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Quantitative traits of selected multivoltine, bivoltine races/breed and hybrids of the silkworm, *Bombyx mori* L. during monsoon season

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Abstract
The present investigation was conducted to know the economic traits of silkworm *Bombyx mori* L. two multivoltine races C. niche and Pure Mysore and two bivoltines NB4D2 and CSR2 were utilized to prepare four hybrids – *viz.,* PM x NB4D2 and PM x CSR2, NB4D2 x PM and CSR2 x PM were analyzed for eleven economic characters namely fecundity, hatching percentage, larval duration, larval weight, cocoon weight, shell weight, shell percentage, length of the filament, pupation rate, denier and renditta in monsoon season. The results revealed that in multivoltine the pure Mysore recorded better performance in economic characters except Length of filament and denier than C.Nichi. The bivoltine CSR2 showed better in all economic character than NB4D2. Accordingly, cross from the pure race/ breeds ie., hybrids NB4D2 x PM recorded better in the more in fecundity, hatching percentage, larval weight, cocoon weight, shell weight, shell percentage, pupation rate and denier. CSR2 x PM has lower larval duration with higher renditta compared to all hybrids.

Keywords: Silkworm, *Bombyx mori*, multivoltine, bivoltine, hybrids, traits, season

Introduction
Sericulture is an agro-based labour intensive cottage industry providing gainful employment to weaker sections in the rural areas of India. This industry is capable of generating more income than many other commercial crops. On account of its economic importance and employment generation potential special emphasis has been given for the development of sericulture industry in our country. It is note worthy that *Bombyx mori,* a silk moth of great economic value is extensively being used for the production of commercial silk in many countries since, this fiber is in association with human culture for the past 4000 years. During the long history of Sericulture, mulberry silkworm has been differentiated into a large number of geographical races (Hirobe, 1968) [6] which show distinct differences in their ethological, biochemical, physiological, genetical and morphological traits (Yokoyama, 1957) [22].

As on today there are more than 2000 races of silkworm, which are maintained in the germplasm banks of several Sericultural countries (Goldsmith, 2010) [5]. The silk has natural sheen, inherent affinity for rich colours, high absorbance, lightweight, poor heat conduction (warm in winter, cool in summer), low static current generation, resilience and excellent drape are some of its irresistibly enduaring qualities. The most mysterious features of silk are the elegant luster, beautiful colours dyed and so it to good feeling. Compared to temperate climatic zones, salubrious climate and profuse sunlight throughout the year in many parts of our country is considered as very congenial for silkworm rearing and mulberry cultivation (Narasimhanna, 1976) [10, 11].

Realizing the importance of tropical environment for the production of quality silk, several studies were undertaken to understand the impact of different seasons on mulberry crop and cocoon production (Narayanan *et al.*, 1964) [12]. It is important to note that the introduction of promising bivoltine races during 1970-2000 has resulted in the increase of silk production by many folds (Datta, 2000b) [2]. The studies have clearly demonstrated the influence of environmental factors on the expression of economic traits irrespective of the silkworm races and breeds. Although the above studies are conducted utilising selected quantitative traits only in a known environmental condition yet, a comparative analysis of the selected multivoltine races along with the bivoltine races/ breed are very limited. Keeping this in view In order to study the extent of expression of twelve economic traits in three different seasons of the year, the above races/ breed, were reared in pre monsoon season.

Materials and Methods

The two multivoltine races and two bivoltine races/breed and four hybrids were selected for the present investigation. The multivoltine races are C. Niche and Pure Mysore (PM) and in bivoltines NB4D2 are bivoltine races and CSR2 is an evolved bivoltine breed.

The combination of multivoltine and bivoltine races/breeds used for the preparation of hybrids and utilized in the experiment are PM x NB4D2, PM x CSR2, NB4D2 x PM and CSR2 x PM. All these two voltine groups are drawn from the germplasm bank. Four hybrid combinations mentioned above were prepared following the standard procedure of Gamo (1976) [4] and Yokoyama (1979) [23] reared in three replicates conducting cellular rearings feeding quality V-1 mulberry leaves. The rearing was conducted in monsoon season and give optimum temperature and relative humidity.

