

Correlation among Shell Percent, Cocoon Yield and Reeling Parameters of Multi x Bi Cocoons under Different Agro-Climatic Conditions of West Bengal, India

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Abstract

Three new Multi x Bi combinations M.Con.4 x (SK6 x SK7), M.Con.4 x NB4D2 and Nistari x (SK6 x SK7) were studied in five seasons i.e. during the period of 18th June -12th July, 30th August - 23rd September, 3rd November - 2nd December, 29th January- 2nd March and 30th March-25th April with one control Nistari x NB4D2 considering nine reeling characteristics along with shell percent and cocoon yield per 100 disease free layings (DFLs) to establish the seasonal effect on all the parameters. Results reveal that all the characters performed well in November-December. Highest yield per 100 DFLs was recorded during November-December in all combinations showing >60 kg yield. Higher correlation of yield/100 DFLs with filament length, non-breakable filament length, denier, raw silk percent, reelability percent and recovery percent was recorded in all combinations of Multi x Bi considered in this study. Variability observed among four combinations indicates the effect of different temperature and humidity of different seasons on expression of different traits. The results indicate that there is significant relationship of raw silk percent with reelability percent, recovery percent and evenness. Reelability percent showed higher correlation with recovery percent. It was observed that neatness was positively correlated with evenness. The overall performance of the newly evolved combinations with regard to productivity and reeling characteristics is discussed emphasizing their utilization at commercial level.

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Introduction

Genesis of quality and quantity of mulberry silkworm cocoons is a challenge for West Bengal – a state of tropical atmosphere. Quality and quantity of silk produced by Multivoltine x Bivoltine silkworms is better than the silk produced by Multivoltine x Multivoltine

silkworms. Adoption of Multi x Bi rearing by the farmers of West Bengal is an approach to meet the challenge. Breeders are engaged in search of season specific suitable breeds/hybrids aiming to provide sustainable productivity at field level. Some Multi x Bi hybrids have already won popularity among farmers. From the commercial point of view yield of cocoons per 100 DFLs and shell

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percent hold the crucial role. Silk – produced by reeling of cocoons is the main commercial parameter (Reddy *et al.*, 2010). Reeling characters viz. Filament lengths (FL), Non-breakable Filament length (NBFL), Denier (D), Renditta i.e. quantity of green cocoon is required to produce 1kg silk yarn, Reelability percent, and Raw Silk percent are the main quantitative parameters and quality of silk depends upon neatness and evenness of the silk. Satenahalli *et al.* (1990) observed positive correlation among cocoon weight, shell weight, shell ratio and FL. According to Ohi and Yamashita (1977), the characters viz. FL, cocoon shape and shell percent are highly heritable. West Bengal experiences wide range of fluctuation in temperature, humidity and precipitation rate (Moorthy and Das, 2007; Moorthy *et al.*, 2011). Highly variable climatic condition in different seasons has its impact on the commercial characters related to production. Higher correlation among cocoon weight, shell weight and co-heritability with silk yield was established by Siddiqui *et al.*, (1989) and Naqvi *et al.*, (2004). Present study is an attempt to find out the possible inter-relationship between the productivity and reeling parameters of Multi x Bi cocoons under varied agro-climatic conditions of W.B., India.

Materials and Methods

Test materials

Two multivoltine breeds M.Con.4 and Nistari and two bivoltine breeds (SK6 x SK7) and NB4D2 were selected for this study and the experiment was conducted at the Silkworm Breeding and Genetics Section, Central Sericultural Research and Training Institute, Berhampore, West Bengal. Cocoons produced by 3 Multi x Bi hybrids viz. M.Con.4 x (SK6 x SK7), M.Con.4 x NB4D2 and Nistari x (SK6 x SK7) were considered as test materials against the traditional Multi x Bi combination Nistari x NB4D2 – the control.

