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CORRELATION ANALYSIS BETWEEN LONGEVITY OF ADULT MOTHS AND ECONOMIC TRAITS IN FEW PURE RACES OF MULTIVOLTINE SILKWORM *BOMBYX MORI* (L)

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ABSTRACT

In silkworm breeding, numerous traits are considered as important for improving them to increase the benefits to silk producers. An attempt was made to correlate the lifespan of adult stage of silkworm *Bombyx mori* multivoltine races with the few yield parameters are found to be significant in deciding the next generation yield. The adult life span was correlated with larval weight, cocoon weight, shell weight, shell percentage and filament length in the six multivoltines. Based on the Pearson correlation co-efficient estimations, there is correlation between adult longevity and larval weight. There is strong correlation between adult longevity and three cocoon characters namely cocoon weight, shell weight and shell percentage. Insignificant correlations were observed among six races selected between adult life span and filament length. But the R^2 values are on the lower side in the multivoltine. Three groups were identified among six multivoltines from the correlation studies. I group involves *pre* and *npnd* races with less R^2 values where as II group includes C.nichi, Nistari and PM with moderate R^2 values. However, Daizo race recorded highest R^2 values. 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: *Bombyx mori, silkworm, multivoltine, yield, correlation co-efficient, adult, longevity, economic traits.*

1. INTRODUCTION

The silkworm, *Bombyx mori* a domesticated insect has been extensively utilized as a laboratory tool for various experimental studies. Among insect species, it ranks next only to the fruit fly, *Drosophila melanogaster* and has been exploited for various genetical studies [1,2]. In addition, to its utility as a laboratory tool, it is an important economic insect by virtue of the lustrous silk fibre it secretes at the end of its larval life. Genetic correlations are often used for developing indirect selection criteria/ selection in crop and animal breeding programmes. In recent years, several breeders have added further dimensions by including biochemical characteristics as surrogate breeding parameters or markers for septic yield traits. Genetic variability is a prerequisite for an effective selection and as a result genetic variability is essential for developing high yielding varieties [3]. In silkworm breeding, numerous traits are considered as important for improving them to increase the benefits to silk producers. Yields are the multiplicative and product of many factors which jointly or singly influences it. [4, 5] are also of the opinion that yield is not an independent character, rather it results from the multiplicative interactions between various yield components. The selection of best genotypes depends on a number of characters. Therefore, a clear understanding and knowledge of association and contribution of various yield components is essential for any selection programme aimed at yield improvement [6]. The pioneering work in this regard has been undertaken by many investigators in plants [7-9]. In animals too, [10, 11] have reported the importance of biochemical parameter relevant to animal breeding. 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. The correlation of some character was found to be positive, while for others it was negative. [12] found significant positive correlation of mature larval weight with cocoon weight and shell weight and cocoon weight and pupal weight in both sexes of *Bombyx mori.* Singh *et al.*, [13] reported the similar results between shell weight and fecundity. Chatterjee et al., [14] investigated the relationship between yield potential and molecular markers in silkworm. Gamo and Shimazaki [15] was the first sericulture scientist who came with the idea of finding and exploiting the correlation between biochemical parameters and yield attributes.

Selection based on heritability coefficients of single cocoon weight and shell weight, can be applied successfully for genetic gain in this trait. Based on correlation coefficients between traits, selection for shell weight can be applied successfully to improve other traits such as single cocoon weight and shell ratio [16]. Similarly, [17] demonstrated that the genotype correlation was higher than the corresponding phenotypic correlation coefficient in spring and summer and heritability (broad sense) together with genetic advance in percent of mean were higher for most of the important characters. The estimates of genotypic and phenotypic variance for various economic traits and their heritability in both multivoltine and bivoltine races was reported by [18] where the higher values of heritability was recorded for the traits of yield by number, shell weight and shell percentage indicating the role of environmental influence. Similarly, cocoon weight and shell weight revealed positive genetic correlation with fecundity and were negatively correlated with fertility and hatchability [19].

Several reports on correlation between larval weight and cocoon traits are recorded both among tropical and temperate race [20]. For instance [21, 22] revealed change in V instar larval weight, the cocoon weight and the pupal weight showed the interdependence for each other, when the regression lines were drawn which clearly demonstrate that V instar larval weight plays an important role in estimating the total cocoon productivity of the races of cocoon weight and larval weight are important characters of single shell weight. Similarly, correlations were observed for cocoon weight, larval weight and shell weight by [23-26]. Further, the correlation between the quantitative parameters such as cocoon weight, shell weight, shell ratio and filament length correspondence to high esterase and phosphates activity, the order of merit in favour of bivoltine than univoltine and multivoltine races was clearly demonstrated by [27, 28]. A quite good number of reports are also available on protease activity in the embryo of *Bombyx mori* which help to identify productivity of the breeds. It is the papain like protease found in the embryo which has positive correlation with respect to viability and cocoon shell percentage. Whereas, trypsin likes protease activity has positive correlation with cocoon weight, reliability and viability percentage. Similarly, chymotrypsin like proteins has positive correlation with cocoon weight and viability [29].

