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Correlation analysis of quantitative traits in different breeds of silkworm, *Bombyx mori* L

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Abstract
The quantitative characters of silkworm, *Bombyx mori* L. Such as larval duration, cocoon weight, cocoon shell weight, survival rate etc., are of utmost importance in sericulture. Mulberry silkworm, *Bombyx mori* L. is the most important insect being used for commercial production of silk in sericulture industry. The study was undertaken to analyze correlation between the yield and some yield contributing characters of twenty breeds of silkworm on the basis of single season rearing performance to study the relationship between yield and different yield contributing characters of silkworm for silk production. Correlation analysis of 10 phenotypic parameters revealed that highly significant and positive correlations were observed among quantitative characters of silkworm. The maximum value of correlation was observed between single cocoon weight with 5th day larva weight (0.864) and minimum value was observed between the silk percentages with single shell weight (0.470).

Keywords: Silkworm, correlation, rearing performances, yield, silk production

Introduction

Globally, 90% of silk is produced from silkworm of the total global output. In India sericulture is practiced predominantly in tropical environmental regions such as Karnataka, Tamil Nadu, Andhra Pradesh, and West Bengal and to a limited extent in the temperate environment of Jammu and Kashmir [1]. The quantitative characters of silkworm, *Bombyx mori* L. such as larval duration, cocoon weight, cocoon shell weight, survival rate etc., are of utmost importance in sericulture. Mulberry silkworm, *Bombyx mori* L. is the most important insect being used for commercial production of silk in sericulture industry. To enhance the productivity and quality of silk fibers, many attempts are being made to improve the silkworm stocks through conventional breeding programmers have contributed substantially by the introduction of improved silkworm breeds [2] and more than 2000 races of silkworm are maintained in the germplasm banks of several countries [3]. In conventional breeding, the parental selection and performance prediction is on the basis of either their performance [4] or performance of the progeny [5].In silkworm breeding, numerous traits are considered for improving them to increase the profit of silk producers and other sections of sericulture industry. Reproductive traits are considered important for egg producers. Yield is the multiplicative end product of many factors which jointly or singly influence it. The selection of the best genotypes depends on a number of characters. Therefore, a clear understanding and knowledge of the association and contribution of various yield components is essential for any selection program aimed at yield improvement. The degree of association or relationship between two variables is measured by the correlation coefficient (r). The correlation coefficient may be positive or negative. Positive correlation indicates that the two variables are varying in the same direction. In other words, if one variable increases, the other variable also increases. In negative correlation, the two variables vary in the opposite direction, i.e., if one variable increases the other decreases. There is very intimate correlation between some of the characters in silkworm and an excellent character may bring down the merit of another character, if not given due consideration at the appropriate developmental stage. Keeping this view the study was undertaken to analyze correlation between the yield and some yield contributing characters of twenty races of silkworm, *Bombyx mori* L. On the basis of rearing performance to study the relationship between yield and different yield contributing characters of silkworm for silk production.

Materials and Methods

The research work was conducted at SKUAST-J on 20 different races of silkworm namely, PO_1, PO_3, SPO, ND_2, ND_3, ND_5, NSP, U-1, U-2, U-3, U-4, U-5, U-6, U-7, U-8, CC_1, CSR_{18}, CSR_{19}, NB_4D_2, and SH_6. The rearing of silkworm was conducted for a good harvest of the quality cocoon crop at the Division of Sericulture Udheywala, SKUAST-J, with standard rearing techniques suggested by [6]. To prevent diseases and to maintain good sanitation, the rearing room and other rearing appliances were disinfected with a 5% formaldehyde solution following [7] procedure. Then the eggs were incubated at 25±1 °C with a humidity 80%± 5% at normal daylight and dark in the night. A black pin-like spot appeared on the egg two days before hatching and on the following day it turned completely blue called body pigmentation of the egg. The eggs at this stage were disinfected with 2% formaldehyde solution for five minutes recommended by [8] and transferred to the rearing house the newly hatched silkworms transferred to the rearing tray with a feather following the brushing technique of [7] Cocoons were harvested after 4 to 5 days of mounting. After that, male and female pupae were segregated and the fresh moths were allowed to mate after emergence. When the egg-laying was completed the females were subjected to microscopic examination. The eggs produced were called disease free layings (dfls) and they were utilized for experiment. After the formation and maturation of cocoons, data of different characters were collected intensively wherever necessary.

Collection of data

The quantitative characters for commercial production performance viz. fecundity, hatching percentage, larval weight of 10 mature larvae, duration of the fifth instar (days), total larval duration (days), malformed cocoon percentage, pupation rate percentage, single cocoon weight, single shell weight, and shell ratio percentage were recorded and evaluated.

Fecundity

It is the total number of eggs laid by a single mother moth and was calculated by counting the total number of eggs laid by the female moth. Average of three layings in each replicate was recorded for analysis.

