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Comparative Assessment of Economic Traits in Selected Parental Breeds and their Hybrids of Bivoltine Silkworm *Bombyx mori* L.

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Abstract

A comparative assessment of key economic traits was conducted between six parental bivoltine breeds of the silkworm *Bombyx mori* L., namely APS12, J2, CSR53, A3, H281 and RB18 and their hybrids, prepared by crossing them in various combinations and named as YCM1, YCM2, YCM3, YCM4, YCM5, YCM6, YCM8, YCM9, YCM11, YCM13, YCM14, YCM15, YCM16 and YCM17. The hybrids were reared in three replications following standard procedures, revealed a significant positive correlation among the hybrids for various traits. The superiority of the hybrids over their parental breeds was demonstrated, with hybrid YCM8 showing higher values for fecundity, effective rate of rearing (ERR), larval weight, cocoon weight, shell weight, pupal weight, pupation rate, filament length, denier and raw silk percentage. Additionally, hybrid YCM4 exhibited a higher hatching percentage than the other hybrids and parental races. Notably, all hybrids studied exhibited varying expressions of economic traits compared to the parental breeds, excelling in five or more traits considered for the present study.

***Key words*:** Silkworm, *Bombyx mori* L., Parental breeds/hybrids, Comparative assessment, Economic traits

The silkworm (*Bombyx mori* L.) is indeed a monophagous insect, meaning it has a diet restricted to a single type of food. It feeds exclusively on mulberry leaves (*Morus* spp.), which are essential for its development and the production of silk. This specificity is one reason why mulberry cultivation is integral to sericulture (silk farming), making *Bombyx mori* highly economically significant due to its role in the silk industry. Its reliance on mulberry leaves is exploited commercially for silk production [5]. Mulberry leaves are not just the primary diet for silkworms but are crucial for high-quality silk production. Approximately 70% of the silk protein, mainly fibroin and sericin, is derived directly from the proteins and nutrients in mulberry leaves. The nutritional quality of these leaves, including their amino acids, minerals, and vitamins, directly influences the silkworm's health, growth rate, and cocoon quality. This close relationship highlights why mulberry leaf quality management is essential in sericulture to ensure optimal cocoon yield and superior raw silk production [17]. India is the only country that produces all four types of silk: Mulberry silk, Tasar silk, Eri silk and Muga silk. It ranks as the second-largest silk producer and consumer globally and is the world's largest silk importer. In 2022-23, the country achieved a raw silk production of 36,582 MT [3]. According to Central Silk Board statistics, more than 90% of the silk produced in India is from multivoltine × bivoltine hybrid cocoons [2], [10].

Further [17] observed that the health of silkworms and cocoon characteristics are strongly influenced by the quality and quantity of food consumed. The variable performance of economic traits in both multivoltine and bivoltine breeds has been well-documented by several breeders [6], [12-14], [18]. Many research efforts on silkworm breeding programs in different countries have resulted in the development of several robust and productive bivoltine hybrids [9], [11], [22]. Several studies have also reported the influence of environmental factors on the expression of silkworm economic traits, regardless of the silkworm's race or breed [23]. While earlier studies focused on selected quantitative traits under controlled environmental conditions, there remains a lack of comparative analysis between selected parental breeds of geographically diverse origins and their hybrids. Thus, this research study aims to conduct a comparative assessment of economic traits between the parental breeds and their hybrids.

MATERIALS AND METHODS

Selection of parental breeds and preparation of hybrids

The pure bivoltine parental breeds, namely A3, H281 and RB18, characterized by white oval cocoons and plane larvae and APS12, J2 and CSR53, characterized by white dumbbell cocoons and marked larvae were collected from the germplasm station at CSGRC, Hosur, Tamil Nadu.

The silkworm hybrids

The resulting bivoltine hybrids were named YCM1(APS12 X A3), YCM2(APS12 X H281), YCM3(APS12 X RB18), YCM4(J2 X A3), YCM5(J2 X H281), YCM6(J2 X RB18), YCM8(CSR53 X H281), YCM9(CSR53 X RB18), YCM11(A3 X J2), YCM13(H281 X APS12), YCM14(H281 X

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J2), YCM15(H281 X CSR53), YCM16(RB18 X APS12) and YCM17(RB18 X J2). Rearing of all six parental breeds was conducted using the cellular rearing methods, following the standard breeding techniques outlined by [7]. By applying these breeding protocols, 14 hybrids lines were prepared by crossing the six parental breeds in various combination. The rearing of all hybrids, along with the parental breeds, was carried out in a completely randomized design (CRD) with three replications, each consisting of 300 larvae maintained after the third instar. Results were recorded, and a comparative assessment was made to evaluate the superiority of the hybrids over the parental breeds using SPSS for one-way ANOVA.

