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Selection of Breeding Resource Materials of *Bombyx mori* L. for the Development of Bivoltine Hybrids Suitable for West Bengal

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Abstract:
The bulk of silk produced in India is from Multivoltines which are of inferior quality. Therefore, it is highly pertinent to have more productive bivoltine silkworm breeds capable of producing quality silk. However, the hot climatic conditions of India is not conducive to rear productive bivoltines. It is a well established fact that the bivoltines are highly vulnerable to high temperature coupled with high and low humidity especially in the late instars. The hot climatic conditions of tropics prevailing particularly in summer are contributing to the poor performance of the bivoltine breeds and the most important aspect is that many quantitative characters such as viability and cocoon traits decline sharply when temperature is high. Therefore, it is highly pertinent to identify more number of bivotine breeds which can withstand adverse climatic conditions. Accordingly, the present study was carried out to select suitable bivoltine breeds to be used as breeding resource materials for the development of bivoltine silkworm hybrids suitable to West Bengal conditions of India.

Keywords: *Bombyx mori* L, bivoltine, breeding resource materials, climatic conditions, selection

1.0 Introduction:
Breeding is defined as the over all improvement of a domesticated animal or plant for maximum exploitation of its genetic resources with reference to or in relation to the climatic zone and geographic area where it is reared. Silkworm is one of the most genetically exploited animal, since its domestication during 'Han Dynasty' in China about 5000 years ago. Silkworm is one of the few organisms wherein the principles of genetics and breeding were applied to harvest maximum output. It is next only to maize in exploiting the principles of heterosis and hybrid vigour.

The success of sericulture industry depends upon several factors of which the impact of the environmental factors such as biotic and abiotic factors is of vital importance. Among the abiotic factors, temperature plays a major role on growth and productivity of silkworm, as it is a poikilothermic (cold blooded) insect (Benchamin and Jolly,1986). It is also known that the late age silkworms prefer relatively lower temperature than young age and fluctuation of temperature during different stages of larval development was found to be more favourable for growth and development of larvae than constant temperature. There is ample literature stating that good quality cocoons are produced within a temperature range of 22-27°C and above these levels makes the cocoon quality poorer (Krishnaswami *et al*., 1973).

Selection of appropriate breeding resource materials for any improvement programme is very essential but not a simple one. The desirable level of success depends on the selection of initial breeding resource materials, their effective utilization in different combinations to the genetic expression of the character under consideration (Mano, 1992). All animal improvement programmes aims at a derivation of better constellation of gene complex which suits to express good phonotypic values on a wide range of traits by amalgamating distinct and different gene pools. It is a well known fact that no breeder can expect a readymade supply of information on distinctness or the magnitude of difference existing amongst one another in a group of breeding resource materials available to him. Therefore, it is imperative to a breeder to identify distinct and different gene pools existing in a group of resource materials.

The success of breeding depends on the initial selection of parents, their judicious utilization in appropriate and desirable combinations and choice of mating systems to generate ample genetic variability for facilitating enough scope for selection. The genetic worth of the initial parents to be utilized in the breeding programme allows the breeder to critically analyze the most suitable and effective genoptype before choosing as a breeding resource material. Therefore, it is of paramount importance that utmost care has to be taken by the breeder in verifying and analyzing the genetic worth of the initial parents to be utilized as potential resource material by employing various selection methods (Suresh Kumar *et al.,* 2006; Lakshmi and Chandrashekariah, 2007 and Harjeet Singh and Suresh Kumar, 2008).

The understanding of the genetic endowment of the parents to be utilized in the breeding programme permits the breeder to critically analyse the most effective genotypes before choosing as a resource material. It is well known that most of the characters of economic importance in silkworm are quantitative in nature, phenotypic expression of which is greatly influenced by the environmental factors such as temperature, relative humidity, light and nutrition. It is essential to measure the degree of phenotypic manifestation for the characters of economic importance under both similar and variable environmental conditions in order to understand the genetic endowment pertaining to adaptability and productivity of the breeding material. Generally, such information is often not available to the breeder who is handicapped in selecting the initial parents from the local races without evaluation. As a result, they were able to fix certain gene blocks rapidly with correlated response in the adverse direction in many cases. Therefore, the problem of balancing and fixing the desirable traits for local environments is a challenge for the breeder (Nirmal Kumar and Yamamoto, 1994). Further, the breeder has to understand the range of reaction of the selected genotypes under variable environmental conditions in order to utilize them appropriately in the breeding programme (Nirmal Kumar and Sreerama Reddy, 1998).

Breeding programmes aimed at breed improvement have generally relied on the use of established breeds or elite lines. The goal of breeding is to bring together the desirable constellations of genes in appropriate combinations in order to improve the genetic performance for maximising the yield and productivity per unit of population. Many silkworm breeders (Nirmal Kumar and Sreerama Reddy, 1988; Kogure, 1993) emphasized the need for better understanding the genetic diversity of parental strains to be utilized in the breeding programme by systematic evaluation. Critical assessment of quantitative nature that is influenced by environmental factors paves the way for breeder for their effective utilization. The significant variations observed in the phenotypic manifestation for the traits analyzed among the breeds can be attributed to the genetic constitution of strains and their degree of expression to which they are exposed. Since, the genetic improvement of multiple traits being the objective of evolving the productive bivoltine hybrids suitable for tropical climate, many breeders (Naseema Begum *et al.* 2001; Ramesh Babu *et al.* 2001 and Sudhakar Rao *et al*. 2001; Lakshmi and Chandrashekariah, 2008) followed specific methods to identify the suitable breeding resource materials. Therefore, it is imperative to a breeder to identify distinct and different gene pools existing in a group of resource materials.