However, a lot of base line information is 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 through the experiments to know the relation between the adult longevity of silk moth *Bombyx mori* with quantitative traits in six multivoltines.

2. MATERIALS AND METHODS

In the present study six multivoltines such as *pre*, *npnd*, C.nichi, PM, Nistari and Daizo were selected based on the study conducted foe their economic characters [30] derived and reared along with parents. 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 [31]. 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 [32] 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.

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

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

The probable error of correlation coefficient and test of significance of correlation coefficient was computed following the methods of [33].

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 [34] and multiple regression function following [32] and [33] 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.

Table 1: The Morphological Characteristic Features of Ten Pure Races/Breed.

Races/ breed	Origin	Larval markings	Cocoon colour	Cocoon shape	Voltinism
pre	Japan	Marked	White	Oval	Multivoltine
npnd	Japan	Marked	White	Oval	Multivoltine
C.nichi	China	Marked	White	Dumbbell	Multivoltine
Daizo	India	Marked	Dark Green	Spindle	Multivoltine
Nistari	India	Marked	Golden yellow	Spindle	Multivoltine
PM	China	Plain	Light green	Spindle	Multivoltine

3. 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 six multivoltine races, in three seasons are presented in Tables 2-4 and depicted in Figures 1-10. 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 Table 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 data pertaining to the mean values of five economic traits and adult life span in the two sexes of the six multivoltine races *viz*., *pre*, *npnd*, C.nichi, PM, Nistari and Daizo along with statistical analysis in pre-monsoon season is shown in Table-2 and depicted in Figures 1-10. Perusal of the Table, clearly indicated that the weight of V instar larvae in female population ranges from 13.3 ± 0.017 g in *pre* race to 23.88 ± 0.016 in females of Daizo. Similarly, in males it ranges from 12.49 ± 0.23 g in *pre* to a highest of 22.32 ± 0.025 g in Daizo. Based on the 'F' values (107.053), the results have revealed highly significant results among six multivoltine races. The data pertaining to cocoon weight, shell weight and shell percentage revealed a uniform trend wherein *pre* recorded lowest values for three traits both in the male and female populations. On the other hand, Daizo race recorded highest value for cocoon weight, shell weight and shell percentage. The concordant 'F' values for cocoon weight, shell weight and shell percentage are 168.17, 35.60, and 11.03 which are statistically significant ($P<0.05$) among six races. In regard to the filament length the data have clearly demonstrated that pre race exhibited lowest filament length of 269 ± 2.30 m in the female population where as in the male it is 299±3.46 m. On the other hand a highest filament length of 431±3.46 m and 445±2.30 m are clearly evident in the female and male populations respectively in Daizo race. The results for filament length revealed statistically significant results among the races ($P<0.05$).

The data pertaining to adult longevity in the six multivoltine races has revealed statistically significant results ($P<0.05$) between races with an 'F' values of 16.28.

The data on the mean value of five economic traits along with adult life span in the six multivoltine races in the monsoon season are presented in Table-3. Perusal of the Table demonstrated that the weight of V instar larvae is lowest in the males of *npnd* race (14.94±0.023g.). The higher larval weight was observed among the females of Daizo race with a value of 26.73±0.46g. The relevant F value for this trait was 143.99 and the data revealed significant differences between ($P<0.05$) the six multivoltine races. In regard to the three cocoon traits cocoon weight, shell weight and shell ratio the data recorded a uniform trend, wherein the females of the multivoltine races recorded a higher metric values, where as the males have recorded the lower values. But for the traits of shell percentage the data has indicated highest values among females of all the races and lowest values in the males. In regard to the trait filament the data ranges from a lowest filament length of 359±5.19m in the females of *pre* to a highest of 477±7.26 m in the females of Daizo race. A scrutiny of the Table also indicates that the data for adult longevity is different among six multivoltine races. The highest adult longevity of 216±6.92 hours was recorded by females of Daizo race while, a lowest of 108±3.46 hours was recorded by *pre* race. Based on the analysis of variance it is evident that there is significant difference for the above five traits between races.

Table-4 presents the data in regard to the mean values of the five economic traits in relation to adult longevity in the six multivoltine races of the silkworm in post-monsoon season. Based on the results, it is clearly indicative that Daizo female recorded a larval weight of 24.73 ± 0.64g, which is the highest for this trait. Similarly for the traits of cocoon weight, shell weight and shell ratio the Daizo race revealed higher values. The relevant F value for these traits are 136.73, 9.48 and 2.69 which are all statistically significant at 5 % level indicating the racial differences between the six multivoltine races. A close scrutiny of the data for the trait filament length; the *pre, npnd* and C.nichi recorded a uniform trend in the female population where as in the males the value of the filament length was significantly lesser thereby indicating the significant differences between the races, (F value 1.91). The data pertaining to adult longevity clearly indicated a lowest adult longevity of 132 ± 2.1 hours in *pre* males and a highest of 240 ± 6.92 hours in the females of Daizo race. The 'F' value for adult longevity was 20.50.