Rearing and Reeling procedure

Three replications @ 400 worms per replication after 3rd moult per combination were maintained throughout the rearing period after 3rd moult. Twenty five good cocoons from each replication of each combination were assessed for cocoon weight, shell weight, and shell percent. For assessment of reeling parameters 300 g

of green cocoons from each replication of each combination were dried in hot oven. The drying chamber was heated upto 120°C. The cocoons were then put into drying chamber to remove moisture mixed with the air inside the cocoon at faster rate, so that inner layer sericin is not affected. The cocoons were subjected to drying schedule of 115°C (one hour) → 100°C (one hour) → 85°C (one hour) → 70°C (one hour) → 55°C (one hour). Hot air dried cocoons were conditioned for a minimum period of 2 to 7 days in atmospheric conditions. The length of the filament was measured using epprovette fitted with meter. Other reeling parameters were studied following standard procedures.

Correlation study

Correlation among shell percent, cocoon yield per 100 DFLs and nine reeling parameters viz. FL, NBFL, denier, renditta, reelability percent, raw silk percent, neatness and evenness were estimated as per standard procedures.

Statistical analysis

Analysis of variance was applied for each character for above mentioned five seasons

Results

Temperature and humidity

Data in Table 1 shows the average temperature and humidity

Table 1. Season wise temperature and humidity of the rearing room

Season	Temperature (°C)		Humidity (%)	
	Max.	Min.	Max.	Min.
June - July	31	24	86	65
August - September,	31	27	86	73
November - December	28	23	82	72
January - March	26	19	80	65
March - April	31	25	87	70

of the rearing room in different seasons. Highest temperature and humidity was observed during the period 30th August - 23rd September. Suitable temperature and humidity for silkworm rearing was observed during the season November - December.

Seasonal influence on productivity and reeling performance

Effect of temperature and humidity prevailed in different

Table 2. Impact of different seasons on shell percent, yield / 100 DFLs and reeling parameters

Season	Combination	Shell (%)	Yield/ 100 DFLs (kg)	FL (m)	NBFL (m)	Denier	Ren-ditta (kg)
June - July	M.Con.4 x (SK6 x SK7)	19.28	33.556	677	540	2.39	10.42
	Nistari x (SK6 x SK7)	18.46	35.111	704	704	2.61	9.68
	M.Con.4 x NB4D2	18.94	33.111	639	590	2.16	9.68
	Nistari x NB4D2	17.99	34.044	692	561	2.19	11.63
	CD at 5%	NS	NS	28	24	0.16	0.30
	CV%	2.93	4.30	2.17	2.10	3.68	1.51
August - September	M.Con.4 x (SK6 x SK7)	18.56	47.911	759	586	2.36	10.08
	Nistari x (SK6 x SK7)	18.17	50.089	747	637	2.44	8.47
	M.Con.4 x NB4D2	20.64	50.711	643	551	2.47	9.34
	Nistari x NB4D2	17.61	52.622	766	652	2.30	8.58
	CD at 5%	1.51	1.29	84	NS	NS	NS
	CV%	4.28	1.36	6.11	8.70	3.12	9.58
November - December	M.Con.4 x (SK6 x SK7)	16.58	64.800	811	808	2.44	9.21
	Nistari x (SK6 x SK7)	16.56	66.667	705	695	2.48	9.77
	M.Con.4 x NB4D2	16.42	66.356	783	783	2.61	8.59
	Nistari x NB4D2	17.48	66.222	661	661	2.82	9.22
	CD at 5%	NS	NS	52	53	0.13	NS
	CV%	5.82	3.63	3.75	3.84	2.65	5.01
January - March	M.Con.4 x (SK6 x SK7)	17.53	60.489	690	653	2.57	9.96
	Nistari x (SK6 x SK7)	16.38	57.311	687	562	2.56	10.45
	M.Con.4 x NB4D2	19.06	59.556	699	699	2.48	9.42
	Nistari x NB4D2	17.11	55.778	661	661	2.48	9.63
	CD at 5%	1.23	2.68	NS	NS	NS	0.48
	CV%	3.73	2.44	6.05	8.29	3.07	2.56
March - April	M.Con.4 x (SK6 x SK7)	18.17	42.045	699	599	2.29	10.22
	Nistari x (SK6 x SK7)	16.86	43.200	697	592	2.59	9.31
	M.Con.4 x NB4D2	18.89	44.267	694	685	2.46	9.58
	Nistari x NB4D2	18.06	54.044	691	598	2.29	10.42
	CD at 5%	0.85	5.21	NS	NS	0.20	NS
	CV%	2.49	6.03	5.94	6.31	4.42	9.10

