Correlation Analysis between Adult moths Longevity and Few Economic Traits in Selected Multi-bi hybrids and Its Reciprocal Crosses.

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ABSTRACT: The correlation studies was carried out in eight hybrids where, multivoltine Pure Mysore (PM) is crossed to bivoltines of C_{108}, KA, NB_4D_2 and CSR_2 races/breed regularly (PMxC_{108}, PMxKA, PMxNB_4D_2 and PMxCSR_2) and reciprocally (C_{108}xPM, KAxPM, NB_4D_2xPM and CSR_2xPM). On the mean adult life span was correlated with larval weight, cocoon weight, shell weight, shell percentage and filament length based on the Pearson correlation co-efficient estimations, there is correlation between adult longevity and larval weight. But the R^2 values are on the higher side in the hybrids. There was a strong correlation between adult longevity and three cocoon characters namely cocoon weight, shell weight and shell percentage. Insignificant correlations were observed among selected hybrids between adult life span and filament length. Three groups were identified among eight hybrids, based on the correlation coefficient values. PMxC_{108} and C_{108}xPM in group I, PMxKA and PMxNB_4D_2 in group II and CSR_2xPM, PMxCSR_2, KAxPM and NB_4D_2xPM belongs to group III. The results obtained in the present studies clearly demonstrates that there is significant correlation between adult longevity and four economic traits, larval weight, cocoon weight, shell weight, shell percentage. However for the trait filament length such correlation could be possible only among selected breeds/hybrids.

KEYWORDS: ***Silkworm, correlation, adult, longevity, hybrids, cocoon characters, economic traits.***

INTRODUCTION: The knowledge of relationship between quantitative characters of economic importance determining silk productivity is of paramount importance to the breeders, cocoon and egg producers, reelers, weavers, twisters, buyers etc. (Singh and Saratchandra, 2004). In silkworm breeding, numerous traits are considered as important for improving them to increase the benefits to silk producers. The selection of best genotypes depends on a number of characters.

The correlation of some character was found to be positive, while for others it was negative (Umashankara and Subramanya 2001). The estimates of genotypic and phenotypic variance for various economic traits and their heritability in both multivoltine and bivoltine races was reported by Murthy and Subramanya (2007). Therefore, a clear understanding and knowledge of association and contribution of various yield components is essential for any selection programme aimed at yield improvement (Ashan and Rahman, 2008). Estimation of correlation and heritability in the genetic studies of quantitative characters are of special significance for selection, as its magnitude indicates the accuracy with which a genotype can be recognized by its phenotypic expression (Narasimharaju *et al*., 1990; Singh *et al*., 1994). It also helps in deciding upon a suitable selection criteria for the genetic improvement of complex characters. Thus, the knowledge of correlation and heritability of basic economic quantitative characters is a prerequisite for selection while creating, evaluating, improving or evolving high productive breeds, hybrids or strains of silkworm (Jayaswal, *et al*., 1990; Rohith, *et al*., 2007; Sabhat, *et al*., 2009). In silkworm, *Bombyx mori* correlation between different characters has been worked out by selection experiments. The studies have shown that direct selection for one trait has correlation with genetic changes with other quantitative characters (Afrin *et al*., 2016). The moth longevity and their relationship in expressing economic traits were reported by several workers like Anantha *et al*., (2018a; 2018b). However, a lot of base line information is

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available on the adult longevity of silk moth in different races of *Bombyx mori* but the information regarding correlation with the adult longevity of silk moth *Bombyx mori* in relation to economic trait are meager. Keeping this in view, an attempt has been made to know the relation between the adult longevity of silk moth *Bombyx mori* with quantitative traits in eight hybrids.

MATERIALS AND METHODS: In the present study a multivoltine Pure mysore (PM) race *and* four bivoltine races/breed C_{108}, KA, NB_4D_2 and CSR_2 (Table - 1) were selected based on the study conducted for their economic characters and utilized for preparation of eight hybrids (Anantha *et al*., 2018a). PM females are used for four regular crosses and PM males were used in four reciprocal crosses. The eight hybrids utilized in the experiment are PM x C_{108}, PM x KA, PM x NB_4D_2, PM x CSR_2, by regular cross and hybrids C_{108} x PM, KA x PM, NB_4D_2 x PM and CSR_2 x PM from reciprocal cross were prepared following the standard procedure of Gamo (1976) & Yokoyama (1979). Both parental races and hybrids were reared in three replicates conducting cellular rearings, feeding quality M_5 mulberry leaves by following standard rearing techniques of Krishnaswamy and Narasimhana (1974). The data related to larval weight (g), cocoon weight (g), shell weight (g), shell ratio (%), filament length (m), and adult longevity of the respective races were recorded in three different seasons of the year *viz*., pre-monsoon, monsoon and post-monsoon following the standard methodology (Krishnaswami *et al*., 1973). The yield related parameters were subjected to correlation co efficient analysis with respect to silkworm, *Bombyx mori* moth longevity. The data was analyzed by employing the following statistical methods.

