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On cocoon uniformity in different crosses of bivoltine hybrids of silkworm Bombyx *mori* L.

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ABSTRACT

The variability in cocoon shape is considered as an important parameter for evolving viable bivoltine silkworm hybrids of different crossing pattern and uniformity in cocoon shape helps in achieving improved reelability and uniform denier, the important post-cocoon quality parameters. In the present study, cocoon length, width, length-width ratio, standard deviation and co-efficient of variation was assessed by utilizing the newly developed 21 each of different crosses of bivoltine hybrids (single, three- way and four- way crosses) along with control hybrids namely, (CSR2xCSR4) and [(CSR2xCSR27)x(CSR6xCSR26)]. The data revealed that wide variations in cocoon uniformity were observed among the different crosses of bivoltine hybrids. The study further revealed that the single-cross bivoltine hybrid, (CSR27xCSR26), three-way cross bivoltine hybrids, [(JPN8xCSR17)xD13] and [(D13xCSR26)xCSR17] and four-way cross hybrids [(JPN8xCSR17)x(D13xS9)] have recorded more cocoon uniformity.

Key words: Bivoltine hybrids, cocoon uniformity, single, three-way and four-way cross hybrids.

INTRODUCTION

Besides productivity, it is an implicit that the qualitative merit of silk is especially important to make sericulture a viable enterprise. Further, it is known fact that improvements in quantitative traits established more emphasis than that of qualitative parameters. Among the various parameters that determine the quality of silk fiber denier variation, neatness and purity are very important. Breeders' point of view, denier deviation test, the most important one for evaluation of breeds and hybrids for assessing the qualitative superiority, primarily depends on the uniformity in cocoon shape and size. Studies have been made on variability of quantitative characters in mulberry silkworm [1, 5, 12, 13, 14 and 15].

Cocoon shape is an important parameter from the standpoint of silk production, evolution as well as evaluation of commercial silkworm hybrids [6, 11]. Cocoon shape variation in parental breeds and their hybrids has been reported by many investigators [3, 9, 13 and 15]. Although, silkworm breeders in sericulturally advanced countries such as Japan and China have made extensive studies on cocoon shape, size variability and considered it as important parameter to identify the breeds / hybrids so as to obtain silk filament with less size deviation [3,10]. Cocoon shape is related to the size of the larva and length of each part of the body of the larva [16]. While, Miura *et al*., [7] studied the cocoon shape construction process through statistical analysis by measuring the changes in size and shape of spinning regions at different stages of larval spinning. Uniformity in cocoon shape helps to get uniform filament size in semi-automatic and automatic reeling machines [6]. In India, limited information is available on cocoon shape variability in hybrid cocoons. Hence, the present study was undertaken to assess the cocoon uniformity in different crosses of bivoltine silkworm hybrids

MATERIALS AND METHODS

In the present study, seven each oval and dumb-bell type bivoltine silkworm breeds *viz*., CSR2, CSR17, CSR27, JPN8, JPN7, S5, BBE226 (oval) and CSR6, CSR16, CSR26, D13, S9, BBE247, BBE247 (dumb-bell) were utilized for preparation of single-cross, three-way cross [(oval x oval) x dumb-bell] and [(dumb-bell x dumb-bell) x oval] and four-way cross [(oval x oval) x (dumb-bell x dumb-bell)]. All the hybrids were brushed together and reared in three replications by following the standard rearing method [2] during different seasons of the year viz., summer, rainy and winter.

One hundred cocoons were taken at random from each replication of all the hybrids. Cocoon length and cocoon width were measured by using Vernier Calipers. Cocoon shape variation was determined by uniformity test on the basis of standard deviation suggested by Mano [6]. Cocoon length / width ratio was calculated for each cocoon and its standard deviation (SD ±) and coefficient of variation (CV %) was considered as adjudicator of the cocoon uniformity. Hybrid cocoons showing comparatively lesser standard deviation (<8.0) were considered as uniform shaped cocoons.