Data on the co-efficient of correlation (r) values to understand relation between longevity and five economic traits in males and females of six multivoltines in pre-monsoon, monsoon and post-monsoon season are presented in Table 5. Perusal of the data in the pre-monsoon season clearly indicated the relationship between the five economic traits and adult longevity as detailed bellow.

Table 2: Mean values of the five economic traits and adult life span in six multivoltine races of the silkworm, *Bombyx mori in* Pre-monsoon season

Races \ Economic Traits		Weight of 10 V-age larvae (g)	Single cocoon weight (g)	Single shell weight (g)	Shell ratio (%)	Filament length (m)	Adult lifespan (h)
pre	Female	13.3 ±0.01	0.74±0.05	0.088±0.002	12.22±0.31	289.00±2.30	132.00±6.92
	Male	12.49±0.02	0.73±0.04	0.089±0.001	12.19±0.17	299.00±3.46	96±3.46
npnd	Female	13.50±0.02	0.83±0.02	0.098±0.001	11.80±0.06	379.00±2.88	136±6.92
	Male	12.11±0.03	0.82±0.02	0.100±0.006	12.13±0.33	388.00±4.61	106±3.46
C.nichi	Female	16.67±0.07	0.89±0.02	0.110±0.006	12.33±0.31	374.00±2.88	168±6.92
	Male	14.74±0.06	0.88±0.01	0.12±0.005	13.62±0.47	386.00±3.46	118±3.46
Pure Mysore	Female	17.50±0.03	0.92±0.03	0.120±0.005	13.03±0.34	381.00±4.04	174±6.92
	Male	16.02±0.05	0.89±0.02	0.090±0.005	11.54±1.55	393.00±1.73	124±3.46
Nistari	Female	19.40±0.04	0.95±0.01	0.140±0.005	14.72±0.43	413.00±4.61	174±6.92
	Male	17.77±0.02	0.94±0.02	0.140±0.005	14.88±0.52	284.75±1.40	124±3.46
Daizo	Female	23.38±0.03	1.10±0.01	0.160±0.006	14.71±0.25	431.00±3.46	198±6.92
	Male	22.32±0.02	1.06±0.02	0.160±0.005	15.06±0.38	445.00±2.30	160±6.92
F-value	Female	13.24	53609.29	94.30	32.04	11.36	200.60
	Male	26.63	174.71	148.64	30.09	4.01	1.152
Significant	Female	**	**	**	**	**	**
	Male	**	**	**	**	NS	NS
CD at 5%	Female	18.82	0.04	0.03	0.01	0.96	9.32
	Male	11.52	0.78	0.02	0.01	2.04	155.80

*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 six multivoltine races of the silkworm, *Bombyx mori* in monsoon season

Races \ Economic Traits		Weight of 10 V-age larvae (g)	Single cocoon weight (g)	Single shell weight (g)	Shell ratio (%)	Filament length (m)	Adult lifespan (h)
pre	Female	15.94±0.36	0.78±0.02	0.100±0.01	12.67±0.56	359±5.19	150±6.92
	Male	15.58±0.05	0.77±0.02	0.11±0.02	13.78±0.71	368±1.73	108±3.46
npnd	Female	16.39±0.05	0.93±0.01	0.120±0.02	12.74±0.50	412±5.77	144±6.92
	Male	14.94±0.02	0.92±0.02	0.12±0.02	13.03±0.46	421±3.46	124±3.46
C.nichi	Female	17.65±0.02	1.05±0.02	0.140±0.02	13.3±0.40	424±2.88	156±6.92
	Male	16.35±0.02	1.04±0.02	0.15±0.02	14.41±0.39	435±2.88	153±6.77
Pure Mysore	Female	19.36±0.03	1.02±0.02	0.150±0.02	14.69±0.39	428±7.50	168±6.92
	Male	17.86±0.03	1.03±0.02	0.16±0.02	15.47±0.43	434±6.88	160.±3.46
Nistari	Female	21.53±0.05	1.11±0.02	0.170±0.01	15.30±0.36	455±2.88	192±6.92
	Male	19.86±0.02	1.08±0.01	0.18±0.02	16.65±0.35	467±3.46	154±3.46
Daizo	Female	26.73±0.04	1.21±0.01	0.18±0.02	14.86±0.33	458±4.04	216±6.92
	Male	25.08±0.04	1.19±0.01	0.20±0.01	16.79±0.32	477±7.26	180±3.46
F-value	Female	16.12	670.38	177.57	27.20	7.07	52.04
	Male	16.27	10752.09	168.16	35.60	11.02	65.81
Significant	Female	**	**	**	**	*	**
	Male	**	**	**	**	**	**
CD at 5%	Female	18.82	0.41	0.02	0.01	1.18	13.56
	Male	17.46	0.08	0.02	0.01	1.26	12.91