Hatching percentage

It is the number of larvae hatched out from the total eggs laid by a mother moth and was recorded as an average of three layings in each replicate and was calculated by the following formula:

$$\frac{\text{Number of eggs hatched}}{\text{Total number of eggs per laying}} \times 100$$

Total larval duration (days and hours)

It was recorded as an average of total larval span in days and hours from brushing to pre- spinning stage including moulting period in each instar.

Weight of 10 mature larvae (g)

Ten mature larvae were picked randomly from each replicate of each breed from 4th to 6th day of fifth instar and weighted on digital balance. Maximum larval weight was recorded in each breed.

Pupation percentage

This parameter represents the average number of live pupae obtained and is represented in percentage. It was calculated by using the following formula:

$$\frac{\text{Number of live pupa in cocoons harvested}}{\text{Total number of larvae retained after IIImoult}} \text{X100}$$

Malformed cocoon percentage

a) Double cocoon percentage

This represented an average number of double cocoons sorted out in each replicate and was determined by using the following formula:

$$\frac{\text{Number of double cocoons harvested}}{\text{Total number of larvae retained after IIImoult}} \text{X100}$$

b) Flimsy cocoon percentage

This parameter was worked out as average number counted in each replicate and was computed by using the following formula:

$$\frac{\text{Number of flimsy cocoons harvested}}{\text{Total number of larvae retained after III moult}} \text{X100}$$

c) Dead cocoon percentage

This was calculated as an average number of cocoons with dead pupae obtained in each replicate and was determined by using the following formula:

$$\frac{\text{Number of dead cocoons harvested with dead pupae}}{\text{Total number of larvae retained after III moult}} \text{X100}$$

Single cocoon weight (g)

Twenty five male and twenty five female cocoons were randomly selected and weighed on digital balance to determine the average cocoon weight by using the following formula:

$$\frac{\text{Weight of 25 male + 25 female cocoons}}{50} \text{X100}$$

Single shell weight (g)

Same twenty five male and twenty five female cocoon shells from each replicate were weighed on digital balance to determine average single shell weight. The formula applied was as under:

$$\frac{\text{Weight of 25 male + 25 female cocoons}}{50} \text{X100}$$

Shell ratio percentage

It was calculated as an average of twenty five male and twenty five female cocoon shells to that of average cocoon weight of same cocoons per replicate and was calculated by using the following formula

$$\frac{\text{Average weight of 25 cocoon shells of each sex}}{\text{Average weight of same cocoons of each sex}} \text{X100}$$

Data Analysis

The collected data were analyzed successfully by following statistical technique:

1. The average mean value and standard deviation were calculated separately for each character.
2. The coefficient of correlation of each character with yield was computed separately and were performed using following formulae:

$$r = \frac{\sum xy - \frac{\sum x . \sum y}{n}}{\sqrt{\sum x^2 - \frac{(\sum x)^2}{n}} . \sqrt{\sum y^2 - \frac{(\sum y)^2}{n}}}$$

Where, in this formula, N is equal to the number of pairs of scores and ∑xy is called the sum of the cross.

Results and discussion

The degree of association or relationship between two variables is measured by a correlation coefficient. The correlation coefficient can be positive or negative. Positive correlation indicates that the two variables are varying in the same direction. In silkworm, there are very intimate correlations between some of the characters and an excellent character sometimes brings down the merit of other correlated character. Correlation coefficient provides the estimates of the degree of association between two or more traits. In *Bombyx mori* L. Although the yield is the trait of prime importance, association of other economic traits of value also helps in improving the efficiency of selection.

The egg laying potential of *Bombyx mori* L. Has been noticed to be a heritable character expressed within the genotypic limitations and the results revealed maximum fecundity in breed CSR_{19} followed by UDHEY-3. The superior fecundity indicates their genetic constitution. Hatching percentage is an important component reflecting variability of the eggs and higher hatching percentage in breed SPO indicates the genetic and physiological state of the female moth. The results fall in line with the results of earlier workers [9, 10]. Larval duration is an important attribute of economic value and shorter larval duration minimizes the quantum of total food consumption and labour requirement. In the present study, the total larval duration was longer in higher matric trait breeds in comparison to UDHEY breeds. The results are in accordance with [9, 10]. Rate of development depends on both genetic and environmental factors [11]. Larval weight is one of the important parameters which determine not only the health of the larvae but also the quality of cocoons spun. Non-significant variation in larval weight of studied breeds was recorded. The present findings confirm the observation made by [12]. Cocoon weight, shell ratio and filament length are highly heritable traits determining the quality, quantity and efficiency of the reeling. The observations made for five important parameters of the cocoon stage revealed significant variations among breeds. Breeds; higher cocoon weight was recorded in breeds UDHEY-3, ND3, and PO3 indicating a clear difference in maximum nutrient utilization by the breeds in 5^{th} instar. The present findings are in agreement with [12]. Present findings are also in conformity with the report of [13].Who concluded that environmental factors influence the physiology of the insect and also have a deleterious effect on the economic traits. Cocoon shell weight is an important character in determining the silk content. Present study results are in conformity with the findings of [14] and [15] who have reported that cocoon shell weight shows variability under varying environmental conditions. The variations in the present finding in the shell weight and silk percent may also be due to racial character. Highly significant and positive correlations were recorded between single cocoon weight and 5^{th} day larva weight (0.864) followed by single shell weight and 5^{th} day larval weight (0.816), single shell weight and single cocoon weight (0.775), malformed cocoon and 5^{th} instar duration (0.730), single shell weight and pupation rate (0.624), total larval duration and 5^{th} instar duration (0.559), single cocoon weight and hatching percentage (0.551), larval weight 5^{th} day and hatching percentage (0.545), single cocoon weight and pupation rate (0.536), pupation rate and larval weight 5^{th} day (0.524), single shell weight and hatching percentage (0492) and silk percent and single shell weight (0.470). These findings are in accordance with the results of [16, 17, 18].