Table 2. (continued)

Season	Combination	Raw silk (%)	Reelability (%)	Recovery (%)	Neatness (%)	Evenness (%)
June - July	M.Con.4 x (SK6 x SK7)	9.59	62.48	80.00	81.25	86.25
	Nistari x (SK6 x SK7)	10.33	65.29	81.81	85.00	90.00
	M.Con.4 x NB4D2	10.33	64.46	81.25	87.50	91.25
	Nistari x NB4D2	8.59	63.17	79.31	85.00	90.00
	CD at 5%	0.25	0.57	NS	0.46	1.07
	CV%	1.38	0.47	1.26	0.29	0.64
August - September	M.Con.4 x (SK6 x SK7)	10.10	66.31	81.68	88.75	90.83
	Nistari x (SK6 x SK7)	11.81	79.70	83.38	87.08	92.08
	M.Con.4 x NB4D2	10.75	68.32	81.70	90.00	95.00
	Nistari x NB4D2	11.66	78.57	85.12	85.83	94.17
	CD at 5%	NS	7.69	1.83	NS	NS
	CV%	8.61	5.58	1.17	2.56	2.93
November - December	M.Con.4 x (SK6 x SK7)	10.70	79.33	83.67	85.83	90.83
	Nistari x (SK6 x SK7)	10.27	80.66	85.10	87.50	92.50
	M.Con.4 x NB4D2	11.67	82.43	85.43	84.14	89.14
	Nistari x NB4D2	10.85	80.99	85.31	82.92	87.92
	CD at 5%	NS	NS	NS	2.55	2.55
	CV%	5.34	1.45	1.98	1.59	1.50
January- March	M.Con.4 x (SK6 x SK7)	10.04	83.07	83.01	85.83	90.83
	Nistari x (SK6 x SK7)	9.57	80.24	81.19	85.83	90.83
	M.Con.4 x NB4D2	10.62	83.14	82.70	85.00	87.83
	Nistari x NB4D2	10.39	79.27	82.84	85.00	90.00
	CD at 5%	0.50	1.84	NS	NS	NS
	CV%	2.60	1.20	1.81	2.80	2.51
March-April	M.Con.4 x (SK6 x SK7)	9.79	75.73	80.42	87.08	92.08
	Nistari x (SK6 x SK7)	10.75	74.19	80.41	80.83	87.92
	M.Con.4 x NB4D2	10.53	71.40	81.15	87.50	92.92
	Nistari x NB4D2	9.69	68.52	80.43	88.75	93.75
	CD at 5%	NS	2.25	NS	2.25	1.66
	CV%	8.45	1.65	2.37	1.39	0.96

seasons on the productivity and reeling performance has been given in Table 2. Analysis of results reveal that all combinations of Multi x Bi performed better during the season November-December concerning yield per 100 DFLs ranging from 64.8

kg in M.Con.4 x (SK6 x SK7) to 66.667 kg in Nistari x (SK6 x SK7) without showing any significant difference among the combinations. Performance of filament length ranged from 661 m in Nistari x NB4D2 to 811 m in M.Con.4 x (SK6 x SK7) and

Table 3. Correlation among different traits of four combinations of silkworm, *Bombyx mori*

	Yield/100 DFLs(kg)	FL (m)	NBFL (m)	Denier	Renditta (kg)	Raw silk (%)	Reelability (%)	Recovery (%)	Neatness (%)	Evenness (%)
Shell (%)	-0.482**	-0.262**	-0.312**	-0.265**	0.113**	-0.109*	-0.506**	-0.362**	0.241**	0.116**
Yield/100 DFLs(kg)		0.283**	0.509**	0.485**	-0.363**	0.351**	0.813**	0.650**	0.070	0.068
FL(m)			0.645**	-0.039	-0.180**	0.190**	0.201**	0.229**	-0.034	0.088*
NBFL(m)				0.287**	-0.291**	0.257**	0.461**	0.442**	-0.135**	-0.075
Denier					-0.352**	0.338**	0.462**	0.345**	-0.317**	-0.231**
Renditta (kg)						-0.986**	-0.421**	-0.625**	0.008	-0.157**
Raw silk (%)							0.398**	0.632**	0.005	0.188**
Reelability (%)								0.581**	-0.083	-0.086*
Recovery (%)									0.007	0.080
Neatness (%)										0.732**