The effect of temperature higher than 30°C on silkworm larvae was reported earlier by Takeuchi *et al.,* 1964 and Ohi and Yamashita, 1977. Huang *et al.* 1979 and He and Oshiki, 1984 used survival rate of silkworm as a main characteristic for evaluating thermo-tolerance. The poor performance of bivoltines in summer is due to hot climatic conditions and as a result many quantitative characters such as survival and cocoon traits decline sharply when temperature is higher than 28°C (Shibukawa,1964). The continued efforts for the improvement of cocoon characters of domesticated silkworm were aimed at increased quality silk production. The main objective of silkworm rearing is to produce qualitatively and quantitatively superior cocoons, which in turn will have a direct bearing on the raw silk production. Therefore, it becomes imperative or essential to develop bivoltine breeds/hybrids which can with stand high temperature stress conditions. Sericulture, the viable agro-based industry aptly matches the socio-economic backdrop of rural India. One of the main aims of the breeders is to recommend silkworm breeds/hybrids to farmers that are stable under different environmental conditions and minimize the risk of falling below a certain yield level. Silkworm breeds that are reared over a series of environment exhibiting less variation are considered stable. The climatic conditions prevailing in the tropics are most unpredictable and the problems of tropical sericulture are occurrence of aggravated silkworm diseases, unsuitable mulberry leaf for bivoltine silkworms and lack of sustainable silkworm breeds for effective selection of desirable characters. In order to introduce bivoltine races in a tropical country like India, it is necessary to have stability in cocoon crop under high temperature environment. The pre-requisite of summer breeds is healthiness and adaptability to adverse conditions of high temperature, low food quality, relatively higher economic traits, with potential for increased cocoon production.

In fact, Genotype environment interactions are of major importance to the silkworm breeders while developing new breeds. The concept of genotype and environment interactions has been well documented in both plants and animal species (Griffing and Zsiros, 1971). Although, it is not necessary to breed a genotype that is adapted to all ecological conditions, breeding methods can be designed towards producing a high yielding one with a considerable degree of general adaptability (Eberhart and Russel, 1966). Further, the methods of management practices, effective disease control through sanitation and raising suitable mulberry leaf under diversified environmental factors prevailing in the tropics plays an important role in the expression of quantitative traits of the silkworm (Benchamin *et al.,* 1983) . Summer breeds are having significant importance in increasing cocoon production through rearing bivoltine hybrids round the year in tropical areas. The advantages of summer hybrids are high pupation rate, adaptabilities to high temperature coupled with high and low humidity and inferior food quality during the rearing. Stable cocoon crop under the bad conditions of high temperature with low quality mulberry leaves are difficult, but summer breeds/hybrids should have the potentiality for increasing production under such un-favourable weather conditions. In West Bengal, rearing of bivoltines are very difficult due to highly fluctuating and variable climatic conditions. Therefore, it is highly pertinent to develop robust bivoltine breeds which can withstand the climatic conditions of West Bengal. Keeping this in view, this study has been undertaken to evaluate bivoltine breeds under West Bengal conditions to identify suitable breeding resource materials for the development of robust bivoltine breeds/hybrids .

2.0 Materials and Methods:

The main objective of the study was to select suitable breeding resource materials to develop bioltine hybrids for varying and fluctuating climatic conditions of West Bengal. Considerable variation exists among the bivoltine silkworm breeds at different rearing conditions, which opens an avenue for selection of suitable bivoltine breeds for tropical conditions of West Bengal.

2.1 Materials:

The following breeds were screened under high temperature conditions to select suitable breeding resource materials.

1) CSR2, 2) CSR4 , 3) CSR6, 4) CSR18, 5) CSR19, 6) CSR26, 7) CSR46, 8) CSR47) 9) Gen3, 10) BHR2, 11) BHR3, 12) SK3, 13) SK4, 14) SK4C, 15) D6PN 16) SK6, 17) SK7, 18) KSO1,19) SP2 20) NP2, 21) Dun6, 22) Dun21, 23) Dun22, 24) ATR16 , 25) ATR29 and 26) NB4D2

2.2 Methods:

Silkworm rearing was conducted following the standard method under natural conditions and also at recommended temperature and humidity conditions (Fig.1). Plastic collapsible mountages were used for mounting the ripened larvae. After 48 hours of mounting, when the larvae formed hammock, the mountages were turned upside down. Cocoon harvesting was carried out on the 7th day of spinning. The cocoons were deflossed and the defective ones were sorted out. Assessment was carried out on the subsequent day. The survival rate was calculated as the number of live pupae to the number of larvae treated.

Fig.1 Rearing of silkworm

2.3 Parameters studied:

Various quantitative traits such as fecundity, yield/10000 larvae by number, yield/10000 larvae by weight, cocoon weight, cocoon shell weight and cocoon shell percentage were calculated.