RESULTS

Difference in cocoon size among the bivoltine single cross hybrids is presented in Table 1. It is clear from the data that, among single-cross hybrids (CSR27xCSR26), (CSR27xS9), (CSR27xD13), (JPN8xBBE267), (CSR17xBBE247) and (S5xBBE267) exhibited more uniformity in cocoon shape showing standard deviation ranging from 7.24 to 7.90 (< 8.00) and CV% from 4.70 to 5.08%. The single-cross hybrid (CSR27xCSR26) has recorded more cocoon uniformity with standard deviation of 7.42 and CV% of 4.58 as against control hybrid, (CSR2xCSR4), with standard deviation of 8.78 and CV% of 5.69.

Variation in cocoon uniformity among the bivoltine three-way cross hybrids (oval x oval) x dumb-bell) is given in Table 2 and 3. The hybrids namely, [(JPN8xCSR17)xD13], [(JPN8xCSR17)xCSR26], [(S5xJPN8)xCSR26], [(JPN8xCSR27)xS9], [(CSR27xCSR17)xCSR26] and [(JPN8xCSR17)xS9] have shown standard deviation below 8.00 and CV% from 4.40 to 4.90. The three-way cross hybrid, [(JPN8xCSR17)xD13] has recorded more uniformity with standard deviation of 6.92 and CV% of 4.40.

Table 1: Cocoon uniformity of bivoltine single-cross hybrids

(Mean values of 3 seasons)

#	Hybrid	Cocoon length (cm)	Cocoon width (cm)	Length/width ratio	SD (±)	CV (%)
1	CSR17xCSR16	3.07	1.86	164.58	8.52	5.18
2	CSR17xCSR26	3.05	2.00	152.67	8.62	5.65
3	CSR17xS9	3.21	1.95	164.90	8.76	5.31
4	CSR17xD13	3.17	1.86	170.92	9.03	5.28
5	CSR17xBBE247	3.11	2.01	154.56	7.45	4.82
6	CSR17xBBE267	3.07	1.85	166.06	8.97	5.40
7	CSR27xCSR26	3.10	1.89	164.50	7.42	4.58
8	CSR27xS9	3.11	2.06	151.22	7.24	4.79
9	CSR27xD13	3.15	2.03	154.92	7.29	4.70
10	CSR27xBBE247	3.05	1.96	160.42	8.60	5.36
11	CSR27xBBE267	3.06	1.89	161.44	8.40	5.19
12	JPN8xS9	3.16	1.95	161.60	8.44	5.22
13	JPN8xD13	3.13	1.97	158.78	8.43	5.31
14	JPN8xBBE247	3.05	1.97	155.08	8.75	5.64
15	JPN8xBBE267	3.13	2.01	155.72	7.44	4.78
16	JPN7xD13	3.01	1.90	158.52	8.34	5.26
17	JPN7xBBE247	3.14	1.93	162.41	8.64	5.23
18	JPN7xBBE267	3.02	1.90	158.95	8.48	5.34
19	S5xBBE247	3.01	1.97	152.39	8.59	5.63
20	S5xBBE267	3.18	2.02	157.85	7.47	4.73
21	BBI226xBBE267	3.10	2.00	155.43	7.90	5.08
22	CSR2xCSR4 **(C)**	3.03	1.96	154.42	8.98	5.69
	Mean	**3.09**	**1.95**	**158.97**	**8.26**	**5.19**

Table 2: Cocoon uniformity of bivoltine three-way cross hybrids [(oval x oval)x dumb-bell]

(Mean values of 3 seasons)