The relationship between two continuous variables was computed following Pearson's correlation co-efficient method as described by Singh (1998) utilizing the following formula.

$$R = \frac{N\Sigma XY - (\Sigma\Sigma X)(\Sigma Y}{(N^2)(SD_X)(SD_Y)}$$

Where, R = Co-efficient of correlation

N = Number of pair of observation.

SD_X = Standard deviation of X series (independent variable or subject series)

SD_Y = Standard deviation of Y series (dependent variable or relative series)

The probable error of correlation coefficient and test of significance of correlation coefficient was computed following the methods of Bailey (1994).

Probable Error (r) = 0.6745 X S.E. (r)

$= 0.6745X_n^{(1-r2)}$

Test of significance (r), $t = r_{1-r2}^{n-2}$

The regression function between the two variables to find out the best fitted straight line or prediction line was also computed following the methods of Palanichamy and Manoharan (1990) and multiple regression function following Bailey (1994) and Singh (1998) using the formula as detailed below.

Y = a+bX

Where,

a = Intercept of the straight line or regression constant which denotes the value of Y when the value of X is zero.

b = slope of straight line or regression coefficient which gives an idea that how change will occur in variable Y when values of X varies by 1 unit.

X and Y = represents the co-ordinates of points of the line. Multiple Regression (X 1.23) = a 1.23 +b 12.3X_2 + 13.2X_3.

The co-efficient of determinations ($R= r^2$) which is the ratio of predicted and total variance was calculated to represent the variability in dependent variable in percentage due to variation of independent variable.

RESULTS AND DISCUSSION: The data on the mean values of five economic traits *viz*., weight of the V age larvae (g) single cocoon weight (g), single shell weight (g), shell ratio (%), filament length (m) and adult longevity (h) in the male and female population of eight hybrids in three seasons are presented in Tables 2-4. Similarly, the co-efficient of correlation calculated by pooling all the data for the three seasons between adult longevity and five economic traits of female and male population are presented in the Tables 5. The diagrammatic representations of the results related to correlation co-efficient are shown in Figures 1-10. The detailed results on the above aspects are described below.

The statistical analysis and relevant CD values pertaining to five economic traits in relation to longevity in pre-monsoon season among eight hybrids are presented in Table-2. It is evident from the Table that the metric values for the economic traits *viz*., weight of V instar larvae, cocoon weight, shell weight, shell ratio and filament length are always on the lower side in the hybrids where PM is used as female parents and the values for the above five traits are higher when bivoltines are involved in the crosses as female parents with Pure Mysore males. Perusal of the Table, it clearly indicated that the weight of V instar larvae in female population ranges from 32.06±0.60g in PM x C_{108} to 41.30±0.61 in females of CSR_2x PM. Similarly, in males it ranges from 31.12±0.60g in PM x C_{108} to a highest of 40.19±0.62g in CSR_2x PM. Based on the F values (4.19 in females and 3.15in males), the results have revealed highly significant results among eight hybrids. The data pertaining to cocoon weight, shell weight and shell percentage revealed a uniform trend wherein PM x C_{108} hybrid recorded lowest values (1.43±0.011; 0.23±0.0057; 16.07±0.27 and 1.40±0.011; 0.24±0.0057; 17.13±0.27) for three traits both in the female and male female populations respectively. On the other hand, CSR_2x PM hybrid recorded highest value for cocoon weight, shell weight and shell percentage

(1.70±0.02, 0.30±0.006; 17.70±0.20 in females and 1.72±0.02; 0.31±0.005; 18.59±0.20 in males respectively). The concordant F values for cocoon weight, shell weight and shell percentage are 22.82, 17.34, and 8.51 in females and 20.90, 16.70 and 5.78 in males respectively which are statistically significant ($P<0.05$) among eight hybrids. In regard to the filament length the data have clearly demonstrated that PM x C_{108} exhibited lowest filament length of 625±4.04m in the female population where as in the male it is 630±2.88m. On the other hand a highest filament length of 842±6.92m and 854±6.35 m are clearly evident in the female and male populations respectively in CSR_2x PM. The results for filament length revealed statistically significant results among the races ($P<0.05$). The data pertaining to adult longevity in the eight hybrids has revealed statistically significant results ($P<0.05$) between races with an F values of 9.88 and 5.94. A close scrutiny of the Table-2 for the adult life span, it is clearly evident that there is a statistical difference ($P<0.05$) between each hybrids and sexes. The adult life span ranges from 148±7.21hours in males of PM x C_{108} and C_{108} x PM to 204 ± 6.92 hours in females of CSR_2 x PM hybrids. The relevant F value for adult longevity was 16.13.