**Significant at 1% level, *significant at 5% level.

NBFL ranged from 661 m in Nistari x NB4D2 to 808 in M.Con.4 x (SK6 x SK7). Renditta i.e. requirement of green cocoon to obtain 1 kg silk yearn, raw silk percent, reelability percent and recovery percent showed better performance in M.Con.4 x NB4D2 8.59 kg, 11.67%, 82.43% and 85.43% respectively. No significant difference was recorded among other combinations for these four economically important characters. Significantly higher performance ($P < 0.05$) concerning neatness and evenness was noted in M.Con.4 x (SK6 x SK7) (85.83% and 90.83% respectively) and Nistari x (SK6 x SK7) (87.50% and 92.50% respectively). No significant result was obtained in shell percent during the season November-December. Among five seasons lowest shell percent was observed during November-December, ranging from 16.42% in M.Con.4 x NB4D2 to 17.48% in Nistari x NB4D2.

Highest shell percent was recorded during the rearing season August-September in M.Con.4 x NB4D2 (20.64%) followed by 19.28% during Shravani in M.Con.4 x (SK6 x SK7), 19.06% in M.Con.4 x NB4D2 in Falgooni and 18.89% in Baisakhi in M.Con.4 x NB4D2.

Lowest yield per 100 DFLs was observed in all combinations during the season June-July, ranging from 33.111 kg in M.Con.4 x NB4D2 to 35.111 kg in Nistari x (SK6 x SK7) without showing any significant difference among yield. During the season highest renditta (11.63 kg) was observed in Nistari x NB4D2.

In all seasons recovery percent, neatness and evenness showed >80% result in all combinations.

Impact of seasons on reeling performance

Reelability percent was lowest in the season June-July for all combinations ranging from 62.48% in M.Con.4 x (SK6 x SK7) to 65.29% in Nistari x (SK6 x SK7) followed by the season August-September ranging from 66.31% in M.Con.4 x (SK6 x SK7) to 79.70% in Nistari x (SK6 x SK7). In March-April season it was ranging from 68.52% in Nistari x NB4D2 to 75.73% in M.Con.4 x (SK6 x SK7), it was 79.33% in M.Con.4 x (SK6 x SK7) to 82.43% in M.Con.4 x NB4D2 in November- December season and it was from 79.27% in Nistari x NB4D2 to 83.14% in M.Con.4 x NB4D2 during the rearing season January-March.

Comparatively finest denier was observed during June-July in M.Con.4 x NB4D2 (2.16) and Nistari x NB4D2 (2.19) followed by 2.39 in M.Con.4 x (SK6 x SK7) and 2.61 in Nistari x (SK6 x SK7).

Raw silk percent was highest (10.70%) during November-December in M.Con.4 x (SK6 x SK7). In Nistari x (SK6 x SK7) highest raw silk percent (11.81%) was observed in August-September, in M.Con.4 x NB4D2 highest raw silk percent (11.67%) was observed during November- December and in Nistari x NB4D2 highest raw silk percent (11.66%) was recorded during August-September season.

Correlation among different parameters

Studies on correlation (Table 3) among shell percent yield per 100 DFLs and reeling parameters indicate the positive correlation of shell percent with renditta, neatness and evenness. Yield per 100 DFLs was highly correlated with FL, NBFL, denier, raw silk percent, reelability percent and recovery percent. Positive correlation of FL was recorded with NBFL, raw silk percent, reelability percent, recovery percent and evenness. NBFL showed positive correlation with denier, raw silk percent, reelability percent and recovery percent. Denier had positive correlation with raw silk percent, reelability percent and recovery percent. Significantly higher negative correlation of renditta was observed with raw silk percent, reelability percent, recovery percent and evenness. Positive correlation of raw silk percent was observed with reelability percent, recovery percent and evenness. Reelability percent was highly correlated with recovery percent. It was observed that neatness was positively correlated with evenness.

