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On the Breeding of Dumbbell Bivoltine Silkworm Breeds of *Bombyx mori* L. Tolerant to High Temperature and High Humidity Conditions of the Tropics

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It is well established fact that under tropical condition, unlike polyvoltines, bivoltines are more vulnerable to various stresses i.e. hot climatic conditions of tropics, poor leaf quality and improper management during summer which are not conducive for bivoltine rearing. Therefore, attempt has been made in this study to develop promising bivoltine breeds tolerant to high temperature and high humidity conditions of the tropics. In the present study, by utilizing temperature tolerant breeds six breeding lines were made and at every generation the 5th instar larvae were exposed to high temperature and high humidity and the survived ones were back crossed with the breeds moderately tolerant to diseases were made to improve the quantitative traits. From F6 generations, alternate rearing in normal temperature and high temperature were conducted. At the end of F12 generation, it was possible to isolate three dumbbell breeds viz., HH8, HH10 and HH12 with improvement in quantitative traits. The methodologies followed for the development are discussed.

Key words: High temperature, High humidity, Back crossing, Quantitative traits

Introduction

Development of robust bivoltine breeds/hybrids is very essential to conduct bivoltine rearing throughout the year at farmer's level to produce more yield and quality silk. In a tropical country like India where several factors influence the success of cocoon crops of which biotic and abiotic factors play a vital role. Among the abiotic factors, temperature plays a major role on growth and productivity (Benchamin and Jolly 1986). India enjoys the patronage of second position for the production of silk in the world next only to China. Sericulture in India is practiced predominantly in tropical environmental regions such as Karnataka, Tamil Nadu, Andhra Pradesh and West Bengal and to a limited extent in temperate environment of Jammu and Kashmir. The existing tropical situation provides scope for exploiting multivoltine x bivoltine hybrid at commercial venture as they are hardy and have tremendous ability to survive and reproduce under varied or fluctuating environmental climatic conditions. But its quality is at low ebb when compared to the existing international standard.

Considering these drawbacks, adoption of bivoltine sericulture became imperative and imminent considering its potentiality even under Indian tropical conditions. Keeping this in view, breeding experiments were initiated at Central Sericultural Research and Training Institute, Mysore to evolve hardy bivoltine silkworm races suited to tropical conditions for achieving the primary objective of establishing bivoltine hybrids as a concept among sericulturists. Accordingly, many productive and qualitatively superior bivoltine hybrids have been developed by utilizing Japanese commercial hybrids as breeding resource material (Basavaraja *et al.,* 1995). However, the hot climatic conditions prevailing particularly in summer are not conducive to rear these high yielding bivoltine hybrids