#	Hybrid	Cocoon length (cm)	Cocoon width (cm)	Length/width ratio	SD (±)	CV (%)
1	(CSR27xCSR17)xBBE267	3.32	2.08	159.78	8.95	5.60
2	(CSR27xCSR17)xD13	3.29	2.04	161.17	9.35	5.80
3	(CSR27xCSR17)xS9	3.21	2.03	158.13	7.75	4.90
4	(CSR27xCSR17)xBBE247	3.41	2.04	167.32	9.39	5.61
5	(CSR27xCSR17)xCSR16	3.51	2.05	171.06	9.40	5.50
6	(CSR27xCSR17)xCSR26	3.16	2.02	156.69	7.65	4.88
7	(JPN8xCSR27)xD13	3.25	1.95	166.21	8.82	5.31
8	(JPN8xCSR27)xS9	3.20	2.04	157.12	7.17	4.57
9	(JPN8xCSR27)xBBE247	3.23	1.94	166.32	9.06	5.45
10	(JPN8xCSR27)xCSR16	3.28	1.96	167.23	8.39	5.01
11	(JPN8xCSR27)xCSR26	3.24	1.93	167.76	9.18	5.47
12	(JPN8xCSR17)xD13	3.21	2.04	157.19	6.92	4.40
13	(JPN8xCSR17)xBBE247	3.28	2.01	163.08	9.10	5.58
14	(JPN8xCSR17)xCSR16	3.45	2.00	172.67	8.43	5.08
15	(JPN8xCSR17)xCSR26	3.20	2.04	156.77	7.04	4.49
16	(JPN8xJPN7)xBBE247	3.36	2.02	166.23	9.33	5.61
17	(JPN8xJPN7)xCSR16	3.26	1.94	167.58	8.78	5.24
18	(JPN8xJPN7)xCSR26	3.18	1.97	161.59	8.49	5.36
19	(S5xCSR27)xCSR16	3.23	1.99	162.14	8.04	5.06
20	(S5xCSR27)xCSR26	3.14	2.04	153.67	8.87	5.77
21	(S5xJPN8)xCSR26	3.26	2.07	157.07	7.06	4.51
22	CSR2xCSR4 **(C)**	3.03	1.96	154.42	8.98	5.69
	Mean	**3.26**	**2.01**	**162.33**	**8.46**	**5.22**

Table 3: Cocoon uniformity of bivoltine three-way cross hybrids [(dumb-bell x dumb-bell) x oval]

(Mean values of 3 seasons)

#	Hybrid	Cocoon length (cm)	Cocoon width (cm)	Length/width ratio	SD (±)	CV (%)
1	(CSR16xCSR26)xBBE226	3.54	2.10	169.03	9.08	5.37
2	(CSR16xCSR26)xS5	3.49	2.08	167.68	8.83	5.27
3	(CSR16xCSR26)xJPN8	3.57	2.07	172.03	9.12	5.30
4	(CSR16xCSR26)xCSR27	3.34	2.05	162.82	6.87	4.22
5	(CSR16xCSR26)xCSR17	3.48	2.09	166.51	8.43	5.06
6	(CSR16xCSR26)xJPN7	3.52	2.05	171.99	8.53	5.49
7	(S9xCSR16)xS5	3.54	2.10	169.00	8.54	5.05
8	(S9xCSR16)xJPN8	3.51	2.09	167.78	9.10	5.42
9	(S9xCSR16)xCSR27	3.33	2.26	147.35	6.87	4.66
10	(S9xCSR16)xCSR17	3.44	2.06	167.26	9.07	5.42
11	(S9xCSR16)xJPN7	3.51	2.05	171.66	8.55	5.09
12	(S9xCSR26)xJPN8	3.27	2.03	160.92	7.09	4.41
13	(S9xCSR26)xCSR27	3.54	2.08	170.35	9.70	5.69
14	(S9xCSR26)xCSR17	3.50	2.09	168.66	9.25	5.48
15	(S9xCSR26)xJPN7	3.52	2.07	169.89	8.51	5.01
16	(D13xCSR26)xCSR27	3.30	2.01	164.34	6.79	4.13
17	(D13xCSR26)xCSR17	3.33	2.02	164.69	6.09	3.70
18	(D13xCSR26)xJPN7	3.52	2.06	170.44	9.13	5.36
19	(D13xS9)xCSR17	3.36	2.08	161.12	6.29	3.91
20	(D13xS9)xJPN7	3.43	2.06	166.50	9.36	5.62
21	(D13xCSR16)xJPN7	3.47	2.08	166.40	8.78	5.27
22	CSR2xCSR4 **(C)**	3.03	1.96	154.42	8.98	5.69
	Mean	**3.43**	**2.07**	**165.95**	**8.32**	**5.03**

Similarly, the three-way cross hybrids [(dumb-bell x dumb-bell) x oval] viz., [(D13xCSR26)xCSR17], [(D13xS9)xCSR17], [(D13xCSR26)xCSR27], [(CSR16xCSR26)xCSR27], [(S9xCSR26)xJPN8] and [(S9xCSR16)xCSR27] have shown standard deviation of < 8.00 and their CV% ranged from 3.70 to 4.66. The hybrid, [(D13xCSR26)xCSR17] has recoded more cocoon uniformity with standard deviation of 6.09 and CV% of 3.70 .