Ten important economic traits are evaluated during rearing namely fecundity, hatching percentage, larval weight, larval duration, cocoon weight, shell weight, shell percentage, pupation rate, length of the filament, and renditta are explained below.

1. Fecundity (nos.): This denotes the numbers of eggs laid by a single moth. The total numbers of eggs per laying were counted.
2. Hatching percentage: It denotes the number of larvae hatched from a disease free laying. The hatching percentage is calculated using the following formula.

$$\text{Hatching\%} = \frac{\text{Total No.of eggs laid}}{\text{Total No.of hatched eggs}} \text{X}100$$

3. Larval duration (h): This indicates total larval period from I-V instars till the commencement of spinning.
4. Larval weight (g): The character denotes the healthiness and robustness of the larvae one day before spinning. The average weight of 10 V instar larvae in each replicate was taken in grams.
5. Single cocoon weight (g): This is the average weight in gram of a cocoon weighed from random sample of cocoons taken from each replicate on sixth day of spinning and considered as the cocoon weight.
6. Single shell weight (g): The trait represents the total quantity of silk in a cocoon. The cocoon shell used for cocoon weight are once again used for calculating the average shell weight, which is expressed in grams.
7. Shell ratio (%): It denotes the total amount of silk available in a single cocoon and is expressed in percentage. It is calculated by taking average weight of 25 male and 25 female cocoons and the shells by using the standard formulae as follows:

$$\text{Shell Ratio} = \frac{\text{Shell Weight}}{\text{Cocoon weight}} \text{X}100$$

8. Silk filament length (m): It is the total length of silk filament in meters unwound from single cocoon. The mean value of filament length is calculated by reeling 10 cocoons collected from each replicate.
9. Pupation rate (%): Pupation rate is expressed in percentage and is calculated by the number of pupae recovered out of unit number of cocoons harvested from the unit number of larva retained after 3rd moult as per the following formula:

$$\text{Pupation rate} = \frac{\text{Number of live pupae recovered}}{\text{Unit number of cocoon harvested}} \text{X}100$$

10. Denier: This denotes the thickness of the filament, 9000 meters of the silk filament weighing 1 gram is considered as 1 denier.

$$\text{Denier} = \frac{\text{Weight of reeled silk (g)}}{\text{Length of reeled silk (m)}} \text{X}9000$$

11. Renditta (kg): It is the measure of production of one Kg of raw silk from good cocoons .It is calculated as follows:

$$\text{Renditta} = \frac{\text{Weight of reeled silk}}{\text{Weight of cocoon}} \text{X}100$$

Statistical Methods

The data obtained on the seasonal performance of the multivoltine and bivoltine was analyzed by employing the statistics SPSS 20.0 packages.

Table 1: Economic characters of two multivoltine, two bivoltine and four hybrids of silkworm *Bombyx mori* L. DURING monsoon season

Race	Fecundity (Nos.)	Hatching (%)	Larval duration (h)	Weight of 10 v instar larva(g)	Cocoon weight (g)	Shell weight (g)	Shell ratio (%)	Length of the filament (m)	Pupation rate (%)	Denier	Renditta (Kg)
Cnichi	371.5	94.64	476.9	16.50	.872	.122	12.61	384.31	96.52	1.785	16.05
PM	387.6	95.98	545.6	16.75	.919	.152	13.72	384.26	96.80	1.768	15.00
NB4D2	496.0	91.01	548.6	38.95	1.686	.345	19.38	877.21	81.09	2.577	8.459
CSR2	515.5	94.76	586.9	44.62	1.812	.420	21.34	986.32	82.55	2.763	7.327
PMXNB4D2	418.0	93.53	598.0	36.37	1.529	.241	16.87	797.49	90.23	2.776	11.25
PMxCSR2	414.9	93.06	596.7	38.25	1.421	.260	17.38	820.55	93.82	2.782	9.196
NB4D2xPM	515.4	97.19	579.4	39.67	1.612	.308	20.10	796.35	95.56	2.823	10.84
CSR2xPM	505.3	93.89	553.0	36.09	1.408	.241	19.76	791.05	94.18	2.777	9.195
Total	453.0	94.26	560.6	33.40	1.407	.261	17.65	729.69	91.35	2.506	10.92
F Value	419.937**	2.530NS	32.109*	483.350**	270.68**	536.77	164.67*	425.891**	33.283*	193.034*	661.87**