3.0 Results and Discussion:

The performance of the bivoltine breeds under optimal temperature (25 ±1°C) and humidity (70 ± 5 %) conditions is presented in Table 1. The fecundity of the 25 breeds considered for the study at 25 ±1°C and 70 ± 5 % RH ranged from 510 to 610 with the lowest of 510 recorded for

CSR19 and the highest of 610 recorded for CSR2. The yield/10,000 larvae by number at 25 ±1°C and 70 ± 5 % RH ranged from 8563 to 9154 with the lowest of 8563 recorded for CSR4 and the highest of 9154 recorded for SK6. The yied/10,000 larvae by weight at 25 ±1°C and 70 ± 5 % RH ranged from 13.390 to 15.798 kg with the lowest of 13.390 kg recorded for NB4D2 and the highest of 15.798 kg recorded for Dun6. The cocoon weight at 25 ±1°C and 70 ± 5 % RH ranged from 1.512 to 1.765 g with the lowest of 1.512 g recorded for CSR19 and the highest of 1.765 g recorded for CSR2. The cocoon shell weight at 25 ±1°C and 70 ± 5 % RH ranged from 0.311 to 0.432 g with the lowest of 0.311 g recorded for BHR3 and the highest of 0.432 g recorded for CSR2. The cocoon shell percentage at 25 ±1°C and 70 ± 5 % RH ranged from 20.4 to 24.5 % with the lowest of 20.4 % recorded for BHR3 and the highest of 24.5% recorded for CSR2.

The performance of the bivoltine breeds under normal temperature (32 ±1°C) and humidity (85 ±5 %) conditions is presented in Table 2. The fecundity of the 25 breeds considered for the study at 32 ±1°C and 85 ± 5 % RH ranged from 387 to 530 with the lowest of 387 recorded for Dun6 and the highest of 530 recorded for NP2. The yield/10,000 larvae by number at 32 ±1°C and 85 ± 5 % RH ranged from 0 to 9187 with the lowest of 0 recorded for CSR2, CSR4, CSR6, CSR26, CSR18, CSR19, CSR46 and CSR47 and the highest of 9187 recorded for SK4C. The yied/10,000 larvae by weight at 32 ±1°C and 85 ± 5 % RH ranged from 0 to 14.230 kg with the lowest of 0 kg recorded for CSR2, CSR4, CSR6, CSR26, CSR18, CSR19, CSR46 and CSR47 and the highest of 14.230 kg recorded for D6PN. The cocoon weight at 32 ±1°C and 85 ± 5 % RH ranged from 0 to 1.547 g with the lowest of 0 g recorded for CSR2, CSR4, CSR6, CSR26, CSR18, CSR19, CSR46 and CSR47 and the highest of 1.557 g recorded for SK7. The cocoon shell weight at 32 ±1°C and 85 ± 5 % RH ranged from 0 to 0.320 g with the lowest of 0 g recorded for CSR2, CSR4, CSR6, CSR26, CSR18, CSR19, CSR46 and CSR47 and the highest of 0.320 g recorded for SK7. The cocoon shell percentage at 32 ±1°C and 85 ± 5 % RH ranged from 0 to 23.9 % with the lowest of 0 % recorded for CSR2, CSR4, CSR6, CSR26, CSR18, CSR19, CSR46 and CSR47 and the highest of 23.9% recorded for Dun6.

Table 1: Performance of bivoltine breeds under optimal temperature (25 ±1°c) and humidity (70 ±5 %) conditions

Sl. No.	Breed	Fecundity	Yield/10000 larvae		Cocoon weight	Cocoon Shell weight	Cocoon Shell Percentage
			By No.	By Wt			
1	CSR2	610	8956	15.785	1.765	0.432	24.5
2	CSR4	542	8563	13.859	1.627	0.366	22.5
3	CSR6	524	8758	13.885	1.589	0.356	22.4
4	CSR26	516	8843	13.857	1.574	0.357	22.7
5	CSR18	508	9012	13.725	1.523	0.332	21.8
6	CSR19	510	8958	13.544	1.512	0.321	21.2
7	CSR46	527	9008	14.285	1.589	0.362	22.8
8	CSR47	536	8755	14.112	1.612	0.356	22.1
9	BHR2	535	9023	13.910	1.542	0.321	20.8
10	BHR3	545	9043	13.780	1.525	0.311	20.4
11	SK3	524	8956	13.810	1.543	0.316	20.5
12	SK4	521	9012	13.925	1.546	0.320	20.7
13	SK4C	532	9016	13.942	1.547	0.322	20.8
14	SK6	554	9154	13.950	1.525	0.318	20.9
15	SK7	543	9136	14.905	1.543	0.319	20.7
16	D6PN	538	9053	13.992	1.546	0.322	20.8
17	KSO1	546	9034	13.935	1.543	0.335	21.7
18	NP2	523	8987	14.065	1.565	0.335	21.4
19	SP2	528	9087	14.012	1.542	0.327	21.2
20	Dun6	568	8956	15.798	1.764	0.427	24.2
21	Dun21	576	9012	15.220	1.689	0.410	24.3
22	Dun22	565	8965	15.014	1.675	0.404	24.1
23	ATR16	548	9015	14.126	1.567	0.368	23.5
24	ATR29	554	9065	14.255	1.573	0.373	23.7
25	NB4D2	528	8865	13.490	1.522	0.327	21.5

3.1 Evaluation Index:

The evaluation index values obtained for the breeds under 25±1°C and 70±5 % RH conditions are presented in the Table 3. The index value for fecundity ranged from 36 to 81 with the lowest of 36 recorded for CSR18 and CSR19 and the highest of 81 recorded for CSR2. The index value for yield/10000 larvae by number ranged from 18 to 65 with lowest of 18 recorded fro CSR4 and the highest of 65 recorded for SK6. The index value for yield/10000 larvae by weight ranged from 38 to 76 with the lowest of 38 recorded for NB4D2 and the highest of 76 recorded for CSR2 and Dun6. The index value for cocoon weight ranged from 40 to 76 and the lowest of 40 recorded for CSR19 and the highest of 76 recorded for CSR2 and Dun6. The index value for cocoon shell weight ranged from 39 to 73 with the lowest of 39 recorded for BHR3 and the highest of 73 recorded for CSR2. The index value for cocoon shell percentage ranged from 37 to 69 with the lowest of 37 recorded for BHR3 and the highest of 69 recorded for CSR2. The cumulative index values for all the traits ranged from 42 to 71 with the lowest of 42 recorded for CSR19 and the highest of 71 recorded for CSR2.