Discussion

Concerning productivity and reeling parameters, better performance of all Multi x Bi combinations in November-December season is attributed to the fact that the temperature and humidity maintained in the rearing room in this season is ideal for better performance. Highest filament length was observed in the period in M.Con.4 x (SK6 x SK7) establishes the superiority of this combination in respect of the most important economic trait related with the productivity of the hybrid (Chattopadhyay *et al.*, 2001; Dayananda *et al.*, 2011). Highest shell percent in the hybrids utilizing M.Con.4 as female component indicate the efficiency of the breed in conversion of leaf to silk compared to the females of Nistari. Quality of raw silk depends upon the ideal temperature and humidity coupled with good quality of leaf. During November-December growth of leaf retards which affect the quantity of cocoons (Gowda and Reddy, 2007). Lowest yield/100 DFLs and reeling performance during June-July was resulted for high temperature and high humidity. This is in agreement with Gowda and Reddy (2006). Low reeling performance in June-July season and in August-September is attributed to the structural changes in the sericin for moisture content in the cocoon layer during spinning stage (Akahane and Tsubouchi, 1994; Naik and Somashekar,

2008). It is also in agreement with Kamatsu (1975) that humidity has an adverse effect on reelability of cocoon compared to the seasons with high temperature by reducing the solubility of sericin and cocoon quality of same combination shows variability in different seasons. In the quality parameters of raw silk i.e. in neatness and evenness percent performance of >80% in all seasons among all combinations indicate the systematic maintenance of microclimatic condition of the rearing and spinning room. Lower shell percent during November-December confirms the findings of Nakada (1972) that females of the hybrids grow too quickly which has an adverse effect on the cocoon shell weight. Finest denier was recorded in June-July in the combinations utilizing NB4D2 as a male component over the combinations using (SK6 x SK7) as a male component emphasizing on the need for season specific breed as donor. Highest raw silk percent of M.Con.4 x (SK6 x SK7) and M.Con.4 x NB4D2 during November-December and highest raw silk percent of Nistari x (SK6 x SK7) and Nistari x NB4D2 in August-September establish the species specificity in conversion of leaf to reelable silk in different seasons.

Variation in reelability is according to specific breed, rearing seasons and the cocoon produced by male/female. Due to high temperature it is reported that sericin degenerates and the reelability and raw silk percent declines.

Less variation in denier among different combinations in different seasons reveals less impact of the season on evenness character of the resultant raw silk thread. Shell percent of silkworm and the yield/100 DFLs are the most important characters and are directly related with the production of silk. Positive correlation of shell percent with renditta observed by Sonwalkar (2001) has also been recorded in this study.

Better quality of silk produced by Multi x Bi is ascertained from the positive correlation of shell percent with neatness and evenness. Higher raw silk percent establishes better neatness character of the filament of the silkworm combinations considered for this study. Positive correlation between yield/100 DFLs and filament length recorded in this study is agreed with the observation of Sekharappa *et al.* (1999). Higher correlation of yield per 100 DFLs with FL, NBFL, denier, raw silk, reelability and recovery percent signifies the fact that productivity depends upon the cumulative effect of all the quantitative characters. High correlation of yield per 100 DFLs with reelability and recovery percent confirm that quality characteristics of the cocoons develop during the growth phase of the silkworm

and need extreme care as cocoon quality contributes to the tune of about 80% of the raw silk quality (Shimazaki, 1964; Nagadevara, 2004). High negative correlation of renditta with raw silk percent and recovery percent strengthen the view that these variables vary in the contrary direction. High correlation of raw silk percent and recovery percent imply that better the recovery of silk from cocoon better the percent of raw silk. It is also confirmed that better recovery of silk is resulted from better reelability. High correlation of neatness with evenness substantiate the better quality of silk produced by the hybrids.

Higher cocoon yield, reeling and raw silk percent with better silk quality in neatness and evenness recorded in M.Con.4 x (SK6 x SK7) followed by M.Con.4 x NB4D2 and Nistari x (SK6 x SK7) recommend these combinations to be utilized at commercial level to increase productivity of quality silk.

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