** - Significant; * - Significant; NS – Non significant.

Results and Discussion

The eleven economic traits of two multivoltine races, two bivoltine races selected along with four hybrids. 'F' values obtained by ANOVA, with significant difference in regard to the expression of quantitative traits among pure races and hybrids for all the thirteen economic traits namely fecundity, hatching percentage, larval weight, larval duration, yield by number, yield by weight, cocoon weight, shell weight, shell ratio, filament length, pupation rate, denier and renditta.

The signification variation in fecundity was higher in PM race and CSR_2 breed (387.6 and 515.5 Nos.) during pre-monsoon period. Among hybrids highest fecundity of 515.4 was recorded in NB4D2xPM followed by CSR2xPM (505.3 Nos.) and PMXNB4D2 (418.0 Nos.). The lowest was noticed in PMxCSR2 of 414.9 Nos.

Hatching percentage has no variation with higher in PM race and CSR_2 breed (95.98 and 94.76%.) during pre-monsoon period. Among hybrids highest hatching was recorded in NB4D2xPM (97.19%) followed by CSR2xPM (93.89%) and PMXNB4D2 (93.53%). The lowest was recorded in PMxCSR2 (93.06%).

Larval duration recorded the significant variation with lower larval duration in C. Nichi and NB4D2 (476.9 and 548.6 h). Among the hybrids lower larval duration was noticed in CSR2xPM (553.0 h) next in the order of NB4D2x PM (579.4 h), and PMxCSR2 (579.4 h). However, larval duration was higher in PMxNB4D2 (598.0 h).

Weight of V instar (10 larvae) in monsoon seasons revealed that the significant variation was noticed in all race/hybrids. The weight of v instar of 10 larvae expressed highest larval weight in PM and CSR2 (16.75 and 44.62 g). However, in hybrids highest was recorded in NB4D2xPM (39.67g) followed by PMxCSR2 (38.25 g) and PMxNB4D2 (36.37 g). the lower weight was noticed in CSR2xPM (36.09g).

The data pertaining to cocoon traits, ie., cocoon weight, shell weight and shell ratio clearly evident that variation among the race/ hybrids indicated significantly. Cocoon weight recorded highest in PM and CSR2 (0.919 and 1.812 g). Among the hybrids more cocoon weight was noticed in NB4D2xPM (1.612 g) followed by PMxNB4D2 (1.529 g) and PMxCSR2 (1.421 g). While, cocoon weight was less in CSR2xPM (1.408 g). In pure races/ breeds shell weight was recorded more in CSR2 and PM (0.420 and 0.152 g). In hybrids more shell weight was observed in NB4D2xPM (0.308 g) followed by PMxCSR2 (0.260 g) and less was recorded in both the hybrids PM x NB4D2 and CSR2xPM (0.241g). Shell ratio was higher in CSR2 and PM (21.34 and 13.72%) and in hybrids NB4D2xPM (20.10%) recorded higher and lower was in PMx NB4D2 (16.87%).

The filament length was significant difference among pure race and hybrids. The length of the filament was more in CSR2 and C.Nichi (986.32 and 384.31 m). Among hybrids filament length was higher in PMxCSR2 (820.55 m) next in the order of PMx NB4D2 (797.49 m), NB4D2xPM (796.35 m) and lower was recorded in CSR2xPM (791.05 m).

Pupation rate was significant variation in race/breed and hybrids. The higher in pupation rate was recorded in CSR2 and PM (82.55 and 96.80%). In hybrids NB4D2xPM (95.56%) recorded highest with respect to pupation rate followed by CSR2xPM (94.18%) and PMx CRS2 (93.82%) and lowest was observed in PMx NB4D2 (90.23%).

With respect to denier showed variation among races/breed and hybrids. Denier is thickness of the filament with higher denier was expressed in CSR2 and PM (2.763 and 1.785%). In hybrids higher diner was recorded in NB4D2xPM (2.823) followed by PMx CRS2 (2.782) and CSR2xPM (2.777). The lower diner was recorded in PMx NB4D2 (2.776).