Cocoon uniformity in four-way cross hybrids is presented in Table 4. The hybrids viz., [(JPN8 x CSR17) x (D13 x S9)], [(JPN8 x CSR17) x (D13 x CSR26)], [(JPN8 x CSR17) x (S9 x CSR26)], [(CSR27 x CSR17) x (D13 x CSR26)], [(JPN8 x CSR27) x (D13 x CSR26)] and [(JPN8xCSR27)x(S9xCSR26)] have shown less variation in cocoon shape with standard deviation of < 8.00 and CV% ranging from 4.17 to 4.54. However, the hybrid [(JPN8 x CSR17) x (D13 x S9)] recoded more cocoon uniformity with standard deviation of 7.20 and CV% of 4.17 as compared to the control hybrid [(CSR2 x CSR27) x (CSR6 x CSR26)] with standard deviation of 8.13 and CV% of 5.12.

Table 4: Cocoon uniformity of bivoltine four-way cross hybrids

(Mean values of 3 seasons)

#	Hybrid	Cocoon length (cm)	Cocoon width (cm)	Length/width ratio	SD (±)	CV (%)
1	[(CSR27xCSR17)x(CSR16xCSR26)]	3.43	2.07	165.86	8.86	5.34
2	[(CSR27xCSR17)x(S9xCSR16)]	3.36	2.04	164.44	8.89	5.41
3	[(CSR27xCSR17)x(S9xCSR26)]	3.37	2.06	164.29	9.02	5.49
4	[(CSR27xCSR17)x(D13xCSR26)]	3.48	2.05	170.03	7.32	4.31
5	[(CSR27xCSR17)x(D13xS9)]	3.42	2.06	165.86	8.55	5.15
6	[(CSR27xCSR17)x(D13xCSR16)]	3.37	2.05	164.12	8.17	5.08
7	[(JPN8xCSR27)x(S9xCSR16)]	3.47	2.04	169.98	8.45	5.17
8	[(JPN8xCSR27)x(S9xCSR26)]	3.44	2.02	170.30	7.72	4.54
9	[(JPN8xCSR27)x(D13xCSR26)]	3.48	2.04	170.59	7.69	4.51
10	[(JPN8xCSR27)x(D13xS9)]	3.37	2.08	162.44	9.01	5.55
11	[(JPN8xCSR27)x(D13xCSR16)]	3.33	2.05	162.60	8.60	5.29
12	[(JPN8xCSR17)x(S9xCSR26)]	3.47	2.06	168.99	7.24	4.29
13	[(JPN8xCSR17)x(D13xCSR26)]	3.46	2.04	169.98	7.23	4.25
14	[(JPN8xCSR17)x(D13xS9)]	3.51	2.03	172.74	7.20	4.17
15	[(JPN8xCSR17)x(D13xCSR16)]	3.37	2.02	166.17	9.20	5.54
16	[(JPN8xJPN7)x(D13xCSR26)]	3.08	1.92	161.60	8.03	5.14
17	[(JPN8xJPN7)x(D13xS9)]	3.15	1.91	164.70	8.14	5.31
18	[(JPN8xJPN7)x(D13xCSR16)]	3.43	2.06	166.24	8.51	5.12
19	[(S5xCSR27)x(D13xS9)]	3.12	1.97	162.60	8.18	5.34
20	[(S5xCSR27)x(D13xCSR16)]	3.39	2.06	164.46	9.09	5.53
21	[(S5xJPN8)x(D13xCSR16)]	3.42	2.05	166.56	9.14	5.49
22	[(CSR2xCSR27)x(CSR6xCSR26)]**(C)**	3.43	2.03	168.52	8.13	5.12
	Mean	**3.38**	**2.03**	**166.50**	**8.29**	**5.05**