Table-3 presents the data related to the five economic traits namely weight of the V instar larvae, cocoon weight, shell weight, and filament length along with mean longevity and relevant statistics during monsoon season. Perusal of the Table shows that the hybrids of PM x C_{108} (male) recorded the lowest larval weight of 32.78 ±0.63 g whereas, the highest larval weight was observed in the hybrids of NB_4D_2 x PM females (42.26 ± 0.064 g). In regard to the single cocoon weight the data ranges from 1.53 ± 0.01g. to 1.78 ± 0.02 g. A similar trend was observed for the other two cocoon parameters of shell weight and shell ratio. However, in regard to the trait filament length, lowest value of 701±6.35 m., 710±4.61 m. was recorded by two hybrids namely Pure Mysore C_{108} (males) and (C_{108} x PM) (males) respectively and a highest of 864±6.35, 848±4.04 was recorded by the males of CSR_2×PM hybrids and males of PM x CSR_2 hybrids. From the Table it is also clear that adult life span is highest in the hybrids of CSR_2×PM (females) and PM × CSR_2 (females).

Table-4 presents the data pertaining to the mean values of the five economic traits in relation to adult longevity in the eight hybrids during post monsoon season. Based on the results, it is evident that, the larval weight ranges from a lowest of 32.19 ± 0.62g (in the males of PM x C_{108}) to a highest of 42.79 ± 0.63g (in the females of CSR_2 x PM hybrids). Similarly, for cocoon weight it ranges from 1.49 ± 0.01g (in the females of PM x C_{108}) to a highest of 1.74 ± 0.01g in the females of CSR_2 x PM. A similar trend was observed for the other two traits namely, shell weight and shell ratio. The data has clearly indicated respective F values of 25.68, 61.37, 18.38 and 10.58 for the traits of larval weight, cocoon weight, shell weight and shell ratio. In regard to filament length it is clear that a lowest of 667 ± 4.61m was recorded in the hybrids of PM x C_{108} female and an highest of 861 ± 3.46m in the males of reciprocal hybrids CSR_2 x PM. The relevant F value for this trait was 260.01 which are statistically significant among different hybrids. A careful scrutiny of the data on the adult life span indicated the results with a minimum adult longevity of 180 ± 3.46 hours in the males of PM x C_{108}, where as the highest adult longevity was recorded in the female of CSR_2 x PM (252 ± 4.5 hours). The relevant F value was 16.08 which indicate statistically significant differences between the four bivoltine races under study.

Table 5 gives the data of coefficient of correlation values to understand the relationship between longevity and five economic traits in males and females in pre monsoon, monsoon and post monsoon seasons of the year for eight hybrids. The graphical representations for the same is shown sex wise and are presented in Figures 1-10 in the eight hybrids.

Relation between weight of the V instar larvae and longevity;

Perusal of the data (Table 5) to understand the relationship between the V instar larvae and adult longevity in the eight hybrids it is clear that 'r' values between the above two traits during pre monsoon season is 0.582 and 0.533 in respective females and males. The data is significant at 1% level. Similar, trend was observed during monsoon and post-monsoon seasons wherein 'r' values for females during monsoon was 0.693 and for males 'r' values are 0.770. On the other hand during post-monsoon season the respective 'r' values for females and males are 0.728 and 0.707. The slope of predicted line value of females having regression function $Y= 0.175\ X\ -2.700$ with a slope of prediction line value of 0.903 in females. Further, in males predicted line value $Y = 0.145\ X + 7.603$ with a slope values of 0.824 was observed (Fig. 1-2).

Relation between cocoon weight and adult longevity;

The co-efficient correlation (r) between cocoon weight and adult longevity exhibited significant positive correlation for females and males with a respective 'r' values of 0.658 and 0.770 during pre- monsoon season, 0.557 and 0.556 in monsoon season and 0.665 and 0.709 during post -monsoon season which are significant at 1% level in all the seasons irrespective of sex. Based on the Fig. 3-4 the regression function Y and X axis was recorded regression function as $Y = 0.005\ X + 0.389$ with a slope of prediction values 0.843 in females and in males the regression function $Y = 0.004\ X +0.768$ with a slope prediction line value of 0.843 was observed.

Relation between shell weight and adult longevity;

From the Table it is evident that during pre monsoon season, shell weight exhibited significant positive correlation with an 'r' value of 0.520 in females and 0.652 in the males. Similarly, during monsoon and post monsoon season the 'r' values are positively and significant for females 0.718, 0.741 and for males 0.692, 0.678 which are significant at 1% level (P<0.01). Based on 'r' values it is clearly indicative that there is association between shell weight and adult longevity. From the Fig. 5-6 it is clearly evident for females and males with respective regression values of Y = 0.001, X = 0.065 and Y = 0.001, X = 0.077 and with slope of prediction line value of 0.910 and 0.761 respectively.

Relation between shell percentage and adult longevity;

The degree of linear relationship between shell percentage and adult longevity revealed positive correlation in all the three seasons of the year which are all significant at 5% level. The 'r' value for the traits during pre monsoon season was 0.570 in females where as it was 0.516 for males which are significant at 5% level in females and 1% level in males. The 'r' values during monsoon season for females are 0.635 and for males 0.623 which are highly significant (P<0.01). Similarly, during post -monsoon season there is significant correlation both for females (0.712) and males (0.732). Based on the regression values Y = 0.036 X+8.827 with the slope of prediction line R^2 = 0.790 in females was observed. Similarly, the regression values Y = 0.019 X +14.11 is clearly evident in males with a slope of prediction value of 0.346. Based on the results (Fig. 7-8), it is clear that there is relation between the adult life span and shell weight.

