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Studies on Cocoon Filament Size Deviation in Multivoltine Breeds and Multivoltine × Bivoltine Hybrids of Silkworm, *Bombyx mori* L.

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Variation in the size of the silk filament will determine the uniformity and quality of the silk reeled. In the present study, an attempt has been made to study the filament size variation in 6 multivoltine parental breeds and 9 multivoltine × bivoltine hybrids in all three seasons of a year. All multivoltine breeds and multivoltine × bivoltine hybrids showed variation in filament size throughout its length from the outer layer to inner layer. Results of the present study indicated that the size of the filament decreased from outer to inner layer. The decrease in filament size was sudden in some breeds/hybrids whereas it was gradual in other. Relationship between filament length to that of slope, average filament size to slope, and maximum filament size to slope was determined based on regression analysis. Regression analysis revealed significant positive correlation between slope vs average filament length ($r = 0.92^{**}$) in multivoltine × bivoltine hybrids. Among parental breeds, 96C showed lowest slope of the curve (b-value: –0.00428) and 96A showed highest slope of the curve (b-value: –0.00269). Among 9 hybrids, PM × NB_4D_2 recorded lowest slope value (b-value: –0.00328) and BL24 × NB_4D_2 showed highest value for slope of the curve (b-value: –0.00234). The breed 96C, which showed lowest slope value can be utilized for future breeding programmes to breed strains with less size deviation. Three multivoltine × bivoltine hybrids *viz.*, PM × NB4D2, 96E × CSR19 and BL67 × CSR_{101}, which showed less slope values (b-values: –0.00328, –0.00300 and –0.00297 respectively) can be utilized for commercial exploitation to produce uniform silk.

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Introduction

Indian sericulture is predominantly multivoltine oriented and the quality of the silk produced from these breeds/ hybrids is poor in both yield and quality. Recently, scientists working at Central Sericultural Research and Training Institute, Mysore have successful in evolving new multivoltine × bivoltine hybrid, CAUVERY (BL67 × CSR101) which produces gradable silk (Raghavendra Rao *et al.*, 2002). The quality of raw silk is determined by size deviation, neatness and cleanliness of the silk. In sericulturally advanced countries, the size deviation estimation is considered as one of the important character for assessing breed/hybrid combination. As very little information is available with regard to size deviation in the cocoon filament of multivoltine breeds/ hybrids, an attempt has been made to study the filament size variation in six multivoltine breeds and twelve multivoltine × bivoltine hybrids.

Materials and Methods

In the present study, five newly evolved multivoltine breeds *viz.*, BL24, BL67, 96A, 96C and 96E with Pure Mysore (PM) a geographical breed and eight newly evolved multivoltine × bivoltine hybrids *viz.*, BL24 × NB_4D_2, BL67 × CSR_5, BL67 × NB_4D_2, BL67 × CSR_{101}, BL67 × PC(g), 96A × CSR_{19}, 96C × CSR_{18} and 96E × CSR_{19} with popular hybrid PM × NB_4D_2, were selected to know size variation in the cocoon filament. Rearing was conducted as per the standard rearing method suggested by Krishnaswami (1978). Rearing was repeated thrice covering all three seasons of the year during 2003. After harvesting, 60 cocoons were selected according to the racial characters for conducting the experiment.

Cocoons were dried in hot air oven. Initially the cocoons were kept at 95°C for one hr and the process of drying completed at 60°C by gradually lowering the temperature. The procedure followed for drying of cocoons is: 95°C (one hr) → 93°C (one hr) → 90°C (one hr) → 85°C (one hr) → 75°C (one hr) → 60°C (one hr)

Cocoon cooking was carried out by three pan cooking method with the help of wire mesh cage. Cocoon cooking was carried out in first pan for 5 min at 100°C and kept out side for one min and the cooking was further continued in second pan for 45 seconds at 45°C followed by cooking in the third pan for 5 min at 80°C. After cocoon cooking, reeling was carried out in mono cocoon reeling machine having its circumference of one meter. The temperature of water bath was constantly maintained at 45°C. Each cocoon was reeled individually and while reeling, after each 100 meters, silk thread was removed and arranged serially one by one from innermost layer to outermost layer of the cocoon. After completion, the total filament length was recorded. Thirty cocoons from each breed/ hybrid was individually reeled in each season.