DISCUSSION

The cocoon characters of the domesticated silkworm have long been investigated from the practical point of view. It is needless to say, silkworm rearing is only to produce cocoons, as main objective, hence, the cocoon weight and other quantitative traits that are directly linked to raw silk production are considered as the most important ones. Though the cocoon shape has not attracted so much attention of the breeders, it is important on account of the evaluation aspect of silkworm breeds / hybrids. The cocoons shape can be roughly classified into groups according to the ancestry strains determined by the spinning behavior of the larva. Also, there are many phenotypic variations in each breed and in most of the breeds the cocoon shape is stable showing less variability. From the point of view of genetic differentiation and evaluation, the cocoon shape characteristic is helpful in finding out the genetic relationship among the silkworm breeds/hybrids.

Quality of cocoon influences the productivity in silk reeling and raw silk quality. Among various commercial characteristics of importance viz., shell thickness, compactness, wrinkles on cocoons, reelability, filament length and size. It is well established that uniformity in shape of the cocoon helps in obtaining filament size with less deviation when reeled in semi-automatic and automatic reeling machines [6]. Generally, oval shaped cocoons have uniform shell thickness throughout the cocoon layers and are preferred as they facilitate uniform cooking and easy unwinding of the silk filaments during reeling. Whereas, dumb-bell shaped cocoons have uneven shell thickness on both the sides of the cocoon shell whereas middle portion of the shell will be thin which lead to uneven cooking affecting the reeling performance and raw silk. Further, uniformity in the shape / size of the cocoons is also important from the reeler's point of view. If the shape / size of the cocoons vary much then there will be variation in the shell ratio, filament length / size, etc.

The mode of inheritance of the cocoon shape in silkworm breeds / hybrids and the number of genes expressing cocoon shape and size have been studied [3, 4]. Rao *et al.*, [15] have found less variability in cocoon weight, shell weight and cocoon shell ratio in F1 hybrids. Ravindra Singh *et al.*, [12, 13] opined that the uniformity in cocoon shape helps to get uniform filament size besides developing a model for rapid measurement of cocoon shape and analyzing the results by multivariate analysis. Hirabayashi [4]; Gamo *et al.*, [3] and Nakada [8] explained the mode of inheritance of cocoon shape in silkworm breeds / hybrids and the number of genes expressing cocoon shape and size characters.

In the present study, the bivoltine single-cross hybrids identified showed less variability (SD < 8.00 and CV % = < 5.00) compared to the control hybrid (SD=8.78 and CV%=5.69). Among the identified three-way crosses [(oval x oval) x dumb-bell] combinations recorded less significant variability (SD=6.92 to 7.75 and CV%=4.40 to 4.90). Similarly, in identified [(dumb-bell x dumb-bell) x oval] combinations minor variability in cocoon uniformity (SD=6.09 to 7.09 and CV%=3.70 to 4.66) when compared to the control hybrid. Further, the four-way cross hybrids top ranked in the study exhibited lesser variability (SD <8.00 and CV%=< 5.00) and these observations are in conformity with the observations of Mano [6].

In light of the above findings of the present study, the top ranking new bivoltine hybrids (CSR27xCSR26) among the single-cross, [(JPN8xCSR17)xD13] among the [(OxO)xD], [(D13xCSR26)xCSR17] among the [(DxD)xO] combinations and [(JPN8 x CSR17) x (D13 x S9)] among four-way cross hybrids scored top ranking showing more cocoon uniformity. Cocoon shape variability is useful in identifying suitable breeds / hybrids for breeding and evaluation to produce uniform shape cocoons which yield uniform filament size, an important qualitative parameter of silk. The present study on cocoon shape variability is useful in identifying potential bivoltie breeds/hybrids for breeding and evaluation to produce uniform cocoons with uniform filament size as well as to know the variability among new bivoltine breeds and hybrids. The outcome results of the study clearly show that evaluating cocoon shape / uniformity among the bivoltine breeds/hybrids identified will enhance total raw silk production as well as qualitative merit of silk.

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