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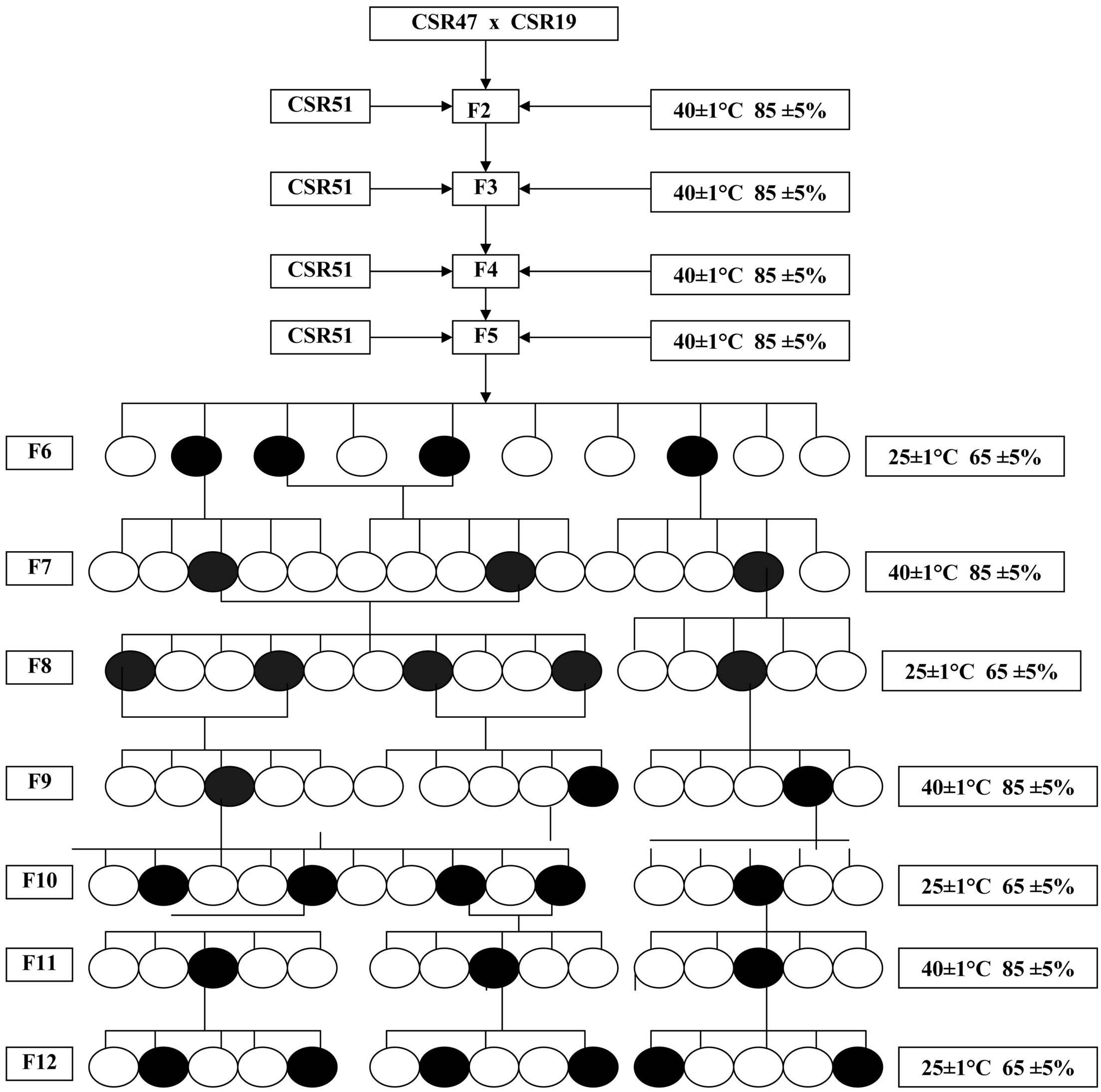

Fig. 1. Breeding plan of HH8.

throughout the year. It is well established fact that under tropical condition, unlike polyvoltines, bivoltines are more vulnerable to various stresses i.e hot climatic conditions of tropics, poor leaf quality and improper management during summer which are not conducive for bivoltine rearing. Therefore, attempts have been made to develop promising bivoltine breeds tolerant to high temperature and high humidity conditions of the tropics.

Materials and Methods

Initially, twenty two silkworm breeds were drawn from the germplasm of Central Sericultural Research and Training Institute, Mysore and screened under high temperature and high humidity conditions (40±1ºC and high humidity i.e. 85±5%) to select the breeding resource materials (Singh and Kumar, 2008). Silkworm rearing was conducted following the standard method under recommended temperature and humidity till 2nd day of 5th instar(Fig. 1, 2 and 3). On the third day of 5th instar 10 replicates of 100 larvae/ breed were subjected to temperature treatments for six hrs daily i.e., from 10 AM to 4 PM till spinning. The remaining larvae served as control and were reared at 25±1ºC and 65±5% relative humidity. For thermal exposure, the larvae were kept in plastic trays and reared in SERICATRON (Environmental chamber with precise and automatic control facilities for uniform maintenance of temperature and humidity) at 40±1ºC and 85±5%, and were fed with fresh mulberry leaves twice a day. When the larvae started spinning, they were shifted to 25±1ºC and 65±5% relative humidity. Plastic collapsible mountages were used for