Table 2: Performance of bivoltine breeds under normal temperature (32 ±1°C) and humidity (85 ±5 %) conditions

Sl. No.	Breed	Fecundity	Yield/10000 larvae		Cocoon weight	Cocoon Shell weight	Cocoon Shell Percentage
			By No.	By Wt			
1	CSR2	525	0	0	0	0	0
2	CSR4	515	0	0	0	0	0
3	CSR6	485	0	0	0	0	0
4	CSR26	475	0	0	0	0	0
5	CSR18	452	0	0	0	0	0
6	CSR19	425	0	0	0	0	0
7	CSR46	445	0	0	0	0	0
8	CSR47	438	0	0	0	0	0
9	BHR2	430	7970	10.090	1.266	0.210	16.6
10	BHR3	517	7430	9.400	1.266	0.259	20.4
11	SK3	512	7568	10.568	1.265	0.257	20.3
12	SK4	480	7687	11.258	1.289	0.265	20.6
13	SK4C	417	9187	12.580	1.273	0.221	17.4
14	SK6	496	9020	13.030	1.445	0.295	20.4
15	SK7	415	8970	13.880	1.547	0.320	20.7
16	D6PN	455	9085	14.230	1.465	0.276	18.9
17	KSO1	431	8640	8.450	1.317	0.262	20.0
18	NP2	530	1260	1.400	1.096	0.206	18.8
19	SP2	486	1000	1.180	1.164	0.211	18.1
20	Dun6	387	8370	10.700	1.278	0.306	23.9
21	Dun21	404	7790	10.520	1.351	0.311	23.0
22	Dun22	414	7910	10.590	1.340	0.308	22.9
23	ATR16	410	9020	13.120	1.365	0.275	20.5
24	ATR29	499	9012	12.730	1.341	0.272	20.3
25	NB4D2	397	8420	10.930	1.297	0.248	19.2

The evaluation index values obtained for the breeds under 32±1°C and 85±5 % RH conditions are presented in the Table 4. The index value for fecundity ranged from 34 to 66 with the lowest of 34 recorded for Dun6 and the highest of 66 recorded for NP2. The index value for yield/10000 larvae by number ranged from 38 to 60 with lowest of 38 recorded for CSR2, CSR4, CSR6, CSR26, CSR18, CSR19, CSR46 and CSR47 and the highest of 60 recorded for SK4C and D6PN. The index value for yield/10000 larvae by weight ranged from 38 to 63 with the lowest of 38 recorded for CSR2, CSR4, CSR6, CSR26, CSR18, CSR19, CSR46 and CSR47 and the highest of 63 recorded for D6PN. The index value for cocoon weight ranged from 36 to 60 and the lowest of 36 recorded for CSR2, CSR4, CSR6, CSR26, CSR18, CSR19, CSR46 and CSR47 and the highest of 60 recorded for SK7. The index value for cocoon shell weight ranged from 36 to 61 with the lowest of 36 recorded for CSR2, CSR4, CSR6, CSR26, CSR18, CSR19, CSR46 and CSR47 and the highest of 61 recorded for SK7. The index value for cocoon shell percentage ranged from 36 to 61 with the lowest of 36 recorded for CSR2, CSR4, CSR6, CSR26, CSR18, CSR19, CSR46 and CSR47 and the highest of 61 recorded for Dun6. The cumulative index values for all the traits ranged from 38 to 59 with the lowest of 38 recorded for CSR19,CSR46 and CSR47 and the highest of 59 recorded for SK6.

Sericulturally advanced countries like Japan has achieved remarkable progress by executing systematic breeding plans for the development of productive races. In silkworms, studies carried out for various characters have shown that the characters could be changed to suit the breeders choice, since selection for one trait has correlation with genetic change of other characters. The selection of breeding resource material helps the breeder to successfully amalgamate desired traits. Appropriate experimental design, selection methods employed in fixing the major traits contributing to the improved cocoon yield leads to the success of any breeding programme. Besides, understanding the genetic diversity of parental strains to be utilized in the breeding programme by their systematic evaluation, critical assessment of their quantitative nature which is greatly influenced by the environmental factors such as temperature, light, relative humidity, nutrition and rearing techniques which paves the way for the breeder for effective utilization (Kogure, 1933; Legay, 1958; Ueda and Lizuka, 1962; Suzuki *et al.*, 1962; Yokoyama,1963; Arai and Ito, 1967; Horie *et al.*, 1967; Naseema Begum *et al.,* 2001 and Sudhakar Rao *et al.*, 2001.

