high cocoon yield (Kang *et al.*, 2001, 2002, 2003). The breeding activities aimed to create new variety in high unit productivity has been needed for each rearing season because of different mulberry leaf condition and rearing condition in terms of temperature and humidity in the rearing season. The silkworm varieties for autumn have been already bred. These include several varieties of silkworm, such as hybrid between Jam 119 and Jam 120 (Lee *et al.*, 1980), Daesungjam (Sohn *et al.*, 1987), Bunongjam (Hong *et al.*, 1992), and non-cocooning variety Hachojam (Kang *et al.*, 2002). Up to now Daesungjam is widely used as a recommended variety for autumn season. The silkworm varieties for summer-autumn (Chugangjam) and spring rearing season (Chunsujam) have also been nominated (Kang *et al.*, 2001, 2003). Currently, furthermore, various varieties have been bred with various interests and purposes.

The sex-limited cocoon color varieties have been already bred for labor saving in egg production (Lee *et al.*, 1989; Hong *et al.*, 1997). The new non-cocooning variety Hachojam has been bred for production of silkworm-born mushroom, vegetable wasp and plant worm (Lee *et al.*, 2001). As shown in a variety Chugangjam (Kang *et al.*, 2003), sex-limited larval marking can be used as a visible marker for ease discrimination between female and male. In this study, we report the new silkworm variety with a sex-limited cocoon color, Kumhwangjam, which was nominated in 2003 as a new recommended variety for spring rearing season. The variety was bred through generation combining ability test and local adaptability test in Korea. In the present report, the major breeding schemes and important characteristics of Kumhwangjam are described.

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Materials and Methods

A silkworm *Bombyx mori* variety, Kumhwangjam, in this study is F_1 hybrid between Japanese race Jam 309 and Chinese race Jam 310. For the target to breed healthy and heavy pure lines, Japanese pure line Jam 309 (breeding line JS149) was crossed between stock lines of Y1 (Hong *et al.*, 1997) and 9153 in 1994 and Chinese race pure line Jam 310 (breeding line CS170) was also crossed between stock lines of Y1 (Hong *et al.*, 1997) and 8586 in 1994.

Targeted characters were selected through two or three times rearing a year with succeeding generation by mass selection in mixed batch rearing system from filial one to filial three and by individual selection in batch rearing system from filial four (F_4) to filial eight (F_8) mainly based on cocoon quality (Kang *et al.*, 2001). Kumhwangjam was selected as the variety with an excellent combination in the combining ability test in spring rearing season of 2001 and spring rearing season of 2003, and it was passed the test of pure line characteristics and adaptability test for spring rearing season, performed at the Department of Agricultural Biology (previously Department of Sericulture and Entomology), National Institute of Agricultural Science and Technology (NIAST), and seven Provincial Institute of Agricultural Science and Technology (PIAST), Korea, in spring rearing season of 2001 and spring rearing season of 2003. It was nominated as a new recommended variety suitable for spring rearing season with the name of Kumhwangjam by Nomination Council of Silkworm Recommended Variety (NCSRV) after the superiority as an autumn variety was recognized through the local adaptability test performed at seven sericultural organizations of PIAST.

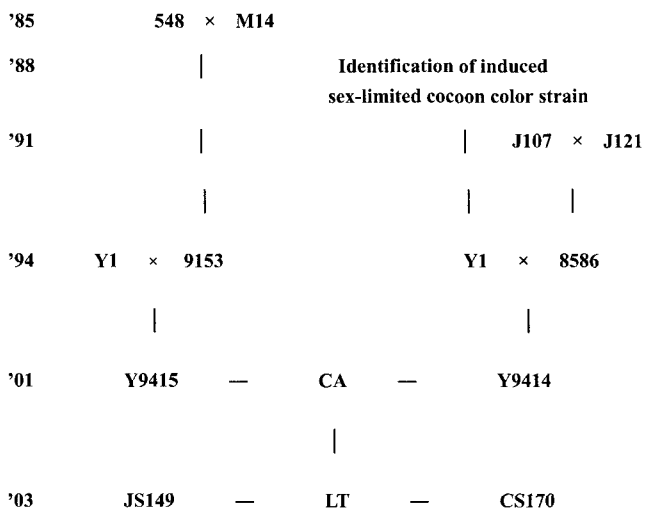

Fig. 1. The Pedigree of Kumhwangjam, the F_1 hybrid between Jam 309 Jam 310.
CA: Combining ability test, LT: Local adaptability test.