Economic characters studied

There are twelve economic characters studied in this analysis. Viz., fecundity, effective rate of rearing (ERR), larval weight, larval duration, cocoon weight, shell weight, shell percentage, pupal weight, pupation rate, filament length, denier and raw silk percentage.

RESULTS AND DISCUSSION

The data obtained from the present study on the comparative assessment of twelve economic traits in both bivoltine parental breeds and hybrids silkworm by rearing them in three replications under controlled conditions were recorded as per standard sericulture practices. And the results are discussed as below:

Table 1 Economic characters of the bivoltine parental breeds and hybrids

Breeds	Fecundity	Hatching (%)	ERR (%)	Larval weight (g)	Larval duration	Cocoon weight (g)	Shell weight (g)	Shell ratio (%)	Pupal weight (g)	Pupation (%)	Filament length (M)	Denier	Raw silk (%)
Economic characters of the parental bivoltine breeds													
APS-12	497.33±6.69	90.01±1.43	86.67±2.05	4.21±0.04	24.33±0.88	1.46±0.04	0.29±0.02	19.82±1.07	1.18±0.03	84.44±1.31	1000.67±3.71	2.16±0.04	12.68±0.62
J2	505.67±3.84	88.10±1.14	84.20±1.14	4.06±0.05	24.00±0.58	1.33±0.05	0.27±0.02	20.33±0.75	1.09±0.03	84.29±3.11	975.33±7.54	2.19±0.04	13.69±0.65
CSR53	483.00±6.56	90.14±1.42	83.42±0.80	4.47±0.14	24.33±0.88	1.75±0.19	0.33±0.04	18.75±0.52	1.43±0.15	85.97±2.66	920.00±15.95	2.31±0.01	13.57±0.49
A3	501.67±6.39	90.36±0.69	87.33±2.20	4.78±0.08	25.33±1.20	1.61±0.19	0.30±0.03	18.47±0.58	1.31±0.15	84.39±0.66	975.00±27.54	2.31±0.15	14.65±0.62
H281	492.33±9.60	92.95±0.61	86.04±0.51	4.45±0.18	25.33±0.33	1.72±0.11	0.32±0.03	18.28±1.03	1.40±0.08	85.13±1.88	1029.67±15.50	2.19±0.04	15.11±0.67
RB18	501.33±4.33	92.42±0.63	86.27±1.12	4.36±0.20	25.00±0.58	1.71±0.11	0.31±0.04	18.17±1.58	1.40±0.08	85.92±1.29	988.67±14.89	2.29±0.03	14.66±0.75
Economic characters of the bivoltine hybrids													
YCM1	509.67±7.84	90.74±1.05	90.26±0.53	4.32±0.05	24.00±0.58	1.63±0.04	0.36±0.02	21.86±0.61	1.27±0.03	85.78±27.89	1009.67±6.64	2.33±0.03	16.79±0.22
YCM2	496.33±9.49	89.98±1.69	91.34±0.73	4.80±0.12	24.00±1.00	1.65±0.05	0.37±0.01	22.16±0.46	1.29±0.04	81.52±2.27	1001.67±4.10	2.61±0.05	17.83±0.24
YCM3	517.00±10.02	90.76±1.11	89.67±0.76	4.67±0.13	23.67±1.20	1.81±0.08	0.41±0.01	22.50±0.46	1.41±0.07	83.86±1.46	1021.33±5.93	2.62±0.15	17.61±0.42
YCM4	527.33±19.23	94.73±0.81	84.78±1.00	4.83±0.06	25.67±0.88	1.81±0.08	0.39±0.01	22.49±0.78	1.42±0.07	85.86±2.69	998.67±4.81	2.40±0.05	14.27±0.07
YCM5	533.33±20.21	91.37±1.95	89.23±2.52	4.60±0.17	24.33±0.88	1.71±0.07	0.36±0.02	20.82±0.83	1.35±0.05	86.61±2.30	1010.33±4.84	2.45±0.04	16.06±0.05
YCM6	510.67±10.09	92.56±0.46	88.43±0.99	4.98±0.12	25.33±1.20	1.82±0.09	0.39±0.02	21.56±0.28	1.43±0.07	86.11±2.06	1011.00±6.43	2.42±0.04	16.88±0.38
YCM8	542.33±6.23	93.86±0.85	92.27±3.65	5.35±0.18	24.00±0.58	2.10±0.06	0.46±0.02	21.72±0.34	1.65±0.04	91.19±0.62	1127.67±17.95	2.77±0.05	18.78±0.07
YCM9	524.00±7.64	93.47±0.81	84.25±1.17	4.76±0.08	24.00±1.15	1.77±0.03	0.36±0.00	20.17±0.56	1.41±0.04	87.23±2.46	1009.67±7.84	2.40±0.07	15.61±0.19
YCM11	521.33±12.35	91.50±0.40	87.69±2.62	4.96±0.02	24.33±0.88	1.80±0.04	0.38±0.01	21.08±0.38	1.42±0.04	84.62±0.82	1054.33±12.81	2.56±0.03	15.74±0.19
YCM13	519.00±14.47	92.49±0.38	85.97±0.93	5.08±0.09	24.67±0.67	1.94±0.01	0.41±0.01	21.13±0.31	1.44±0.08	88.47±1.13	985.67±19.89	2.36±0.02	13.13±0.06
YCM14	489.33±6.12	92.81±0.90	88.14±0.58	4.82±0.01	24.00±0.58	1.79±0.06	0.34±0.01	19.71±0.48	1.45±0.05	85.82±1.18	954.00±10.39	2.62±0.04	16.18±0.04
YCM15	517.00±6.35	93.13±1.53	88.48±1.66	4.99±0.11	23.67±1.20	1.86±0.06	0.38±0.01	20.60±0.08	1.48±0.05	84.18±0.60	1015.33±4.67	2.48±0.01	15.88±0.15
YCM16	497.00±7.00	92.23±0.64	86.74±1.06	4.67±0.13	24.33±0.88	1.74±0.03	0.38±0.01	21.86±0.69	1.36±0.03	81.96±1.22	956.33±12.57	2.47±0.03	14.94±0.10
YCM17	495.67±7.31	93.49±0.69	85.19±1.59	4.82±0.08	24.33±1.20	1.72±0.03	0.37±0.01	21.32±0.49	1.35±0.03	92.45±0.62	1002.00±4.16	2.34±0.02	15.84±0.15
F-test	*	**	*	NS	**	NS	NS	NS	NS	**	**	NS	**
CD	23.403	3.004	4.598	0.331	N/A	0.243	0.06	1.993	0.199	2.34	N/A	0.178	N/A
SEm	8.143	1.047	1.603	0.115	0.907	0.085	0.021	0.695	0.069	0.86	711.079	0.062	125.065
SEd	11.516	1.481	2.267	0.163	1.282	0.12	0.03	0.983	0.098	8.54	1,005.62	0.087	176.869
CV%	2.771	1.974	3.179	4.252	6.428	8.454	10.2	5.83	8.706	1.84	105.96	4.434	498.226
F-Value	2.459	1.000	2.306	7.509	.428	3.637	4.675	4.024	2.761	1.399	1.021	7.249	1.011