Table 3: Evaluation index of bivoltine breeds under optimal temperature (25 ±1°c) and humidity (70 ±5 %) conditions

Sl. No.	Breed	Fecundity	Yield/10000 larvae		Cocoon weight	Cocoon Shell weight	Cocoon Shell Percentage	Cumulative Index
			By No.	By Wt				
1	CSR2	81	49	76	76	73	69	71
2	CSR4	51	18	44	56	55	53	46
3	CSR6	43	33	45	51	52	53	46
4	CSR26	39	40	44	49	52	55	47
5	CSR18	36	53	42	42	45	48	44
6	CSR19	36	49	39	40	42	44	42
7	CSR46	44	53	51	51	54	56	51
8	CSR47	48	33	48	54	52	50	48
9	BHR2	48	54	45	44	42	41	46
10	BHR3	52	56	43	42	39	37	45
11	SK3	43	49	44	44	41	38	43
12	SK4	41	53	45	45	42	40	44
13	SK4C	46	54	46	45	42	41	46
14	SK6	56	65	46	42	41	41	48
15	SK7	51	63	61	44	41	40	50
16	D6PN	49	57	47	45	42	41	47
17	KSO1	53	55	46	44	46	47	49
18	NP2	42	51	48	48	46	45	47
19	SP2	45	59	47	44	44	44	47
20	Dun6	63	49	76	76	72	66	67
21	Dun21	66	53	66	65	67	67	64
22	Dun22	61	50	63	63	65	66	61
23	ATR16	54	54	49	48	55	61	53
24	ATR29	56	58	51	49	57	63	55
25	NB4D2	45	42	38	41	44	46	43

According to Allard and Bradshaw, 1964, performance of the strain itself in a given environment indicates its superiority. While evaluation, emphasis was given on the phenotypic expression of traits of economic importance under different temperature conditions. However, as the objective of the study was for greater viability and high productivity merits, equal importance was given on these two traits while selection of parents. The significant variations observed in the phenotypic manifestation for the traits analyzed can be attributed to the genetic constitution of the breeds and their degree of expression to which they are exposed during their rearing. Such variations in the manifestation of phenotypic traits of the breeds studied can be ascribed to the influence of environmental conditions. Variable gene frequencies at different loci make them to respond differently. The results are in line with the findings of (Watanabe,1928; Hassanein and Sharawy, 1962; Krishnaswami and Narasimhanna, 1874; Ueda et al., 1975;Rajanna, 1989;Raju, 1990; Maribashetty, 1991;Kalpana, 1992;Nirmal Kumar,1995; Basavaraja, 1996 and Sudhakar Rao et al., (2001).

It is important to measure the phenotypic expression of the major contributing traits of economic importance in the silkworm strains under diversified environmental conditions to understand the genetic endowment pertaining to adaptability and productivity. The balancing of desirable traits during the course of the breeding for varied climatic conditions is a challenging task for the breeder. The choice of parental material is critical and difficult to evaluate all the available silkworm breeds,. However, a few strains of known genetic background, pedigree and specific traits desirable for the new breeding programme have to be taken into consideration while evaluating the breeding material. It is also equally important to understand the traits related to productivity and viability. All the breeds selected for the evaluation are having one or more desirable traits as per the objectives of the present study.

Table 4: Evaluation index of bivoltine breeds under optimal temperature (32 ±1°c) and humidity (85 ±5 %) conditions

Sl. No.	Breed	Fecundity	Yield/10000 larvae		Cocoon weight	Cocoon Shell weight	Cocoon Shell Percentage	Cumulative Index
			By No.	By Wt				
1	CSR2	65	38	38	36	36	36	41
2	CSR4	63	38	38	36	36	36	41
3	CSR6	56	38	38	36	36	36	40
4	CSR26	54	38	38	36	36	36	40
5	CSR18	49	38	38	36	36	36	39
6	CSR19	43	38	38	36	36	36	38
7	CSR46	47	38	38	36	36	36	38
8	CSR47	46	38	38	36	36	36	38
9	BHR2	44	57	55	56	52	53	53
10	BHR3	63	56	54	56	56	57	57
11	SK3	62	56	56	56	56	57	57
12	SK4	55	56	57	56	57	57	56
13	SK4C	41	60	60	56	53	54	54
14	SK6	59	59	60	59	59	57	59
15	SK7	40	59	62	60	61	57	57
16	D6PN	49	60	63	59	57	55	57
17	KSO1	44	58	53	57	56	57	54
18	NP2	66	41	40	53	52	55	51
19	SP2	56	40	40	54	52	55	50
20	Dun6	34	58	56	56	60	61	54
21	Dun21	38	56	56	57	60	60	55
22	Dun22	40	57	56	57	60	59	55
23	ATR16	39	59	61	57	57	57	55
24	ATR29	59	59	60	57	57	57	58
25	NB4D2	36	58	57	56	55	56	53

In the present study, which envisages to evaluate bivoltine breeds to identify more resistant bivoltines that can give rise to stable cocoon crops with better viability, even though productivity is low compared to the existing productive bivoltine breeds that are currently used in the field. In silkworms, the correlation for some characters is positive and for some it is negative (Gamo and

Ichiba, 1971 and Gamo, 1976) . Such a negative correlation is observed for the traits productivity and viability and hence the attempt made was to increase the viability of the developed breeds. Moreover as suggested by Lekuthai and Butrachand (1974) and Strunnikov and Strunnikov (1986), the selection parameters were primarily aimed at improving the viability character such as yield by number without sacrificing much of the productivity traits like cocoon weight, cocoon shell weight and yield by weight. In addition, during later generations of inbreeding, selection was applied to select desired genotypes to improve the traits of commercial importance like viability and productivity as suggested by Mano (1993 and 1994) to improve the yield of bivoltines.