Results and Discussion

Combining ability test

For the breeding of a new silkworm variety with a sex-limited cocoon color for spring rearing season, Japanese race Jam 309 and Chinese race Jam 310 were crossed. Japanese race pure line Jam 309 (breeding line JS149) was selected by crossing between stock lines of Y1 and 9153, and Chinese race pure line Jam 310 (breeding line CS170) was also bred by crossing between stock lines of Y1 and 8586 (Fig. 1). The F_1 hybrid between Jam 309 and Jam 310 was selected as Kumhwangjam. The economic characteristics of Jam 309 and Jam 310 were described in Table 1.

The results of F_1 hybrid between Japanese and Chinese races with control variety Baegokjam performed in spring rearing season of 2001 are shown in Table 2. The major commercial characteristics of Kumhwangjam were compared with the reference variety Baegokjam. Kumhwangjam recorded high pupation rate of 96.9% and showed a heavier single cocoon weight (2.26 g) than Baegokjam (2.14 g). Furthermore, Kumhwangjam showed longer cocoon filament length than the reference variety Bae-

Table 1. The economic characteristics of the parental lines for breeding of Kumhwangjam

Line	Rearing season	Larval period	Pupation percentage	Cocoon yields from 10,000 3rd molted larvae	No. of cocoon per liter	Single cocoon weight	Cocoon shell weight	Cocoon shell percentage
		days. hrs	%	kg	ea	g	cg	%
Y1	'94 spring	24.21	92.2	16.6	61	2.06	51.1	24.8
9153	'91 summer	22.22	91.4	17.6	81	2.04	47.8	23.5
Jam 309	'94 summer	24.00	92.4	17.2	74	2.18	54.3	24.9
Y1	'91 spring	24.21	92.2	16.6	61	2.06	51.1	24.8
8586	'85 autumn	24.07	10.0	3.2	-	1.82	45.4	24.9
Jam 310	'94 summer	23.06	91.0	16.0	66	1.91	46.6	24.4

Table 2. The major commercial characteristics of Kumhwangjam of the combining ability test in autumn 2001

Variety	Pupation percentage	Cocoon yield from 10,000 3rd molted larvae	Single cocoon weight	Cocoon shell weight	Cocoon shell percentage	Cocoon filament length	Raw silk percentage	Raw silk yield
	%	kg	g	cg	%	m	%	kg
Baegokjam	96.8	20.5	2.14	51.7	24.2	1,392	20.36	4.17
Kumhwangjam	96.9	20.7	2.26	55.3	24.4	1,673	20.12	4.16

Table 3. Rearing results of Kumhwangjam through the local adaptability test performed at 8 places in spring 2003

Variety	Useful hatchability	Larval period	Pupation percentage	Best cocoon rate	Double cocoon rate
	%	days. hrs	%	%	%
Kumokjam	96	23.21	94.4	92.3	0.6
Kumhwangjam	92	24.09	94.0	92.6	1.2

Variety	Cocoon yield per 10,000 3rd molted larvae	No. of cocoons per liter	Single cocoon weight	Cocoon shell weight	Cocoon shell percentage
Kumokjam		ea	g	cg	%
	21.1	55	2.35	56.9	24.2
Kumhwangjam	20.9	55	2.29	56.8	24.7

gokjam. Jam 309, Japanese race parent of Kumhwangjam, showed high general combining ability (GCA) in single cocoon weight and cocoon shell weight out of examined important commercial characters, and Chinese parent of Kumhwangjam Jam 310 recorded high GCA in cocoon shell percentage.

Local adaptability test

Rearing: Cooperative experiment for the productivity test and local adaptability of Kumhwangjam (Jam 309 × Jam 310) was performed at the Department of Agricultural Biology, NIAST and seven PIAST in spring rearing season of 2003. The characetristics of Kumhwangjam through the local adaptability test are shown in Table 3. The useful hatchability of Kumhwangjam (92%) was over 90% of recommending criteria for a new variety (Kang *et al.*, 2001, 2002, 2003). This value is less than the check variety Kumokjam with useful hatchability of 96%. The larval duration of Kumhwangjam was 12 hrs longer than that of check variety. Pupation rate (94.0%) of Kumhwangjam was also passed the recommending criteria of 92%. The cocoon yield of Kumhwangjam was slightly less than check variety, which showed 20.9 kg per 10,000 of 3rd molted larvae. The result shows that the rearing results of Kumhwangjam in local adaptability test were similar to those of the check variety Kumokjam.