*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 six multivoltine races of the silkworm, *Bombyx mori* in post-monsoon season

Races \ Economic Traits		Weight of 10 V-age larvae (g)	Single cocoon weight (g)	Single shell weight (g)	Shell ratio (%)	Filament length (m)	Adult lifespan (h)
pre	Female	15.32±0.040	0.79±0.02	0.095±0.03	12.02±0.03	355±3.77	174±6.92
	Male	14.52±0.023	0.77±0.01	0.097±0.02	12.59±0.04	350±5.19	136±7.21
npnd	Female	15.26±0.034	0.90±0.011	0.110±0.03	12.19±0.02	361±3.46	180±6.92
	Male	13.98±0.023	0.88±0.01	0.11±0.02	12.46±0.4	281±3.11	148±7.21
C.nichi	Female	17.40±0.0288	0.98±0.01	0.13±0.05	13.25±0.43	395±2.30	192±6.92
	Male	16.14±0.080	0.98±0.02	0.14±0.05	14.27±0.50	403±4.73	162±6.92
Pure Mysore	Female	18.52±0.057	0.99±0.02	0.14±0.01	14.17±1.08	414±3.30	216±6.92
	Male	17.14±0.023	0.97±0.01	0.15±0.02	15.43±1.00	425±2.30	168±6.92
Nistari	Female	20.04±0.023	1.09±0.01	0.15±0.02	14.20±1.03	421±6.73	216±6.92
	Male	18.48±0.046	1.07±0.01	0.17±0.02	15.86±0.90	433.±4.73	168±6.92
Daizo	Female	24.73±0.64	1.16±0.02	0.17±0.02	14.64±0.85	448±4.04	240±6.92
	Male	24.18±0.046	1.14±0.02	0.18±0.01	15.76±0.85	461±3.46	217±6.92
F-value	Female	13.32	180.25	149.05	7.79	1.67	25.93
	Male	15.19	6656.18	149.05	11.28	3.50	1.74
Significant	Female	**	**	**	*	NS	**
	Male	**	**	**	**	NS	NS
CD at 5%	Female	18.82	0.71	0.02	0.02	2.33	16.88
	Male	19.08	0.12	0.02	0.02	2.25	145.62

*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 six multivoltine races in three seasons of the year

Economic traits	Sex	Adult longevity	Weight of larvae	Weight of cocoon	Shell weight	Shell percentage	Season
Weight of the larvae	Female	0.687 **					Pre-monsoon
	Male	0.719 **					
Cocoon weight	Female	0.704 **	0.960**				
	Male	0.760 **	0.933**				
Shell weight	Female	0.710 **	0.952**	0.961**			
	Male	0.629 **	0.816**	0.866**			
Shell percentage	Female	0.560 *	0.825**	0.780**	0.904**		
	Male	0.405 **	0.595 *	0.635 *	0.840**		
Filament Length	Female	0.680**	0.600**	0.693**	0.654**	0.664*	
	Male	0.610**	0.611**	0.687**	0.646**	0.656**	
Weight of the larvae	Female	0.529 **					Monsoon
	Male	0.364 **					
Cocoon weight	Female	0.621 **	0.870**				
	Male	0.710 **	0.809**				
Shell weight	Female	0.710 **	0.874**	0.957**			
	Male	0.772 **	0.884**	0.943**			
Shell percentage	Female	0.659 **	0.707**	0.742**	0.902**		
	Male	0.526*	0.803**	0.773**	0.925**		
Filament Length	Female	0.673**	0.679**	0.662**	0.654**	0.601**	
	Male	0.659**	0.660**	0.656**	0.606**	0.646**	
Weight of the larvae	Female	0.665 **					Post-monsoon
	Male	0.710 **					
Cocoon weight	Female	0.701 **	0.903**				
	Male	0.676 **	0.866**				
Shell weight	Female	0.756 **	0.804**	0.909**			
	Male	0.676 **	0.796**	0.930**			
Shell percentage	Female	0.625 **	0.542 *	0.666 *	0.801**		
	Male	0.551 **	0.611 *	0.750**	0.938**		
Filament Length	Female	0.647**	0.654**	0.625**	0.667**	0.651*	
	Male	0.650**	0.511*	0.459*	0.550**	0.458*	

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

3.1. Relation between weights of the V instar larvae and adult longevity:

From the Table 2-4, it is evident that, during pre-monsoon season the weight of the larvae exhibited significant positive correlation with an 'r' value of 0.887 in females and 0.919 in the males. Similarly, during monsoon season the 'r' values are positive and significant for females (0.929) and males (0.764). Further, during post-monsoon season the 'r' values are 0.865 in females and 0.910 in males which are all significant at 1% level. Based on the 'r' values it is clearly evident that there is an association between weight of V age larvae and adult longevity. The regression of Y and X axis represented in Figures 1-2 clearly indicates the predicted variation (r^2) revealed significant correlation. The predicted function of the two variable recorded for females is Y= 0.145 X - 6.469, where as for males the predicted function is Y=0.167 X- 4.433.