Thermal acclimatization and stress have been studied during different developmental stages of insects (larvae, pupae and adults) as well as different physiological conditions (Melanby, 1954; Lee *et al.,* 1988) . Surviving a thermal stress depends in part upon the individual organism's stress history. Brief exposure to a mild stress can protect an organism against a normally lethal stress. Brief exposure to a mild temperature than the optimum temperature induces tolerance (Thermo-tolerance) in insects. Once thermo-tolerance has been induced, it may persist for days (Carretero *et al*., 1991; Yocum and Denlinger, 1992). Some stresses will even increase an organism's sensitivity to a future stress. Survival of high temperature stress appears to be energy dependent in insects and the loss should be compensated by nutrition (Haveman and Hahn, 1981; James et al., 1986).

The fluctuations noticed in the pupation rate among the bivoltine breeds considered for this study can be partially attributed to the influence of environmental factors and the interaction of alleles responsible for the expression of the trait. The fecundity is largely dependent on the genotype of mother moth and environmental conditions prevailing at the time of oviposition.. The phenomenon of cocoon yield is correlated to cocoon weight and because of high temperature stresses it was drastically reduced. It was observed that under optimal conditions it reached to maximum and under stress conditions it was minimum. The overall picture shows that cocoon weight was low in the high temperature treated batches when compared to room temperature batches. Generally as the temperature increases, larval weight decreases. High temperature did not favour the productivity and tends to the withering of mulberry leaves which were fed to the silkworms, thereby reducing the feeding quantum. But high temperature accelerates the growth rate leading to poor cocoon quality (Pillai and Krishnaswami, 1980). This may be due to the fact that high temperature will cause leaf withering leading to low rate of ingestion by the silkworm. During this situation the silkworm larvae cannot eat more time on provided leaf and it leads to decline in the cocoon weight (Gangawar *et al.,* 1993). Further, the analysis of variance indicating significant ($P < 0.001$) differences can be attributed to differential selection response. Similarly, cocoon shell weight which was found to exhibit variation during the process of selection indicating interesting results. The cocoon shell weight which was known as moderately heritable (Tsuchiya and Kurashima, 1959; Gamo and Hirabayashi, 1983) showed positive selection response in both the temperature conditions. Application of selection for the trait not only increased the cocoon shell weight but also concomitant increase for most of the productivity traits as suggested by Kobayashi (1962).

With regards to cocoon shell percentage, the results indicated positive selection response. It has been pointed out by many Japanese breeders that the trait is very difficult to increase by selection (Gamo and Hirabayashi, 1983; Mano et al., 1988). However, an attempt made in the present experiment indicates that the response was slow at high temperature and varied response was observed whereas at room temperature, lower values were observed. Thus cocoon shell percentage was significantly improved under optimum conditions than high temperature conditions. These findings are in agreement with Shivakumar *et al.,* (1997). Silkworm breed which are reared over a series of environments exhibiting less variation are considered stable. One of the objectives of the breeder is to recommend stable breeds to the farmers for rearing under different environmental conditions. Effect of high temperature and high humidity in terms of cocoon crop depends on several factors that operate within and outside the body of the silkworm. In the present study, it was observed that apart from the temperature, humidity also influences the productivity pattern in the silkworm and is in agreement with Krishnaswami (1986) and Sudhakar Rao (2003). It was also reported that the cocoon yield/10000 larvae, cocoon weight, cocoon shell weight and cocoon shell percentage were also low in the high temperature treated batches when compared to the batches reared under optimum rearing conditions which corroborates the findings of the present study.

Improvement of breeds necessarily means selection of desirable genes in appropriate combinations, which contribute to the overall genetic worth of the population. With respect to the economic value, the focus should be on all the genes affecting the traits thereby contributing to the viability and productivity. Therefore, selection of breeds emphasizes the need to organize the genetic material in a way that help to improve the manifestation of commercially important traits (Nirmal Kumar, 1995, Lakshmanan and Suresh Kumar 2012a, 2012b, 2012c; Suresh Kumar *et al*., 2012). This can be achieved precisely by adopting a strategy by setting up a common index giving adequate weightage to all the component traits manifested among an array of breeds. The rationale for judging the utility of multiple trait evaluation index in the present study is based on major metric traits, which are considered to be economically important. However, asymmetry is found in most of the traits as evidenced by indices of the individual component traits that the index value obtained individually for each trait can fail but the overall index values help in adjudicating the performance of the breeds. In view of this, all the major traits have been considered together to obtain the aggregate index value, since exclusion of any one trait can result in negative situation.

4.0 Conclusion:

The main objective of the study was to identify potential breeding resource materials which can withstand the adverse, fluctuating and variable climatic conditions of West Bengal and the same to be used for the development of robust bivoltine breeds/hybrids. Accordingly, after screening, potential bivoltine breeds were identified to be used as breeding resource materials for the development of bivoltine breeds which can withstand the adverse climatic conditions of West Bengal.

References:

1) Allard, R.B. and Bradshaw, A.O. (1964) : Implications of genotype environment interaction in applied plant breeding. *Crop.Sci*. **4:** 503-506.
2) Arai and Ito (1967) : Nutrition of the silkworm, *Bombyx mori* L. XVI Quantitative requirements of essential amino acids, *Bull.Seric.Exp.Stn.,* **21:** 373-384.
3) Basavaraja, H.K. (1996) : Studies on the synthesis of productive bivoltine strains of *Bombyx mori* L. through hybridization, selection and genetic evaluation, Ph.D thesis, University of Mysore, Mysore, .
4) Benchamin, K.V. and Jolly, M.S. (1986) : Principles of silkworm rearing. *Proc. of Sem. On problems and prospects of sericulture.* S.Mahalingam (Ed),Vellore, India., 63-106.
5) Benchamin, K.V., Benjamin, D.A.I., Geethadevi, R.G. and Jolly, M.S.(1983) : Further studies on spacing in silkworm rearing with special reference to survival rate and cocoon characters (*B.mori* L.). *Nat.Sem.Silk.Res.Dev*., Bangalore, AB. No.76,
6) Carretero, M.T., Carmona, M.J. and Diez, J, L. (1991) : Thermo-tolerance and heat shock proteins in *Chironomus J.Insect Physiol.,* **37:** 239-246.
7) Eberhart, S.A. and Russel, W.A. (1966) : Stability parameters for comparing varieties. *Crop. Sci.* **6:** 36-40.
8) Gamo, T. and Ichiba, S. (1971) : Selection experiments on the fibroin hydrolyzing ratio in silkworm cocoons and its effects upon the economical characters, *Japan.J.Breed.,* **21(2):** 87-92.
9) Gamo, T.(1976) : Recent concepts and trends in silkworm breeding. *Farming Japan.* **10(6):** 11-22.
10) Gamo, T. and Hirabayashi, T. (1983) : Genetic analysis of growth rate, pupation rate and some quantitative characters by diallel crosses in silkworm, *Bombyx mori* L. *Japan J.Breed.,* **33(2):** 178-190.
11) Gangawar, S.K., Somasundaram, P. and Thangavelu, K. (1993) : Feeding behavior of silkworm, *Bombyx mori* L., *J.Adv.Zool.,* **14(2):** 115-118.
12) Griffing, L.V. and Zsiros, Z. (1971) : Heterosis associated with genotype-environment interactions, *Genetics.* **68:** 443-445.
13) Hassanein, M.H. and Sharawy, M.F.E. (1962) : The effect of feeding the silkworm, *Bombyx mori* L. with different mulberry varieties on the fecundity of moth, *Revue.Du Ver a Soie.,* **14:** 163-170.
14) Haveman, J. and Hahn, G.M. (1981) : The role of energy in hyperthermia induced mammalian cell inactivation: A study of the effects of glucose starvation and uncoupler of oxidative phospholation. *J..Cellular Physiol.,* **107:** 23-241.
15) He, Y. and Oshiki, T. (1984) : Study on cross breeding of a robust silkworm race for summer and autumn rearing at low latitude area in China, *J.Seric.Sci.Jpn.,* **53 :** 320-324.
16) Hirobe, T. (1968) : Evolution, differentiation and breeding of the silkworm-the silk road-past and present, Genetics in Asian countries,

XII International cong. Genetics (Tokyo), 25-26.

17) Horie, Y., Watanabe, K. and Ito, T. (1967) : Nutrition of the silkworm, *Bombyx mori.* XVIII.Quantiitative requirements of potassium, phosphorus, magnesium and Zinc. *Bull.Seric.Exp.Stn.* **22:** 181-193.

18) Huang, P.J., Chen, J.H., Hong, D.H. and Chen, C.N. (1979) : Preliminary study on the inheritance of tolerance to high temperature in some silkworm strains. *J.Agric.Assoc.China,* **105:** 23-39.

19) James. JW (1972) Optimum selection intensity in breeding programmes. *Animal Production*. **14:** 1-9.

20) Kalpana, G.V. (1992) : Breeding of superior races of silkworm, *Bombyx mori* L. for tropical climates, Ph.D Thesis, University of Mysore, Mysore. .288.

21) Kobayashi, E. (1962) : A selection experiment in the progeny of cross between two different strains of the silkworm with special regard to effect of selection of F2, *J.Seric.Sci.Jpn.,* **31(2):** 108-113.

22) Kogure, K. (1933) : The influence of light and temperature on certain characters of silkworm, *Bombyx mori* L., *J.Dept.Agric.Kyushu Univ.,* **4:** 1-93.

23) Krishnaswami, S. (1986) : *Improved methods of rearing young age (chawki) silkworms*, Central Silk Board, reprinted from the Bulletin No.3 of the CSRTI, Mysore 1-24.

24) Krishnaswami, S. and Narasimhanna, M.N. (1974) : Large scale trials of bivoltine hybrids in Mysore state, *Indian J. Genet.Pl. Breed.* **34:** 229-236.

25) Krishanaswami, S., Narasimhanna, M.N., Surayanarayana, S.K. and Kumararaj, S. (1973) : “Manual on sericulture”, Vol 2. Silkworm rearing UN Food and Agriculture Organisation, Rome, 54-88.

26) Lakshmanan, V. and Suresh Kumar N. (2012a) Selection of breeding resource material from bivoltine strains of *Bombyx mori* L *Indian J.Seric*. 51(2): 100-108

27) Lakshmanan, V. and Suresh Kumar N. (2012b) Analysis of heterosis in new double hybrid combinations in bivoltine silkworm, Bombyx mori L. *Int. J.Sci.Nature* **3(1)** : 197-204.

28) Lakshmanan, V. and Suresh Kumar N. (2012c) Evaluation of new bivoltine silkworm hybrids of Bombyx mori L for sub-tropical Int. J.Sci.Nature 3(1) : 129-136.

29) Suresh Kumar, N., Lakshmi, H., Saha, A.K., Bindroo, B.B. and Longkumer, N. (2012) Evaluation of bivoltine silkworm breeds of Bombyx mori L. under West Bengal Conditions. *Univ. J. Env.Res and Tech.,* **2(5) :** 393-401

30) Legay, J.M. (1958) : Recent advances in silkworm nutrition, In: *Ann.Rev.Entomol*. **3:** California, 75-86.

31) Lekuthai, P. and Butrachand, S. (1974) : Improvement of bivoltine silkworm races, *Bull. Thai. Seric. Res. Trai. Cent*., **2:** 48-54.