Relation between filament length and adult longevity;

The data pertaining to the co-efficient of correlation (r) between filament length and adult longevity clearly indicates a positive correlation. However, there is no correlation between there two traits (P> 0.05) in the males with correlation value of 0.009 during monsoon season where 'r' value is 0.638 and 0.634 for females and males respectively which are highly significant (P<0.01). In post- monsoon season a similar; trend was observed wherein the 'r' values are 0.674 and 0.623 for females and males respectively. Based on the Figures 9-10 the regression of Y and X axis is recorded regression function as Y = 4.043 X –171.5 with a slope of predicted line value for females was 0.946. But in males regression function Y = 3.154 X +142.7 with a slope of prediction line value of 0.719 was evident. From the results it is clear that there is correlation between five economic traits under study except for filament length in the male population during pre- monsoon season.

The detailed investigations on the correlation of economic traits in relation to longevity of silk moth are very meager. Keeping this in view, the studies were conducted to understand the correlation of five quantitative traits utilising eight hybrids and to understand, how longevity studies can be utilized in the silkworm breeding programmes. Perusal of the data in Table 5, in regard the correlation studies between adult longevity and five economic traits in the eight hybrids of the two sexes, it is clearly evident that in pre-monsoon season there is relation between adult longevity and weight of the larva and other three cocoon characters namely, cocoon weight, shell weight and shell percentage with adult longevity. The data also presents correlation co-efficient values between filament length and adult longevity. It is clear that there is a positive and significant correlation between male and female sexes between these traits (Rohith L. Shankar, *et al*., 2010a,b,c,d) and longevity of moths. For instance based on the 'r' value, which is the ratio of predicted and total variance, which was calculated to represent the variability in dependent variable in percentage due to variation of independent variable and as result there exists significant correlation between adult longevity and five traits under study.

The literature survey pertaining to the correlation of other traits with those of larval weight was reported by Chatterjee (1992) Similarly, Umashankara and Subramanya (2002) demonstrated the correlation between larval weight and cocoon characters. But, in pioneer experiments Kang *et al*., (1999) demonstrated correlation between longevity and commercial characters in the temperate bivoltine races. The present studies of the author tallies with the results of Kang *et al*., (1999) for larval weight and adult longevity. The Figures (1-10) clearly indicate the scattered dots between X and Y-axis and the regression line drawn indicate stronger relationship between larval weight and longevity. A comparison between bivoltine and multivoltines for these two variables, the regression equations of the two variables recorded by bivoltines is on the higher side compared to multivoltine races has been reported by Anantha *et al*., (2018b; 2018a). Thus, it is a clear indication that correlation is more evident in bivoltine races than mutivoltines. As a result, the degree of straight-line association between the values of two variables is different in both the races. A similar trend is observed in the multi x bi hybrids also. The data pertaining to the correlation between the three cocoon characters namely, cocoon weight, shell weight and shell percentage in the eight hybrids of the two sexes in three seasons of the year clearly demonstrated that there is a positive and significant correlation between adult longevity and three cocoon characters. One interesting aspects of the present study is that the correlation coefficient value between the three cocoon characters and adult longevity is comparatively lesser than the 'r' values obtained for correlation of different characters. 'r' values ranges from a lowest to a highest for the traits of shell percentage and longevity. Data presented in Tables 5 also clearly indicates a similar type of correlation between the longevity and cocoon characters among eight hybrids.

The perusal of literature in regard to the longevity studies and its relevance to the economic characters has also been reported in the non-mulberry silkworms, Rajendra Singh and Prasad (1987), Ghosh *et al*., (1996), Yadav and Goswami (1999) demonstrated a direct correlation between the cocoon weight and shell weight, shell weight and shell percentage and shell percentage and filament length. Such reports in mulberry silkworms have also indicated a direct correlation between different quantitative traits (Kumareshan *et al*., 2002; Jayswal *et al*., 2000; Umashankara and Subramanya, 2002). Another, important aspects involved in the study are correlation of filament length with longevity. It is important to note that in many instances in the multivoltine races as well as hybrids, it is very difficult to draw the correlation between the filament length and adult longevity. In a similar correlation studies Kang *et al*., (1999), demonstrated the relationship between longevity and filament length, though he has shown lower "r" values in temperate races. Based on the above studies to understand the relationship between the correlation of five economic characters with one of the biological character "longevity" the author is of the opinion that the long living moths has revealed higher R^2 values in the present study. Tribhuvan singh *et al*., (2011) opined that correlation and heritability studies of quantitative traits are a pre-requisite for judicious selection for genetic improvement of complex characters of economic importance. The success of selection is governed by the degree to which the desired trait is transmitted to the succeeding generation. The nature of selection is to be given due consideration at appropriate developmental stages for pursuing selection in desired direction while improving or evolving high productive breeds or hybrids of the silkworm. Characters showing high heritability as well as high genetic advance respond better to simple phenotypic selection while those having low heritability and low genetic advance may respond better to mass selection. Characters showing high heritability and low genetic advance may yield good response to hybridization and recurrent selection. The overall picture that emerges out of the correlation studies is that adult longevity may be considered as one of the "breeding index" in addition to the analysis of quantitative traits during hybridization and selection of silkworms by the breeders (Murakami, 1989a and 1989b). Though, there is disparity in the results (correlation values) in the races/breed and hybrids, it may be due to racial differences. Thus, it is pertinent to mention here that adult life span in silkworm is one of the biological character which can be used as an important breeding index in the evolution of races.