*Significant; **Highly significance; NS- Non significance

Comparative performance of hybrids and parental breeds

The results revealed significant differences in economic traits across the hybrids and parental breeds. Among the parental breeds H281 and RB18 stand out for their superior hatching rates and silk yields, with H281 achieving the highest yield (15.11%). J2 and A3 also show excellent silk production, with A3 demonstrating strong larval weight and cocoon weight. APS12 and CSR53, though consistent, have slightly lower silk yield, compared to the top performers. The data emphasize that H281, RB18 and A3 are among the most productive breeds for silk yield. The analysis of percentage mean values demonstrated in the hybrids have revealed superiority over the parents. The hybrids YCM8 and YCM4, were excelled over all the other hybrids and parental breeds, similar to the results reported by [21]. YCM8 exhibited superior performance across multiple traits, including fecundity, effective rate of rearing (ERR), larval weight, cocoon weight, shell weight, pupal weight, pupation rate, filament length, denier and raw silk percentage, highlighting the role of hybrid vigor in improving cocoon and silk yield in bivoltine hybrids [16]. The hybrid's superior cocoon and shell weight directly contribute to increased raw silk yield, a critical economic trait in sericulture [8]. YCM4 displayed a significantly higher hatching percentage, a crucial trait for ensuring successful rearing, as higher hatching rates lead to more larvae reaching the cocooning stage. Although its performance in other traits did not surpass YCM8, its high hatching percentage positions it as a viable option in environments where hatching success is critical [15]. All the 14 hybrids expressed more than 90% hatching percentage and 81% pupation rate respectively as that is a crucial yardstick for evaluation of any new breeds [4] and filament length more than 1000 meter in 10 hybrids.