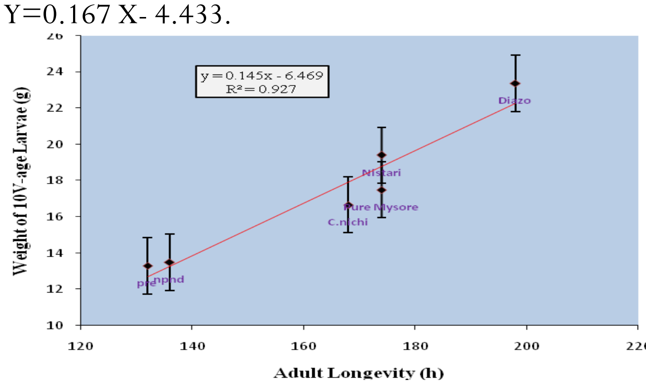

Fig. 1: Longevity v/s Larval weight in six female multivoltine races

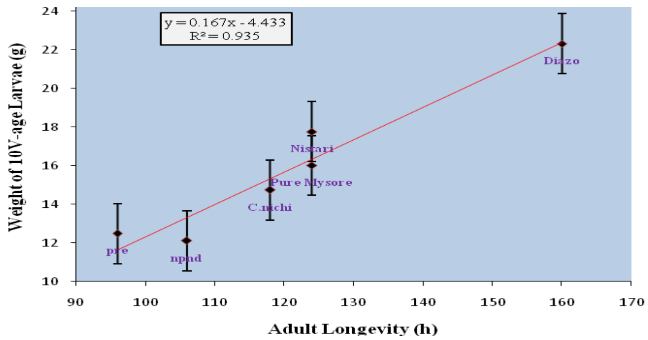

Fig. 2: Longevity v/s Larval weight in six male multivoltine races

3.2. Relation between cocoon weight and longevity:

The data presented in the Table-5, helps us to understand the relationship between the cocoon weight and adult longevity. It is clear that 'r' values between the two traits during pre-monsoon season are 0.964 and 0.960 in the respective females and males and the data is significant at 1% level. During monsoon season, the 'r' values are 0.821 for females and 0.910 for males, which is significant at 1 % level. Similarly, during post-monsoon seasons the 'r' value is 0.961 (P<0.01) in females and in males the 'r' values is 0.847 (P<0.01).

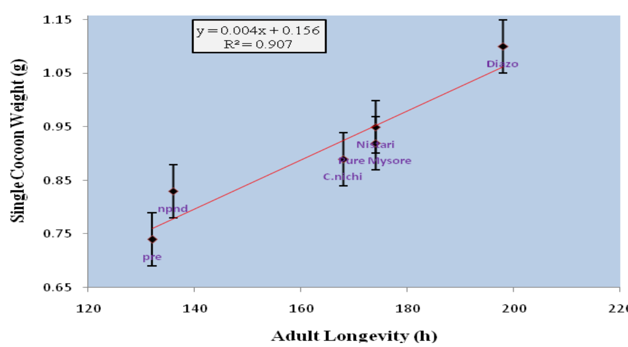

Fig. 3: Longevity v/s single cocoon weight in six female multivoltine races

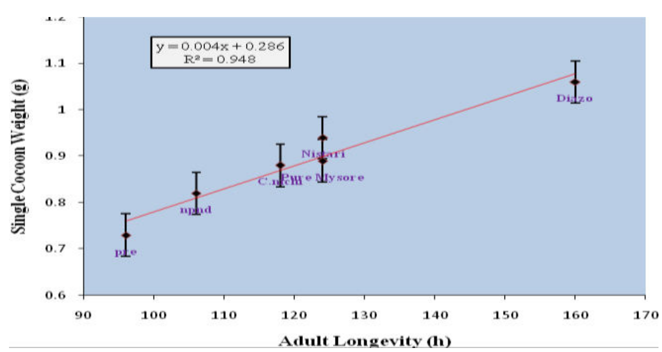

Fig. 4: Longevity v/s single cocoon weight in six male multivoltine races

Based on Figures 3-4 the regression of Y and X-axis recorded regression function as Y = 0.004 X + 0.156 with a slope of predicted line value 0.907 for females and in males the regression function Y = 0.04 X + 0.286 with a slope of prediction line value of 0.948 in males is very clear. Based on the results, it is possible to derive a relation between adult life span and cocoon weight.