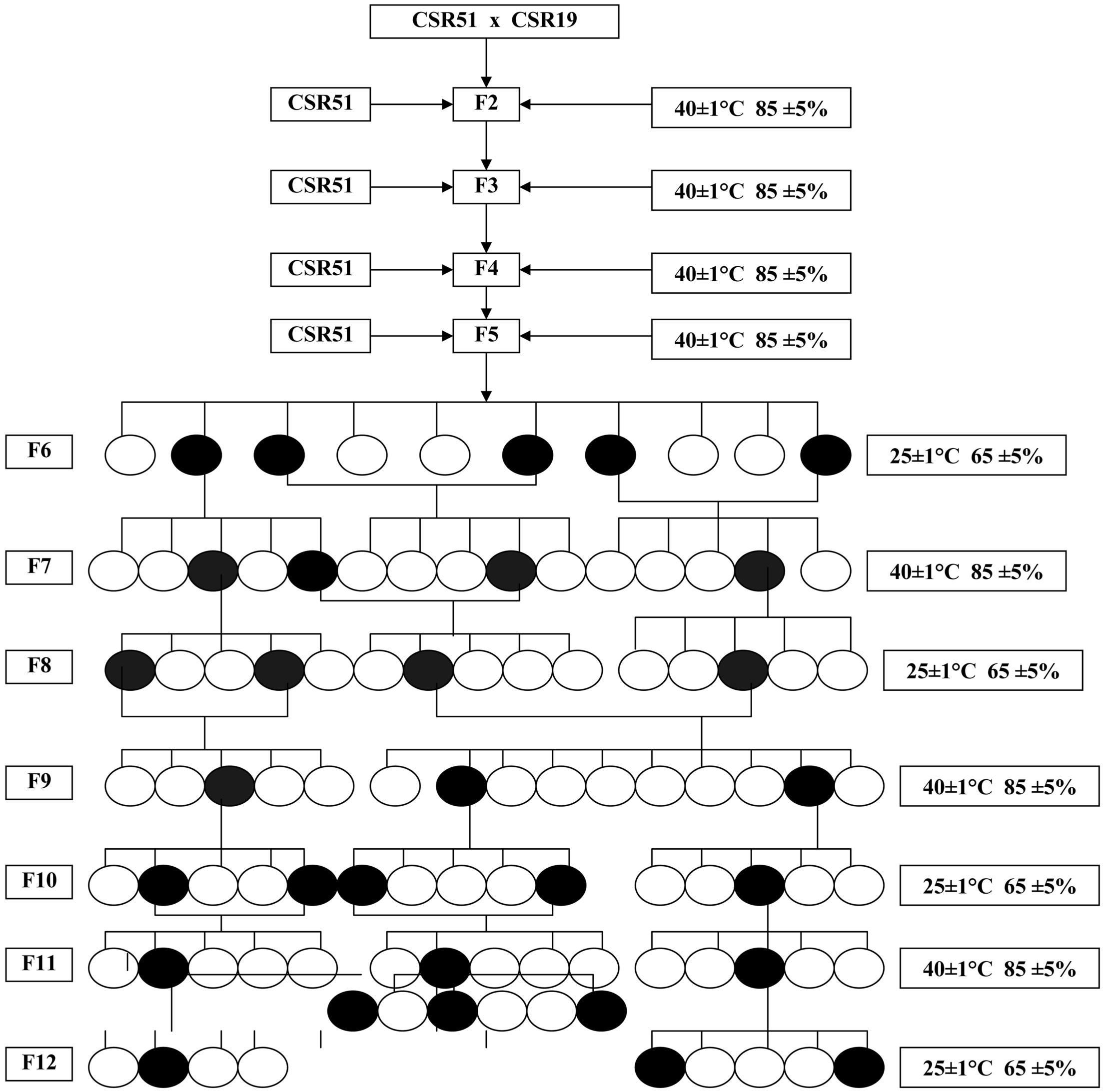

Fig. 2. Breeding plan of HH10.

mounting the ripened larvae. Cocoon harvesting was carried out on the 7th day and assessment was carried out on the subsequent day. The pupation rate was calculated as the number of live pupae to the number of larvae reared at 25±1ºC and 65±5% relative humidity and 40±1ºC and high humidity i.e. 85±5% respectively. Three dumbbell breeds were developed by utilizing selected bivoltine breeds as breeding resource material and crosses were made as dumbbell x dumbbell. In this breeding programme, repeated back crossing was given in the earlier (F2 to F5) by the respective productive breeds to increase the productivity traits in the resultant breeds. Owing to thermal effect in successive generations, it was observed after 5th generation that both qualitative and quantitative characters have declined. So the normal rearing was conducted every alternate generation to regain the lost vitality. Mass rearings were conducted from F1 to F5, while cellular rearings were conducted from F6 onwards. Further directional selection was employed in the following 5 generations. To obtain stability based on pupation rate and cocoon shape as important selection criteria. During the process of breeding care was also taken to maintain the productivity traits in the resultant breeds (Singh and Kumar 2009).