32) Lian ren Lee, Liao-mini; Hell Chen (1988) : Stability of double cross hybrid combined with current silkworm varieties for spring and early autumn under normal rearing condition. *Acta Serica Sinica*., **14(1):** 42-44.

33) Mano, Y. (1993) : *Observations on silkworm breeding in India, A report*- Submitted to CSB, Bangalore, pp. 1-2,.

34) Mano. Y. (1994) : *A comprehensive report on silkworm breeding* Submitted to CSB, Bangalore, 1-180.

35) Mano, Y., Nishimura, M., Kato, M. and Nagayasu, K. (1988) : Breeding of an autosexing silkworm race, N140 x C145, *Bull.Seric.Expt.Stn*., **30(5):** 753-785.

36) Maribashetty, V.G. (1991) : Evolution of superior bivoltine races of silkworm *Bombyx mori* l for tropics, Ph.D. thesis, University of Mysore, Mysore 234.

37) Melanby, K. (1954) : Acclimatization and the thermal death point in insects. *Nature,* **173:** 582-583.

38) Naseema Begum, A., Basavaraja, H.K., Rekha, M., Ahsan, M.M. and Datta, R.K. (2001) : Identification of breeding resource material for the development of thermo-tolerant breeds in the silkworm, *Bombyx mori* L., *Int.J.Indust.Entomol*., **2(2):** 111-117.

39) Nirmal Kumar, S. (1995) : Studies on the synthesis of appropriate silkworm breed (*Bombyx mori* L) for tropics, Ph.D. thesis, University of Mysore, Mysore 316.

40) Ohi, H. and Yamashita, (1977) : On the breeding of the silkworm races J137 and C137, *Bull.Seric.Exp.Stn.,*. **27:** 97-139,

41) Rajanna, G.S. (1989) : Evolution of suitable bivoltine races of silkworm, *Bombyx mori* L. for tropics. Ph.D Thesis, University of Mysore*,* Mysore 231.

42) Raju, P.J. (1990) : Studies on the hybridization and synthesis of new breeds of silkworm, *Bombyx mori* L., Ph.D. Thesis, University of Mysore, Mysore.

43) Shibukawa , K. (1964) : *Acta Sericologia*, **16:** 1.

44) Shiva Kumar, C., Sekharappa, B.M. and Sarangi, S.K. (1997) : Influence of temperature and leaf quality on the rearing performance of silkworm, *Bombyx mori* L., *Indian J. Seric*. **36(2):** 116-120.

45) Sudhakar Rao, P. (2003) : Studies on the evolution of adaptive bivoltine breeds of silkworm, *Bombyx mori* L for tropical climates, Ph.D Thesis, University of Mysore, Mysore.
46) Sudhakar Rao, P., Singh, R., Kalpana, G.V., Nishitha Naik, V., Basavaraja, H. K . and Ramaswamy, G. N. (2001) : Evaluation and identification of promising bivoltine hybrids of silkworm, *Bombyx mori* L. for tropics, *Int. J. Indust. Entomol*., **3(1):** 31-35.
47) Suzuki, C., Karasawa, T. and Kimura, R. (1962) : Relation between the occurrence of silkworm disease and the three factors, sir current, air composition and temperature, *Nippon Sanshigaku Zashi*, **31:** 134-138.
48) Strunnikov, V.A. and Strunnikov, L.V.(1986) : The nature of genes controlling the silk productivity of silkworm cocoons, *Dokl.Akad. Nauk., USSR*. **290(1):** 234-237.
49) Takeuchi, Y., Kosaka, T. and Ueda, S. (1964) : The effects of rearing temperature upon the amount of food ingested and digested. *Tech. Bull. Seric. Exp. Stn.* . **84:** 1-12.
50) Tazima, Y. (1984) : Silkworm moth, evolution of domesticated animals. Longman, New York, 416-424.
51) Tsuchiya, S. and Kurashima, H. (1959) : Studies on the heritability of measurable characters in *Bombyx mori* (III) Heritability in the hybrids of two different strains, *J. Seric. Sci. Japan*, **27(4):** 253-256.
52) Ueda, S. and Lizuka, H. (1962) : Studies on the effects of rearing temperature affecting the health of silkworm larvae and upon the quality of cocoons-1 Effect of temperature in each instar, *Acta Sericologia Jpn,* **41:** 6-21.
53) Ueda, S., Kimura, R. and Suzuki, K. (1975) :Studies on the growth of the silkworm, *Bombyx mori* L. IV Mutual relationship between the growth in the fifth instar larvae productivity of silk substance and eggs. *Bull.seric. Expt. Stn. Japan*., **26(3):** 233-247.
54) Venugopala Pillai, S. and Krishnaswami, S.(1980) : Effect of high temperature on the survival rate, cocoon quality and fecundity of *Bombyx mori* L., *Proc.Seric.Symp.Sem.,* Tamil Nadu Agricultural University, India, 141-148.
55) Watanabe, K.(1928) : Further studies on the voltinism in the silkworm, *Bombyx mori L Bull.Seric.Exp.Stn.Jpn.*, **7:** 285-303.
56) Yocum, G.D. and Delinger, D. l. (1992) : Prolonged thermo-tolerance in the flesh fly, *Sarcophaga crassipalpis* does not require continuous expression or persistence of the 72 kDa heat shock protein, *J.Insect Physiol.* **38(8):** 603-609.
57) Yokoyama, T. (1963) : Sericulture, *Ann. Rev.Entomol*., **7:** 287-306.