Reeling: Cocoon and raw silk characteristics of Kumhwangjam compared with check variety Kumokjam are shown in Table 4. Filament length of Kumhwangjam with 1,525 m was similar to that of the check variety Kumokjam with 1,563 m, but filament weight of Kumhwangjam with 50.0 cg was 2.7 cg lighter than check variety with 52.7 cg. Cocoon reelability and raw silk yield in the Kumhwangjam were 77% and 4.55 kg, respectively. The neatness and degumming rate of Kumhwangjam were 95 points and 26.1%, respectively.

Adaptability test for the artificial diet at young larval stages: The results of the adaptability test for artificial diet of young silkworm of Kumhwangjam were illustrated in Table 5. Kumhwangjam was recommendable for artificial diet with good adaptability compared with check variety Baegokjam, which was widely propagated for artificial diet.

Main characteristics of parental lines: The major characteristics of Jam 309 and Jam 310, which are parental lines of Kumhwangjam were examined with Jam 125 and Jam 140, which are parents of Kumokjam, as controls are illustrated in Table 6. Japanese race Jam 309 showed plain on larval marking and peanut shape cocoon, and cocoon color was discriminated between female (yellow) and male (white). The pupation rate and cocoon yields by 10,000 of the 3rd molted larvae with 89.9% and 15.9 kg were less 3.7% and 1.5 kg than check variety Jam 125, and fecundity with 411 each per moth was also decreased than that of 522 each of Jam 125.

Chinese race Jam 310 also showed a sex-based cocoon color: yellow for female and white for male with elliptical cocoon shape. The pupation rate and cocoon yields by 10,000 of the 3rd molted larvae with 89.1% and 14.1 kg

Table 4. Cocoon reeling results of Kumhwangjam through the local adaptability test performed at 8 places in spring 2003

Variety	Filament length	Filament weight	Filament size	Reelability
	m	cg	d	%
Kumokjam	1,563	52.7	3.04	78
Kumhwangjam	1,525	50.0	2.98	77

Variety	Raw silk percent	Raw silk yield	Neatness	Degumming rate
	%		point	%
Kumokjam	22.26	4.70	96	23.4
Kumhwangjam	21.83	4.55	95	26.1

Raw silk yield was calculated from multiplication between cocoon yield per 10,000 3rd molted larvae and raw silk percent.

Table 5. Adaptability test of the artificial diet of silkworm in spring 2004

Variety	Bristling rate	Larval period from 1st to 3rd	Molting rate			Adaptability
			2nd	3rd	4th	
	%	days. hrs	%	%	%	
Baegokjam	96	12.08	94	94	96	Good
Kumhwangjam	96	12.08	93	92	95	-

Table 6. The major commercial characteristics of the parents of Kumhwangjam

Variety	Useful hatchability	Larval period	Pupation rate	Cocoon yield per 10,000 3rd molted larvae	Single cocoon weight	Cocoon shell weight	Cocoon shell percentage
	%	days. hrs	%		g	cg	%
Japanese races							
Jam 309	86	24.22	89.9	15.9	1.94	49.3	25.4
Jam 125	93	23.04	93.6	17.4	1.93	44.9	23.3
Chinese races							
Jam 310	79	24.04	89.1	14.1	2.08	48.2	23.1
Jam 140	88	22.23	92.8	17.0	2.18	52.2	24.0

Variety	Moth emergence	Duration from incubation to emergence	No. of eggs per batch	Percentage of moth laid normal eggs	Larval marking	Cocoon shape	Cocoon color
	%	days	ea	%			
Japanese races							F: yellow
Jam 309	99	57	411	94	mark	peanut	M: white
Jam 125	98	56	522	100	mark	long peanut	white
Chinese races							F: yellow
Jam 310	98	56	464	94	plain	elliptical	M: white
Jam 140	100	55	527	89	plain	elliptical	white

were relatively decreased to those of check variety Jam 140, and fecundity with 464 each per moth was also decreased than that of 527 each of Jam 140.

In conclusion, a new silkworm variety, Kumhwangjam, showed relatively lower pupation rate and cocoon yields than check variety, but Kumhwangjam showed a sex-limited cocoon color: yellow for female and white for male with elliptical cocoon shape. This sex-based cocoon color can be used as a valuable marker for discrimination between female and male.

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