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TABLE 1: THE MORPHOLOGICAL CHARACTERISTIC FEATURES OF PURE RACES/BREED.

Sl. No.	Races/	Origin	Larval	Cocoon Colour	Cocoon	Voltinism

	Breed		**Markings**		**Shape**	
MULTIVOLTINE RACE						
1.	PM	China	Plain	Light green	Spindle	Multivoltine
BIVOLTINE RACES/BREED						
1.	C_{108}	China	Plain	White	Oval	Bivoltine
2.	KA	India	Plain	White	Oval	Bivoltine
3.	NB_4D_2	India	Plain	White	Dumbbell	Bivoltine
4.	CSR_2	India	Plain	White	Oval	Bivoltine

Table 2: Mean values of the five economic traits and adult life span in eight hybrids of the silkworm, *Bombyx mori in* pre-monsoon season

Hybrids \ **Economic Traits**		**Weight of 10V-age larvae (g)**	**Single Cocoon weight (g)**	**Single Shell weight (g)**	**Shell ratio (%)**	**Filament length (m)**	**Adult life span (h)**
PM x C_{108}	Female	32.06±0.60	1.43±0.011	0.23±0.0057	16.07±0.27	625±4.04	168±6.92
	Male	31.12±0.60	1.40±0.011	0.24±0.0057	17.13±0.27	630±2.88	148±7.21
PMxKA	Female	36.2±20.63	1.45±0.011	0.25±0.0057	17.23±0.25	705±2.30	174±6.92
	Male	35.34±0.58	1.42±0.011	0.26±0.0057	18.30±0.25	715±8.66	150±3.46
PM x NB_4D_2	Female	38.81±0.63	1.50±0.011	0.27±0.0057	17.99±0.24	776±3.46	172±5.29
	Male	37.32±0.58	1.49±0.011	0.27±0.0057	18.11±0.24	786±3.46	150±3.46
PM x CSR_2	Female	39.13±0.59	1.51±0.011	0.28±0.0057	18.53±0.23	789±5.19	192±6.92
	Male	38.24±0.59	1.48±0.011	0.28±0.0057	18.91±0.24	796±3.46	168±3.46
C_{108}x PM	Female	34.12±0.58	1.46±0.011	0.24±0.0057	16.43±0.26	643±4.61	168±6.92
	Male	33.27±0.58	1.44±0.011	0.25±0.0057	17.35±0.25	654±5.19	148±7.21
KAxPM	Female	36.82±0.63	1.49±0.011	0.25±0.0057	16.76±0.25	721±3.46	192±6.92
	Male	35.71±0.63	1.45±0.011	0.26±0.0057	17.92±0.25	734±2.30	156±3.46
NB_4D_2x PM	Female	39.50±0.72	1.53±0.011	0.26±0.0057	16.98±0.24	778±7.50	192±6.92
	Male	38.31±0.63	1.51±0.011	0.26±0.0057	17.20±0.25	787±5.39	156±3.46
CSR_2x PM	Female	41.30±0.61	1.70±0.02	0.30±0.006	17.70±0.20	842±6.92	204±6.92
	Male	40.19±0.62	1.72±0.02	0.31±0.005	18.59±0.20	854±6.35	196±7.21
F-value	Female	4.19	22.82	17.34	8.51	9.88	235.16
	Male	3.15	20.90	16.70	5.78	5.94	0.96
Signi-ficant	Female	*	**	**	**	**	**
	Male	*	**	**	*	*	NS
CD at 5%	Female	15.36	1.42	0.02	0.01	0.58	3.84
	Male	10.84	1.38	0.02	0.01	0.57	213.25

Index : NS: Non Significant. *: Significant at 5% level ($P < 0.05$). **: Significant at 1% level ($P < 0.01$).

Table 3: Mean values of the five economic traits and adult life span in eight hybrids of the silkworm, *Bombyx mori in* monsoon season.