3.3. Relation between shell weight and adult longevity:

There is a significant positive correlation between shell weight and adult longevity in all the three seasons. The 'r' value for this trait during pre monsoon is 0.910 in female and it is 0.829 for males which are all statistically significant at 5% level. The 'r' values during monsoon season are 0.910 for females and 0.872 for males. Similarly, during post-monsoon season also significant correlation was observed both in the female (0.956) and males (0.876). Based on the regression of Y and X axis recorded in the graphs 5-6, exhibited a regression function as Y = 0.001 X - 0.043 with a slope of prediction line value is R^2 = 0.870 in females. Similarly, the regression value Y = 0.01 X + 0.015 is clearly evident in the males with a slope of prediction line value of 0.679. Based on the results, it is clear that there is relationship between the adult life span and shell weight.

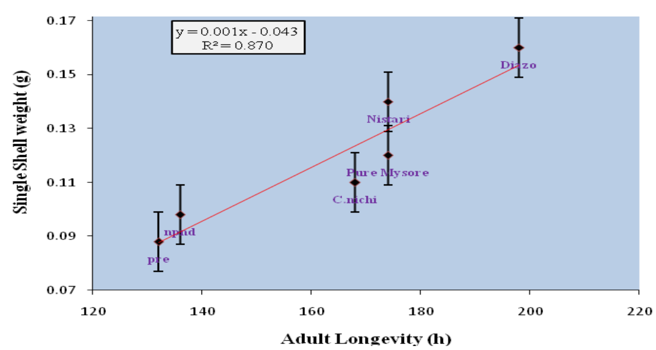

Fig. 5: Longevity v/s single shell weight in six female multivoltine races

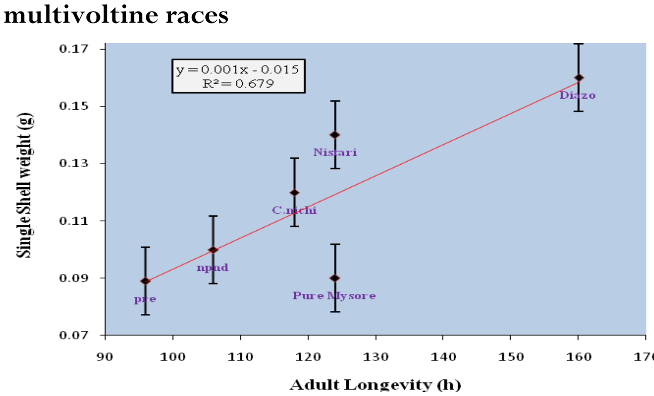

Fig. 6: Longevity v/s single shell weight in six male multivoltine races

3.4. Relation between shell percentage and adult longevity

Perusal of the data (table 2 and figure 7-8) to understand the relationship between the shell percentage and adult longevity, it is clear that 'r' values between the above two traits during pre monsoon season is 0.760 and 0.605, wherein both males and females, the data is significant at 5% level. Similarly, during monsoon season the 'r' value is 0.859 which is significant at 1% level in females ($P<0.01$) where as in males the 'r' value is 0.726 which is significant at 5% level. On the other hand during post monsoon season there is highly significant correlation at 1% level where in the 'r' values are 0.825 and 0.751 for males and females respectively. Based on Figures 55-56 the regression of Y and X axis is recorded regression function as Y=0.41 X +6.350 with a slope of predicted line value of females in males the regression function Y = 0.047 X +7.53 with a slope of prediction line value of 0.660 in females and 0.464 in males.