After reeling, serially arranged silk threads were dried at 100°C in drying chamber for four hrs followed by at 60°C for six hrs. After drying, the silk threads were transferred to dessicator and silk weight was recorded after one hr. The weighing of the silk filament was carried out with the help of precision balance. 100 meters of cocoon filament were taken as one unit and the weight was recorded one by one from innermost to outermost layer. Denier of the silk filament was calculated by using the following formula:

$$\text{Filament size} = \frac{\text{Conditioned weight of raw silk}}{\text{Total length of raw silk}} \times 9000$$

Stastical analysis

By regression analysis by least square method was employed to know the relationship between filament length vs slope and filament size vs slope as peretermined (Singh and Chaudhary, 1979). The slope of the denier curve of the silk filament of multivoltine breeds and multivoltine × bivoltine hybrids from outer layer to inner layer was calculated by following the formula:

$$\text{Slope of denier curve (b): } \frac{\frac{\sum xy-\sum x\sum y}{n}}{\frac{\sum x-(\sum x)}{n}}$$

Where b- is slope, x- filament length, y- filament size and n- number of observations

Results

Data on average filament length, filament size and slope of the denier curve of the multivoltine breeds are presented in Table 1. The average filament length of multivoltine breeds ranged from 445 (PM) to 695m (96A). The maximum filament size in multivoltine breeds ranged from 2.30 (PM) to 3.70 (96C) whereas minimum filament size ranged from 0.32 (PM) to 1.33 (96A). The average filament size of multivoltine breeds ranged from 1.31 (PM) to 2.29 (96A). The slope of the denier curve was determined by regression analysis (least square method). The slope in multivoltine breeds ranged from –0.00428 (96C) to –0.00269 (96A). Regression analysis pertaining to slope on average filament length, slope on maximum and minimum filament size and slope on size deviation in multivoltine breeds are presented in Table 2. Positive correlation was observed for slope on average filament length, maximum and minimum filament size whereas negative correlation was observed for slope on size deviation. However the correlation observed for different characters vs slope was non significant in multivoltine breeds.

Size deviation from outer layer to inner layer of the cocoon filament of multivoltine breeds are plotted and are graphically presented in Fig. 1. It is clear from the figure that size of the cocoon filament in all multivoltine breeds

Table 1. Cocoon filament length, filament size and slope of multivoltine breeds of mulberry silkworm

Sl. no.	Breed	Average filament length (m)	Maximum filament size	Minimum filament size	Average filament size	Slope (b- value)
1	96A	695	3.25	1.33	2.29	-0.00269
2	96C	656	3.70	0.45	2.07	-0.00428
3	96E	652	3.20	1.06	2.13	-0.00293
4	BL67	658	3.05	0.56	1.80	-0.00361
5	BL24	564	3.10	0.54	1.82	-0.00385
6	Pure Mysore	445	2.30	0.32	1.31	-0.00402

Table 2. Regression analysis for multivoltine breeds

	Number of breeds (n)	Degree of freedom	R^2	S. E. of coefficient	r
Slope on average filament length	6	4	0.278	0.0000040	0.53NS
Slope on average filament size	6	4	0.360	0.00072	0.60NS
Slope on maximum filament size	6	4	0.007	0.00068	0.08NS
Slope on size deviation	6	4	0.467	0.00046	-0.68NS

NS - non significant.