With respect to renditta showed significant variation among races/breed and hybrids. CSR2 and PM (7.327 and 15.00 recorded higher in renditta. In hybrids, renditta was higher in CSR2xPM (9.195) followed by PMx CRS2 (9.196) and NB4D2xPM (10.84) and lower renditta was recorded in CSR2xPM (11.25) (Table 1).

Similarly, Samson and Sudhakaran (1974) [17] demonstrated in Indian breeds that high density of larval populations in a rearing bed greatly reduces the cocoon characters by reducing cocoon weight and increase of melt age in the cocoons. The influence of different seasons of pre-monsoon, monsoon and post-monsoon on yield of cocoons with an emphasis on pupation rate was clearly demonstrated by Sengupta (1969) [18] and Narasimhanna (1976) [10, 11] among multivoltine races. A wealth of information was made available in regard to the performance of newly evolved bivoltine and multivoltine races in different germplasm banks (Narasimhanna *et al.*, 1976; Subramanya, 1985; Rajanna and Sreerama Reddy, 1990; Raju, 1990) [10, 11, 15, 16, 20].

Further, Narayanan *et al*. (1964) [12], Sidhu and Azeez Khan (1969) [19] demonstrated that the scientific method and duration of incubation period significantly affect the hatching percentage of multivoltine races. Thus, based on the present studies on fecundity and hatching percentage, it is clear that hatching percentage is almost similar both in bivoltine and multivoltine races but fecundity is higher in all the bivoltine races compared to multivoltine races. It is evident that multivoltine PM exhibited the longest larval duration irrespective of the seasons compared to other five multivoltine races. The present results in regard to the differences in the larval duration among different multivoltine races will be ascribed to the "*lme*" genes as revealed by Tazima (1988) [21].

In regard to the multivoltine race, larval weight of PM exhibited highest weight. Similarly, among the bivoltine races/breed the CSR2 recorded highest larval weight which is superior. Such a study was clearly established utilizing popular temperate bivoltine races by Ohi *et al.* (1970) [13], Petkov *et al*. (1984) [14]. Further, in tropical breeds of India Narasimhanna (1976) [10, 11] and Mallik *et al*. (2006) [9] recorded higher larval weight in the bivoltine races during monsoon period. Krishnaprasad (2003) [8] recorded superior performance of CSR2 and CSR4 breeds for cocoon weight, shell weight and shell ratio. Similarly, Basavaraja *et al.* (1995) [1] and Kamble (1998) [7] have demonstrated the superior performance of CSR2 breed for cocoon traits. Considering the influence of the three seasons on the expression of the three important traits mentioned above it is noteworthy that several Japanese breeders recorded the highest values for this trait in the temperate races/breed during spring season (Hirobe, 1968 and Gamo, 1976) [6, 4].

The superior performances of the CSR2 amongst several bivoltine breeds for this trait has also been reported by Basavaraja *et al*. (1995) [1] and Datta *et al*. (2000a) [3] in their findings. In regard to the data on the filament length, among the four bivoltine races it is important to note that CSR2 exhibited longest cocoon filament length of 986 m in monsoon. The data for pupation rate among multivoltine races, it is evident that Pure Mysore recorded highest pupation rate. The highest pupation rate recorded especially by the PM race bears a testimony to its adaptation to the local environmental conditions. Supporting the above findings the superiority of the PM compared to many other multivoltine races for this trait is well documented (Narasimhanna, 1976; Subramanya, 1985) [10, 11, 20].

Conclusion

From the results of the present investigation it can be inferred that multivoltines (C.Nichi and PM) from eleven economic traits the Pure Mysore, higher performance in all economic traits, *viz.*, fecundity, hatching percentage, larval weight, cocoon weight, shell weight, shell percentage, pupation rate and renditta but C.nichi, has exhibited lower larval duration with higher in length of filament and Denier. In case of bivoltine CSR2 indicating the superior performance of in all economic characters. Among hybrids NB4D2xPM hybrid has better than all the hybrids.

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