The parentages of the three breeding lines are as follows.

Sl. No.	Breeding lines	Parentage	Breeding Plan
		DUMBBELL	
1	HH8	CSR19,	(CSR47 × CSR19) × CSR51
2	HH10	CSR47,	(CSR51 × CSR19) × CSR51
3	HH12	CSR51.	(CSR51 × CSR47) × CSR51

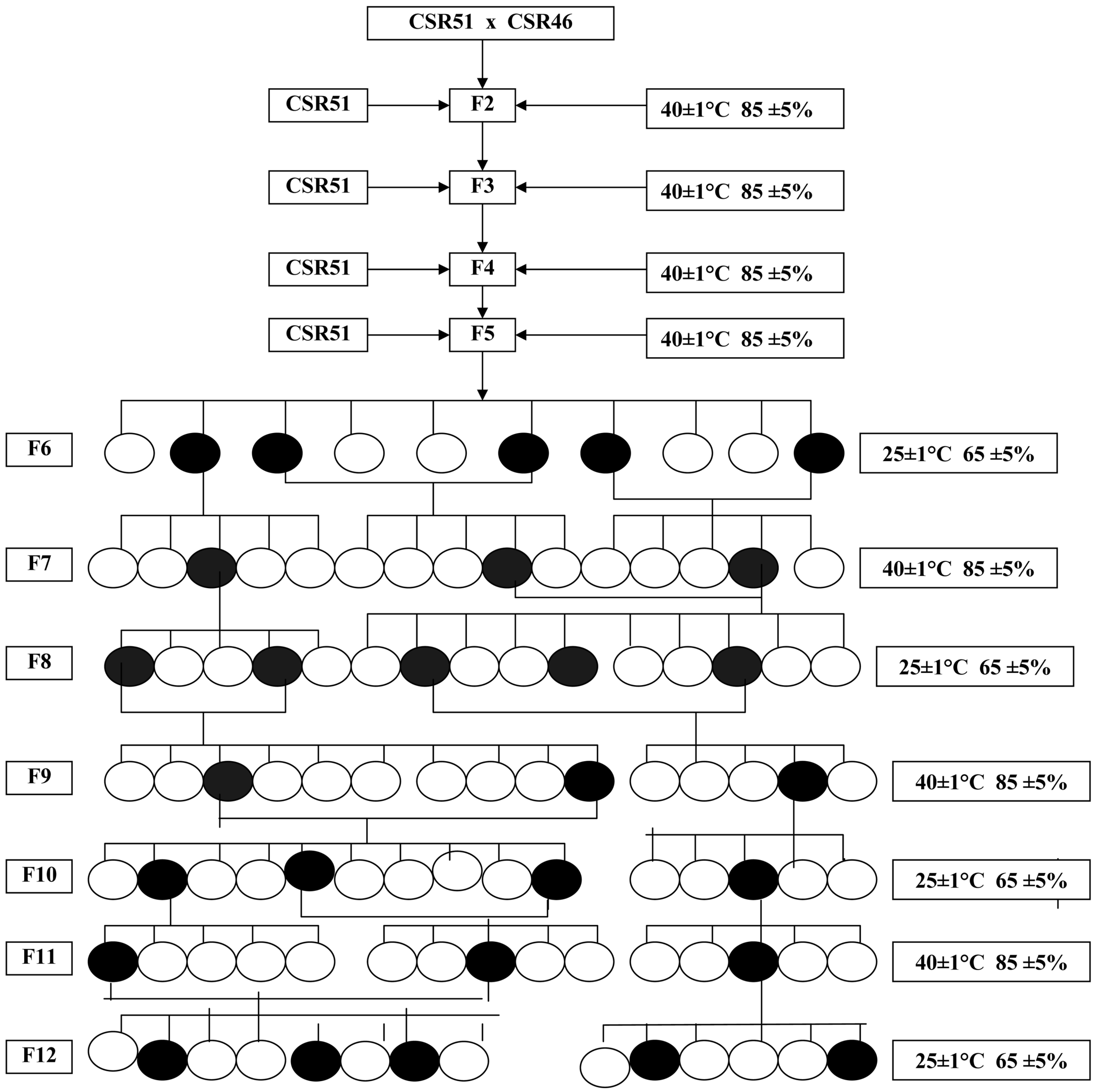

Fig. 3. Breeding plan of HH12.