The study's results reveal that the hybrids exhibited better performance with desirable positive heterosis for most economic traits, likely due to the improved inherent characteristics of bivoltine hybrids [18]. The hybrids display a wide range of economic traits that are critical for silk production. YCM1 show moderate fecundity (509.67 eggs) and high hatching (90.74%), a good effective rate rearing (ERR) at 90.26%, cocoon weight of 1.63g, and a raw silk yield of 16.79%. However, it has a good pupation rate (85.78%) but decent filament (1009.67m). YCM2 has lower fecundity (496.33 eggs) but boasts a very high ERR (91.34%) and cocoon weight (1.65g). It also displays a strong silk yield of 17.83% and a high pupation rate (81.52%). YCM3 offers good fecundity (517 eggs) with a solid ERR (89.67%), relatively heavier cocoons (1.81g), and a high raw silk percentage (17.61%). YCM4 stands out with high fecundity (527.33 eggs) and the highest hatching rate (94.73%). However, its ERR is lower at 84.78%. Nonetheless, it maintains a good cocoon weight (1.81g) and a strong pupation rate (85.86%). YCM5 features the highest fecundity (533.33 eggs), with a good ERR (89.23%) and cocoon weight (1.71g). its pupation rate is high (86.61%), though the raw silk yield is moderate at 16.06%. YCM6 present moderate fecundity (510.67 eggs) and a good hatching rate (92.56%). It also has a solid cocoon weight (1.82g) and a raw silk percentage of 16.88%. YCM8 is particularly noteworthy as it has the highest fecundity (542.33 eggs), ERR (92.27%) and the heaviest cocoons (2.10g). It also boasts an exceptional raw silk yield of 18.78% and a long filament length (1127.67m), making it ideal for commercial silk production making. YCM9 has high fecundity (524 eggs) and a strong hatching rate (93.47%). Its cocoon weight is 1.77g, with a moderate raw silk percentage (15.61%). YCM11 shows good fecundity (521.33 eggs) and a solid hatching rate (91.50%). It has a decent cocoon weight (1.80g) with a moderate raw silk yield (15.74%). YCM13 features moderate fecundity (519 eggs) with a good hatching rate (92.49%) and a cocoon weight of 1.94g, although it has a lower raw silk percentage (13.13%). YCM14 has slightly lower fecundity (489.33 eggs) but maintains a high hatching rate (92.81%). Its cocoon weight is 1.79g, with a raw silk percentage of 16.18%. YCM15 shows good fecundity (517 eggs) and a hatching rate of 93.13%. Its cocoon weight is 1.86g, and the raw silk percentage is 15.88%. YCM16 has moderate fecundity (497 eggs) with a high hatching rate (92.23%). The cocoon weight is 1.74g and the raw silk yield is 14.94%. YCM17 has the lowest fecundity (495.67 eggs) but a high hatching rate (93.49%). Its cocoon weight is 1.72g, and the raw silk percentage is 15.84%.

The hybrid YCM8, with its enhanced performance in key economic traits, emerges as a superior hybrid for increasing silk yield and profitability. In contrast, YCM4's higher hatching rate provides significant advantages in environments where ensuring the survival of larvae is critical. Overall, the differential expression of economic traits among the hybrids highlights the potential for careful selection and breeding strategies to improve silk production efficiency significantly [20]. YCM2 and YCM5 also demonstrate strong performance in hatching, ERR and raw silk percentage, making them viable alternatives. The findings of this study hold important implications in the selection of superior hybrids for commercial rearing [1]. The use of hybrids like YCM8 and YCM4 can boost the competitiveness of the sericulture sector by increasing both yield and quality provided further selection and evaluation for the characters studied till the fixation of traits [15] at the conclusion of the breeding program.

CONCLUSION

This study confirmed the potential of bivoltine hybrids and the relevance of the economic traits considered for future commercial exploitation. All the hybrids in the study exhibited over dominance compared to the parental races in one or the more traits, with five or more traits showing significant improvement. These findings highlight the importance of hybridization in sericulture and contribute to ongoing efforts to enhance silk yield and quality.

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