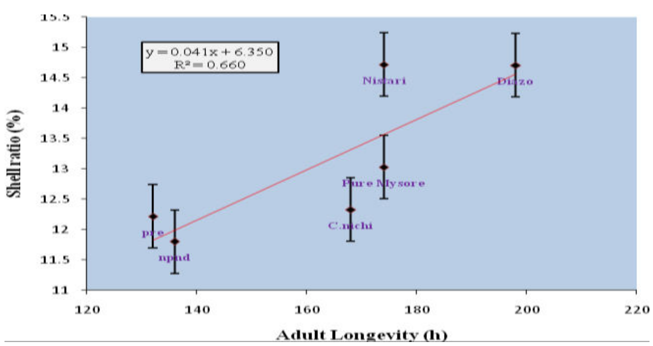

Fig. 7: Longevity v/s shell ratio in six female multivoltine races

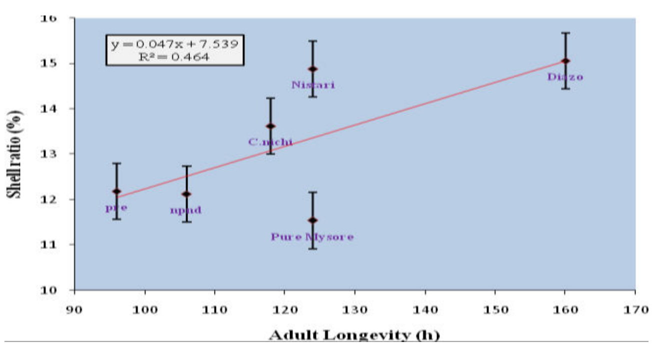

Fig. 8: Longevity v/s shell ratio in six male multivoltine races

3.5. Relation between filament length and adult longevity

The co-efficient correlation (r) between filament length and adult longevity (figure 9-10) exhibited significant positive correlation only for the females with 'r' values of 0.780 during pre monsoon season. However, there is no correlation between these two traits ($P>0.05$) in the males with correlation value of 0.452. A similar, trend was observed in post-monsoon season (females 0.847 which is significant at 5% level and males 0.339 which are non significant at 5% level but the data presented for monsoon season clearly indicated that there is correlation between the above traits irrespective of the sexes. (r=0.773 for females and 0.859 for males which are significant at 1% level). The regression of Y and X-axis recorded as regression function as Y =1.568 X +121.1 with a slope of prediction line value of 0.652 for females. On the other hand, the regression of Y=1.753 X + 153.2 with a prediction value of 0.389.

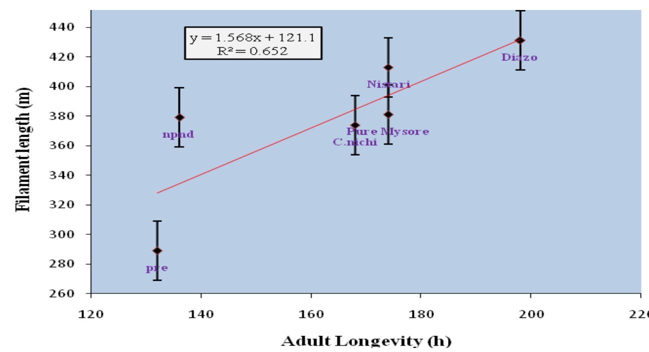

Fig. 9: Longevity v/s Filament length in six female multivoltine races

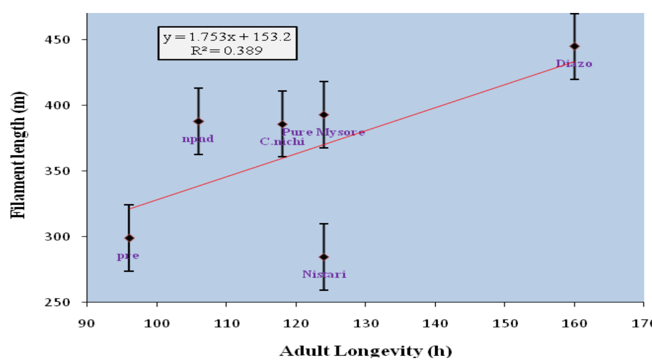

Fig. 10: Longevity v/s Filament length in six male multivoltine races

The silkworm, *Bombyx mori* is one of the important laboratory model systems for various experimental studies. It ranks second next to Drosophila for studies related to basic and applied studies [1,2]. The characters under selection during silkworm breeding are important from the breeders point of view because these traits needs an understanding of their inheritance and their response to selection. White [35] postulated that understanding the nature of genetic system underlying quantitative variability has primaryimportance in the theory of evolution and in the improvement of cultivated plants and animals. Bowman [36] in a monograph proposed that selection for one character leads to changes in other characters. Falconer in [37] explained how correlation plays an important role to understand the selection differential in animal breeding programme and opined that when selection is applied to one character "X" any phenotypically correlated character "Y" will have positive correlation and used the term "correlated" where as for positive correlation used the term "apparent".

In silkworm *Bombyx mori*, all the characters that contribute to the yield of silk are quantitative in nature and are under the control of polygenic system. Any attempt to improve these quantitative traits will have either the correlation for one or two traits or negative correlation with those of other traits. As a result breeders used to compromise with the antagonistic correlation during selection programmes [38]. Many investigations were carried out both in temperate and tropical races to understand the correlation between different characters in mulberry silkworm [39-43, 26, 21, 20]. Similarly, several reports are available on the correlation complexities for quantitative traits in non-mulberry silkworm [44-48, 25, 49, 50]. Similarly, correlation between digestive enzymes and biological parameter has been studied utilising both mulberry and non mulberry silkworms [51-55]. Further, correlation between nutritional parameters in silkworms has been carried out by Ramadevi *et al*. [56], Magdum *et al*. [57], Jayaramaiah and Sannappa [58], Sannappa *et al.,* [59] and Chandrappa *et al*., [60]. The above studies by various authors have shown that the correlations of some characters were found to be positive and in some it was negative for the traits observed during egg, larvae and cocoon traits. The above studies by various authors have shown that the correlations of some characters were found to be positive and in some it was negative for the traits observed during egg, larvae and cocoon traits. Many reports highlighted the correlation between silkworm races and disease resistance/susceptibility. However, a lot of baseline studies are reported on adult longevity and economic traits utilizing temperate races of silkworm *Bombyx mori* [61]. But 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 six multivoltines, four bivoltines and 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 six multivoltine races in 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 & 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 lifespan of females of all the six races were found to be more in all the three seasons may be due to the biochemical paramaeters, that are found to be more in females in all the stages of the life cycle [62] and that may be also due to the nutritional aspects of the mulberry leaves provided during their feeding stage [63].