Hybrids \ Economic Traits		Weight of 10V-age larvae (g)	Single Cocoon weight (g)	Single Shell weight (g)	Shell ratio (%)	Filament length (m)	Adult life span (h)
PM x C_{108}	Female	34.72±0.64	1.56±0.02	0.26±0.006	16.49±0.29	683±4.61	198±6.92
	Male	32.78±0.63	1.53±0.01	0.27±0.005	17.63±0.24	701±6.35	172±7.21
PMxKA	Female	39.21±0.58	1.60±0.02	0.28±0.006	17.49±0.23	814±6.92	222±6.92
	Male	37.28±0.65	1.57±0.02	0.29±0.006	18.46±0.23	828±4.04	196±7.21
PM x NB_4D_2	Female	39.84±0.63	1.61±0.02	0.30±0.005	18.62±0.22	826±4.04	228±6.92
	Male	37.74±0.63	1.60±0.01	0.30±0.006	18.74±0.22	838±5.77	196±7.21
PM x CSR_2	Female	42.46±0.64	1.70±0.01	0.32±0.005	18.81±0.21	839±5.19	242±7.21
	Male	41.21±0.64	1.66±0.02	0.32±0.005	19.27±0.21	848±4.04	202±7.21
C_{108}x PM	Female	35.65±0.66	1.60±0.01	0.27±0.006	16.86±0.23	689±4.61	216±6.92
	Male	34.54±0.65	1.58±0.02	0.28±0.006	17.71±0.23	710±4.61	172±7.21
KAxPM	Female	39.19±0.68	1.63±0.01	0.28±0.006	17.17±0.23	824±2.88	222±6.92
	Male	38.04±0.59	1.61±0.01	0.29±0.005	18.01±0.22	837±9.23	196±7.21
NB_4D_2x PM	Female	42.26±0.64	1.75±0.02	0.31±0.005	17.70±0.21	849±6.35	228±6.92
	Male	41.07±0.58	1.71±0.01	0.31±0.006	18.12±0.21	861±3.46	198±3.46
CSR_2x PM	Female	43.30±0.61	1.78±0.02	0.32±0.006	17.97±0.20	856±6.92	246±6.92
	Male	41.19±0.62	1.76±0.02	0.33±0.005	18.74±0.20	864±6.35	214±7.21
F-value	Female	4.64	23.99	47.55	16.07	12.10	170.76
	Male	4.42	25.16	44.51	12.37	6.33	132.11
Signi-ficant	Female	*	**	**	**	**	**
	Male	*	**	**	**	*	**
CD at 5%	Female	15.83	1.45	0.02	0.01	0.53	12.22
	Male	15.613	1.43	0.02	0.01	0.51	13.11

Index: NS: Non Significant. *: Significant at 5% level ($P < 0.05$). **: Significant at 1% level ($P < 0.01$).

Table 4: Mean values of the five economic traits and adult life span in eight hybrids of silkworm, *Bombyx mori in* post-monsoon seasons

Hybrids \ Economic Traits		Weight of 10V-age larvae (g)	Single Cocoon weight (g)	Single Shell weight (g)	Shell ratio (%)	Filament length (m)	Adult life span (h)
PM x C_{108}	Female	33.22±0.64	1.49±0.01	0.24±0.04	16.10±0.26	667±4.61	204±6.92
	Male	32.19±0.62	1.51±0.02	0.26±0.05	17.20±0.25	679±5.19	180±3.46
PMxKA	Female	38.26±0.64	1.55±0.02	0.27±0.04	17.41±0.24	749±4.61	228±6.92
	Male	37.17±0.61	1.53±0.01	0.28±0.05	18.29±0.23	754±2.84	192±3.46
PM x NB_4D_2	Female	38.47±0.63	1.61±0.01	0.29±0.04	18.01±0.22	826±4.04	240±6.92
	Male	37.19±0.60	1.59±0.01	0.29±0.04	18.23±0.23	858±5.77	198±3.46
PM x CSR_2	Female	41.07±0.61	1.70±0.02	0.31±0.04	18.22±0.21	832±2.30	252±6.92
	Male	40.01±0.57	1.67±0.01	0.32±0.05	19.15±0.21	838±4.61	220±7.21
C_{108}x PM	Female	35.18±0.62	1.50±0.02	0.25±0.04	16.66±0.25	678±4.61	216±6.92
	Male	34.06±0.58	1.49±0.02	0.26±0.05	17.44±0.25	689±6.35	180±3.46
KAxPM	Female	37.79±0.64	1.58±0.01	0.27±0.05	17.08±0.24	787±5.19	240±6.92
	Male	36.64±0.63	1.56±0.01	0.28±0.04	17.94±0.23	794±2.30	216±3.46
NB_4D_2x PM	Female	41.29±0.63	1.72±0.02	0.30±0.05	17.43±0.21	831±3.46	246±6.92
	Male	40.19±0.58	1.70±0.02	0.30±0.04	17.64±0.21	842±4.61	226 ±7.21
CSR_2x PM	Female	42.79±0.63	1.74±0.01	0.31±0.05	17.81±0.21	851±3.46	252±4.51
	Male	41.61±0.64	1.71±0.01	0.32±0.05	18.70±0.21	861±3.46	228±3.46
F-value	Female	6.30	25.76	72.95	29.42	9.07	306.06
	Male	18.07	27.47	57.42	16.66	7.94	260.40
Significant	Female	*	**	**	**	**	**
	Male	**	**	**	**	**	**
CD at 5%	Female	15.77	1.44	0.02	0.01	0.53	9.41
	ale	10.68	1.38	0.02	0.01	0.52	10.46

Index: NS: Non Significant. *: Significant at 5% level ($P < 0.05$). **: Significant at 1% level ($P < 0.01$).