Table 3. Cocoon filament length, filament size and slope of multivoltine x bivoltine hybrids of mulberry silkworm

Sl. no.	Hybrid	Average filament length (m)	Maximum filament size	Minimum filament size	Average filament size	Slope (b- value)
1	96A x CSR19	906	3.94	0.93	2.43	-0.00287
2	96C x CSR18	1061	3.60	0.48	2.04	-0.00264
3	96E x CSR19	894	3.59	0.61	2.10	-0.00300
4	BL67 x CSR101	824	3.44	1.15	2.30	-0.00297
5	BL67 x CSR5	980	3.56	0.87	2.21	-0.00253
6	BL67 x NB4D2	977	3.57	0.54	2.05	-0.00266
7	BL67 x PC(g)	966	3.74	1.11	2.43	-0.00257
8	BL24 x NB4D2	783	3.45	0.54	2.00	-0.00234
9	PM x NB4D2	733	3.40	0.87	2.13	-0.00328

decreased through out its length except in 96C where it was observed that the first 100 meters, the filament size was increased and then continuously decreased throughout its length.

The results of nine multivoltine x bivoltine hybrids are presented in Table 3. The average filament length of multivoltine x bivoltine hybrids ranged from 733 (PM x NB_4D_2) to 1061m (96C x CSR_{18}). The maximum size of the filament recorded for the hybrids ranged from 3.40 (PM x NB_4D_2) to 3.94 (96A x CSR_{19}) while the minimum size ranged from 0.48 (96C x CSR_{18}) to 1.15 (BL67 x CSR_{101}). The average filament size of the hybrids ranged from 2.00 (BL24 x NB_4D_2) to 2.43 (96A x CSR_{19} and BL67 x PC(g)). The slope of the hybrids ranged from -0.00328 (PM x NB_4D_2) to –0.00234 (BL24 x NB_4D_2).

Regression analysis pertaining to slope on average filament length, slope on maximum and minimum filament size and slope on size deviation in multivoltine x bivoltine hybrids are presented in Table 4. Positive correlation was observed for slope vs average filament length, slope vs filament size both maximum and minimum and slope vs size deviation, however the correlation was significant only slope on average filament length (r = 0.92**).

Size deviation from outer layer to inner layer of the cocoon filament of multivoltine x bivoltine hybrids are plotted and presented graphically in Fig. 2. All hybrids showed decrease in filament size from outer layer to inner layer of the cocoon filament except in 96E x CSR_{19} where in first 100 meters the size of the filament increased and the gradually decreased through out its length and increase in filament size in the inner most 100 meters of the hybrids BL67 x CSR_5, BL67 x CSR_{101} and BL67 x PC(g).

Table 4. Regression analysis for multivoltine x bivoltine hybrids

	Number of breeds (n)	Degree of freedom	R^2	S. E. of coefficient	r
Slope on average filament length	9	7	0.849	0.0000004	0.92**
Slope on average filament size	9	7	0.092	0.0006	0.30NS
Slope on maximum filament size	9	7	0.220	0.00056	0.47NS
Slope on size deviation	9	7	0.043	0.0004	0.21NS

**, significant at 1% level, NS- non significant.

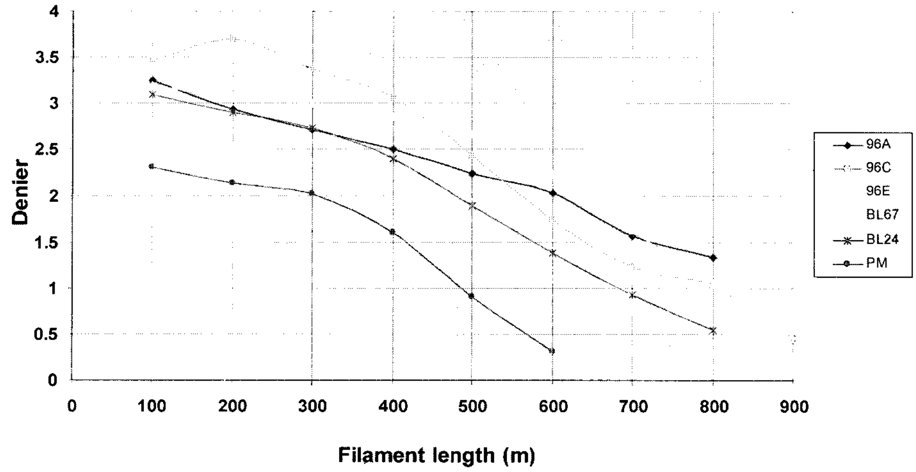

Fig. 1. Cocoon filament size deviation in some multivoltine breeds.