The present data on the significant difference between the larval weight and adult longevity revealed an 'r' value of 0.887 for females and 0.919 for males which are significant at 1% level. The literature survey pertaining to the correlation of other traits with those of larval weight was reported by [64] who has revealed negative correlation of larval weight with digestive amylase. Similarly, [20] demonstrated the correlation between larval weight and cocoon characters. But, in pioneer experiments [61] demonstrated correlation between longevity and commercial characters in the temperate bivoltine races. The present studies of the author tallies with the results of [61] for larval weight and adult longevity. A similar trend in regard to the correlation of these two traits was also clearly evident from the results of the author during monsoon, post monsoon season. 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.

The data pertaining to the correlation between the three cocoon characters namely, cocoon weight, shell weight and shell percentage in the six multivoltine races in 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. In a detailed experiment utilizing temperate bivoltine races Murakami [65,66] demonstrated that the adult lifespan in silkworm *Bombyx mori* is one of the important biological character in the life history of silkworm *Bombyx mor*i and opined that this particular biological character denoted as "longevity of moths" can be used as a important breeding index in the evolution of races [30,67]. But a detailed investigation utilizing several temperate races in order to understand the relevance (correlation) of lifespan with commercial characters was attempted by Kang *et al*. [61]. The present studies corroborates with the findings of the [61] by exhibiting higher correlation coefficient values in all the three seasons for these traits among six multivoltine races. 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 of 0.399 for larval weight and longevity to a highest of 0.742 for the traits of shell percentage & longevity.

The perusal of literature in regard to the longevity studies and its relevance to the economic characters has also been reported in many of the dipteron insects *viz*., fruit fly, *Drosophilla melanogastor* and house fly *Musca domestica*. Lee *et al*., [68] demonstrated the relevance of longevity with those of fecundity in *Musca domestica*. Similarly, Paukku and Kotiaho [69] demonstrated the effect of mating and its relevance to the longevity in the seed beetles *Calloso bruchus maculatus*. Further, Partridge and Farquhar [70] demonstrated that increasing sexual activity reduces longevity in the male fruit fly *Drosophilla melanogastor*. He has also correlated the longevity with those of the size of the fly. In an interesting experiment Hempel and Wolf [71], demonstrated that there is inverse relationship between foraging strategy and life span in the worker honey bee *Apes meliphera*. But Burger and Promislow [72] reported in *Drosophilla* and mice that the dietary restriction is one of the most successfulways to extend longevity. Contrary to these, Hopkin [73] while experimenting on longevity in many species of live stock animals demonstrated that restricting diet yields animals that are leaner and have increase longevity. The correlation of environmental factors such as larval density, temperature, photoperiod and adult diet with those of adult longevity in Mosquito species *C. quinquefasciatus*, *A. Egyptius* is well documented [74]. In the non-mulberry silkworms, Rajendra Singh and Prasad [43], Ghosh *et al*. [46], Yadav and Goswami [47] 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 [16, 20, 22].

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. For instance the correlation co-efficient values between the above two variables is 0.252 during pre-monsoon season, 0.139 during post-monsoon season in multivoltine races. In a similar correlation studies [61], 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. Among the multivoltine races (Fig. 1) the three groups can be identified in relation to the economic characters on the Y axis and adult longevity on the X axis. It is clear from the graphical representation that *pre* and *npnd* falls in to first group, Nistari, PM, C.nichi are grouped in the second category. Whereas, Daizo is categorized under the third group. Though, there is exists relationship between the two variable the economic characters have clearly indicated that lower the adult life span the lesser will be the economic traits and longer the life span the higher will be the economic traits. The linear Pearson correlation line drawn from Figures 1-10 clearly supports the above findings of the author. However, present study indicates that there are many instances positive correlations could not be drawn between longevity and filament length. So the above results of the author corroborates with the findings of the pioneer works conducted utilizing temperate races by [61]. 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 [75]. Though, there is disparity in the results (correlation values) in the races, 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 new silkworm races for commercial exploitation.

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