Table 5: Correlation between longevity and economic traits among four multivoltine and bivoltine hybrids in three seasons of the year

Economic traits	Sex	Adult longevity	Weight of larvae	Weight of cocoon	Shell weight	Shell percentage	Season

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Weight of the larvae	Female	0.582 **					**Pre-monsoon**
	Male	0.533 **					
Cocoon weight	Female	0.658 **	0.925**				
	Male	0.507 **	0.913**				
Shell weight	Female	0.520 **	0.910**	0.982**			
	Male	0.652 **	0.898**	0.803**			
Shell percentage	Female	0.270 *	0.702**	0.481 *	0.916**		
	Male	0.516 **	0.621 *	0.398 *	0.866**		
Filament Length	Female	0.654**	0.760**	0.635**	0.679**	0.617**	
	Male	0.650**	0.735**	0.630**	0.692**	0.610**	
Weight of the larvae	Female	0.693 **					**Monsoon**
	Male	0.770 **					
Cocoon weight	Female	0.577 **	0.913**				
	Male	0.556 **	0.888**				
Shell weight	Female	0.718 **	0.960**	0.878**			
	Male	0.692**	0.943**	0.911**			
Shell percentage	Female	0.635 **	0.797**	0.533 *	0.869**		
	Male	0.623 **	0.753**	0.528 *	0.830**		
Filament Length	Female	0.638**	0.626**	0.620**	0.615**	0.628**	
	Male	0.634**	0.610**	0.623**	0.696**	0.679**	
Weight of the larvae	Female	0.728 **					**Post-monsoon**
	Male	0.707 **					
Cocoon weight	Female	0.665 **	0.956**				
	Male	0.709 **	0.926**				
Shell weight	Female	0.741 **	0.970**	0.957**			
	Male	0.678 **	0.950**	0.925**			
Shell percentage	Female	0.712 **	0.851**	0.756**	0.913**		
	Male	0.432 *	0.763**	0.606 *	0.862**		
Filament Length	Female	0.674**	0.615**	0.618**	0.636**	0.631**	
	Male	0.623**	0.677**	0.658**	0.652**	0.654**	

Index: NS: Non Significant. *: Significant at 5% level (P < 0.05). **: Significant at 1% level (P < 0.01).