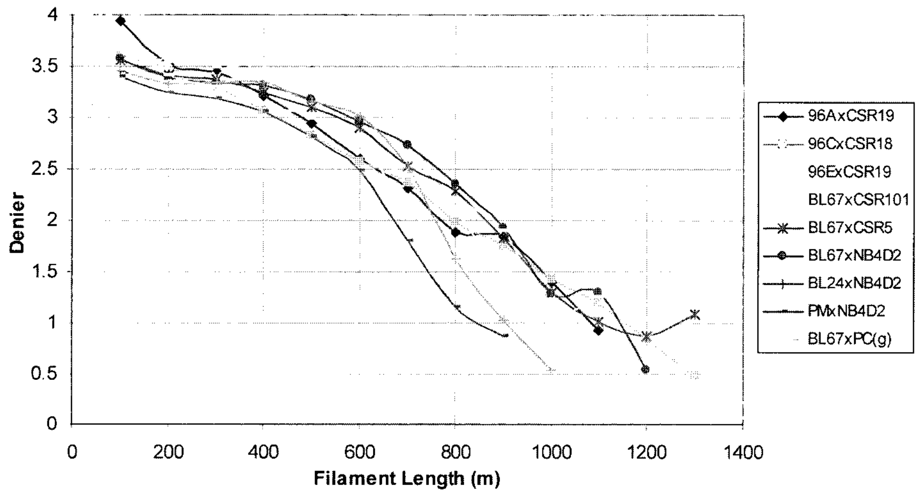

Fig. 2. Cocoon filament size variation in multivoltine × Bivoltine hybrids.

Discussion

In the present study, a great deal of variation was observed in filament length in both multivoltine breeds and multivoltine x bivoltine hybrids. The filament length ranged from 445 to 695m in multivoltine breeds and 733 to 1061m in multivoltine × bivoltine hybrids. The maximum filament size and minimum filament size ranged from 2.30 to 3.70 and 1.31 to 2.29 in multivoltine breeds and 3.40 to 3.94 and 2.00 to 2.43 in multivoltine x bivoltine hybrids respectively (Table1 and 3). Filament size of 100 meters sections from outer layer to inner layer were plotted and presented in Fig. 1 for multivoltine breeds and in Fig. 2 for multivoltine x bivoltine hybrids. It is clear from the Fig. 1 that the size of the filament decreased from outer layer to inner layer in all multivoltine breeds studied except 96C where filament size increase was observe in first 100 m then there was gradual decrease in all its length. Similar results were observed in C. Nichi race by Mahadevappa *et al.* (2000). The present findings are in agreement with that of the earlier workers (Mahadevappa *et al.*, 2000; Suresh Kumar *et al.*, 2002).

It is clear from Fig. 2 that the filament size in three hybrids *viz.*, 96E × CSR_{19}, BL67 × CSR_{101} and PM × NB_4D_2 varies narrowly in outer 50% of silk filament followed by decrease in size in the inner layer. This kind of steady maintenance of size for 50% of average filament length enhances the uniformity characteristics of silk. Increase in filament size in last 100m section was observed in the hybrids BL67 × CSR_{101}, BL67 × CSR_5 and BL67 × PC(g). Variations observed in filament length and size can be attributed to their origin and genetic make up of particular breed/hybrid.

Regression analysis on filament length vs slope, filament size vs slope and slope on size deviation revealed positive correlation, however the correlation was significant in multivoltine × bivoltine hybrids with slope on average filament length (Table 2 and 4). To produce better quality raw silk, it is important to maintain the size deviation of individual filament within an acceptable range (Narayanan *et al.*, 1967; Sonwalker, 1990). Based on present findings, multivoltine breed 96C which showed less slope (–0.00428) can be utilized for future breeding programmes to breed breeds with less size deviation and two hybrids *viz.*, 96E × CSR_{19}, BL67 × CSR_{101} and PM × NB_4D_2 can be exploited commercially for the production of uniform silk.

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