Table 1: Mean Performance of bivoltine silkworm breeds for egg, larval and cocoon traits

Breeds	Fecundity (no.)	Hatching percentage	Larva weight 5th day (g)	5th instar duration (days)	Total larval duration (days)	Malformed cocoon (%)	Pupation rate (%)	Single cocoon weight (g)	Single shell weight (g)	Silk percent
PO_1	554	91.58	3.7	7.00	27.00	3.98	84	1.707	0.350	20.50
PO_3	497	90.30	3.7	6.00	27.00	3.52	87	1.725	0.360	20.86
SPO	531	96.28	3.6	6.00	27.00	3.01	88	1.674	0.350	20.90
ND_2	515	89.90	3.7	7.00	27.00	3.16	88	1.718	0.350	20.37
ND_3	561	90.32	3.7	7.00	27.00	3.33	90	1.726	0.360	20.85
ND_5	552	91.50	3.6	7.00	27.00	3.24	92	1.686	0.360	21.35
NSP	545	89.73	3.6	7.00	29.00	3.03	90	1.628	0.340	20.88
U-1	574	88.72	3.4	6.00	26.00	2.76	86	1.450	0.300	20.68
U-2	511	94.88	3.5	6.00	26.00	2.92	84	1.575	0.325	20.63
U-3	574	91.70	3.7	6.00	26.00	2.78	88	1.800	0.350	19.44
U-4	535	85.49	3.5	6.00	26.00	2.88	85	1.522	0.320	21.02
U-5	494	91.47	3.6	6.00	27.00	2.24	84	1.632	0.330	20.22
U-6	522	84.59	3.4	6.00	26.00	2.20	82	1.425	0.310	21.75
U-7	511	89.36	3.5	6.00	27.00	2.94	89	1.590	0.341	21.44
U-8	507	87.33	3.5	6.00	27.00	2.70	88	1.570	0.302	19.23
CC_1	503	86.79	3.4	7.00	26.00	3.71	85	1.563	0.340	21.75
CSR_{18}	567	90.11	3.6	7.00	28.00	3.46	86	1.620	0.340	20.98
CSR_{19}	639	94.11	3.6	7.00	28.00	3.61	87	1.614	0.330	20.44

NB_4D_2	476	87.27	3.4	7.00	28.00	3.55	82	1.506	0.290	19.25
SH_6	550	88.15	3.4	7.00	27.00	3.79	84	1.639	0.300	18.30
MEAN	535.9	89.97	3.55	6.50	26.95	3.14	86.45	1.618	0.332	20.54
SD	37.46	2.99	0.11	0.51	0.82	0.49	2.72	0.09	0.02	0.89

Table 2: Correlation analysis on morphological traits

Character	**Fecundity**	**Hatching**	**5^{th} day larva weight**	**V^{th} instar Duration**	**Total larval duration**	**Malformed cocoon**	**Pupation rate**	**Single cocoon weight**	**Single shell weight**	**Silk percent**
Fecundity										
Hatching	0.326									
5^{th} day larva weight	0.258	0.545*								
V^{th} instar Duration	0.282	-0.011	0.134							
Total larval duration	0.151	0.187	0.253	0.559*						
Malformed cocoon	0.221	0.135	0.149	0.730*	0.337					
Pupation rate	0.303	0.326	0.524*	0.132	0.268	0.017				
Single cocoon weight	0.193	0.551*	0.864*	0.235	0.184	0.336	0.536*			
Single shell weight	0.160	0.492*	0.816*	0.167	0.079	0.212	0.624*	0.775*		
Silk percent	-0.009	-0.018	0.058	-0.086	-0.165	-0.160	0.208	-0.193	0.470*	

* Correlation significant at $p < 0.01$ level

Conclusion

The positive and significant correlation was observed among quantitative characters and suggest a mechanistic basis for phenotypic association between traits. In the present study, total larval duration, single cocoon weight, single shell weight, pupation rate and silk percentage exhibited a significant positive correlation with weight of mature larvae. Hence, these are the core characters determining economic end product (the yield). These traits also revealed a strong phenotypic association with one another. Hence, simultaneous selection of these traits would help in increasing the efficiency of selection while evolving high yielding breeds.

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