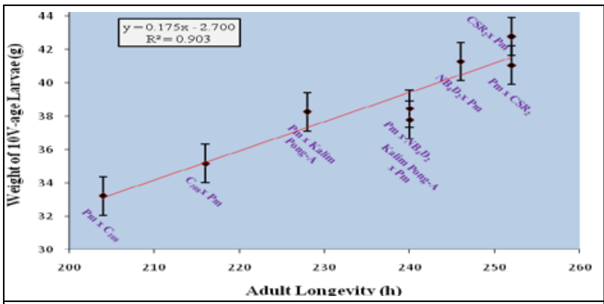

Fig. 1: Longevity v/s Larval weight in eight female hybrids

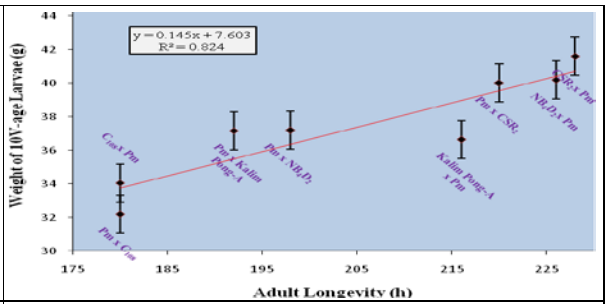

Fig. 2: Longevity v/s Larval weight in eight male hybrids

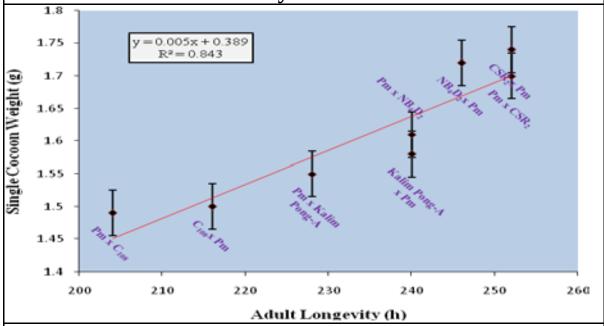

Fig. 3: Longevity v/s single cocoon weight in eight female hybrids

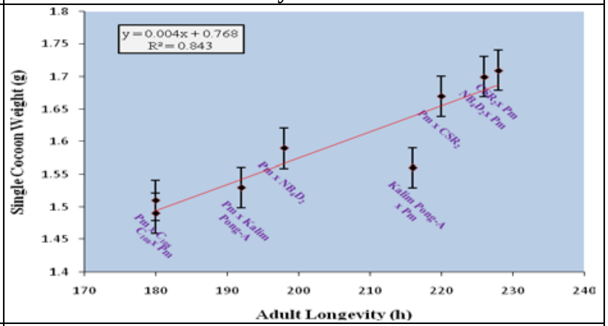

Fig. 4: Longevity v/s single cocoon weight in eight male hybrids

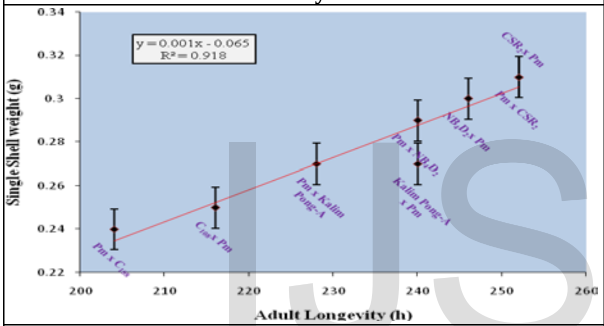

Fig. 5: Longevity v/s single shell weight in eight female hybrids

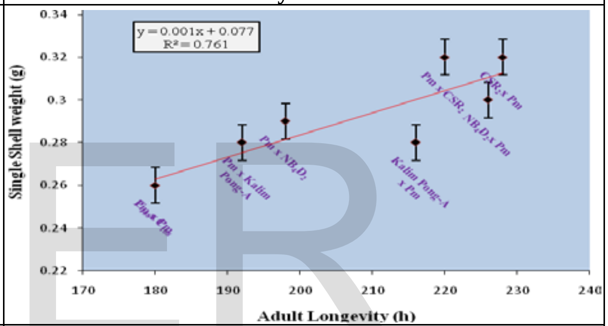

Fig. 6: Longevity v/s single shell weight in eight male hybrids

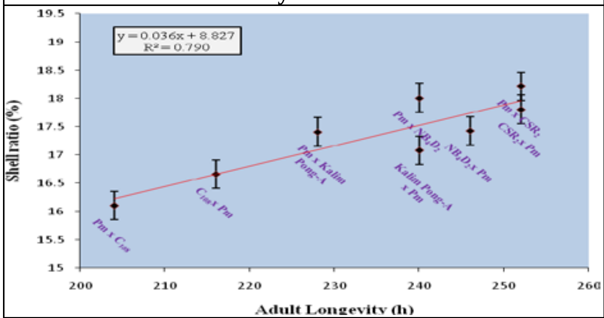

Fig. 7: Longevity v/s shell ratio eight female hybrids

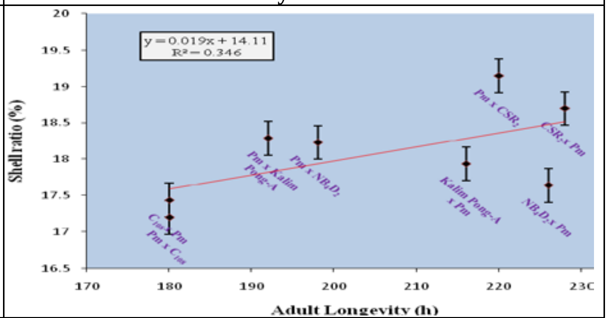

Fig. 8: Longevity v/s shell ratio in eight male hybrids

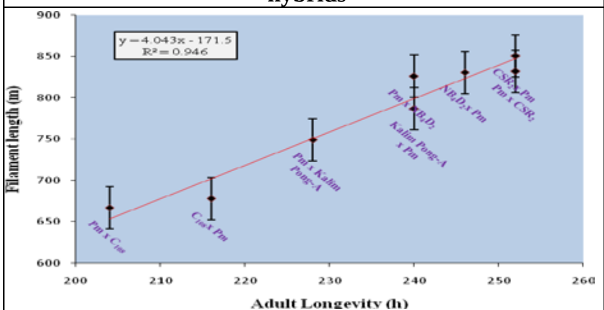

Fig. 9: Longevity v/s Filament length in eight female hybrids

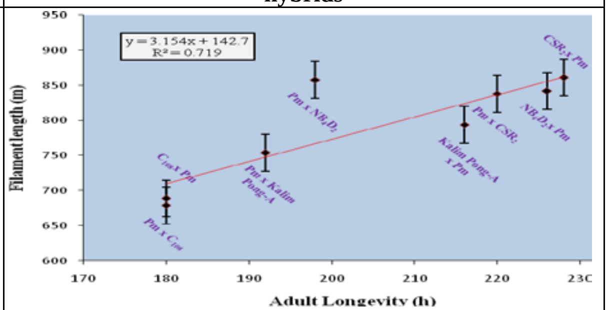

Fig. 10: Longevity v/s Filament length in eight male hybrids