The breeding lines were subjected for high temperature (40 ± 1ºC) and high humidity (85 ± 5% RH) as well as at room temperature (25 ± 1ºC and 65 ± 5% RH) treatments. Based on high pupation rate at high temperature and high humidity conditions, three oval lines were continued. Though, the resultant lines were more robust and relatively tolerant to silkworm diseases, the productivity traits were inferior to that of the already developed productive CSR breeds. Therefore, resorted to repeated out crossing with productive breeds to improve the productivity traits. Accordingly, all the three dumbbell lines (HH8, HH10 and HH12) were out crossed with CSR51 to improve the quantitative traits. Mass rearing with directional selection was resorted up to F5 generations. Based on high pupation rate a minimum of three bathes were selected and resorted to either inbreeding or inter batch crossing. Further, directional selection was employed in the following 5 generations based on pupation rate and cocoon shape as selection criteria. Single cocoon assessment was carried out to select the cocoons for continuation of the progeny by maintaining the qualitative and quantitative characters at high profile. Though, no positive selection response was noticed on survival rate when reared at high temperature followed by directional selection, progenetive lines performed remarkably superior in subsequent generations at room temperature conditions.

Results

Perusal of the data clearly indicates that there is significant difference in performance of the three breeds under

Table 1. Generation wise mean performance for rearing of HH8 at two temperature conditions

		40 ± 1ºc and 85 ± 5%RH						25 ± 1ºc and 65 ± 5%RH						
Generation	Fecundity (No)	V age larval span(hrs)	Pupation rate (%)	Yield/ 10,000 larvae(kg)	Cocoon Wt.(g)	Shell Wt.(g)	Cocoon Shell%	Fecundity (No)	V age larval span(hrs)	Pupation rate (%)	Yield/ 10,000 larvae(kg) (No)	Cocoon Wt.(g) (g)	Shell Wt.(g) (g)	Cocoon Shell% (%)
F1	680	130	53.00 (46.74)	15.67	1.566	0.324	20.67 (27.04)	680	148	94.1 (75.9)	17.92	1.784	0.396	22.19 (28.11)
F2	446	134	54.7 (47.7)	14.65	1.562	0.316	20.26 (26.75)	446	144	92.6 (74.2)	17.23	1.726	0.393	22.78 (28.51)
F3	430	134	55.3 (48.8)	15.59	1.580	0.329	20.85 (27.16)	430	144	92.8 (74.4)	17.81	1.695	0.379	22.37 (28.25)
F4	420	134	65.7 (54.1)	14.82	1.588	0.328	20.67 (27.04)	420	144	92.0 (73.5)	17.61	1.781	0.406	22.81 (28.53)
F5	425	134	76.3 (60.8)	15.22	1.593	0.324	20.34 (26.31)	425	150	91.6 (73.1)	18.55	1.933	0.440	22.77 (28.50)
F6	428	---	---	---	---	---	---	428	144	90.9 (72.4)	18.58	1.789	0.402	22.45 (28.28)
F7	608	134	77.0 (61.3)	14.37	1.607	0.332	20.70 (27.05)	608	150	91.3 (72.8)	18.23	1.785	0.405	22.71 (28.46)
F8	434	---	---	---	---	---	---	434	144	91.8 (73.3)	18.05	1.803	0.405	22.45 (28.28)
F9	616	132	80.3 (63.6)	15.79	1.598	0.342	21.42 (27.57)	616	144	91.6 (73.1)	18.42	1.824	0.407	22.33 (28.20)
F10	438	---	---	---	---	---	---	438	144	91.6 (73.1)	18.48	1.767	0.397	22.46 (28.29)
F11	611	132	79.0 (62.7)	15.73	1.569	0.329	20.98 (27.26)	611	144	91.9 (73.4)	18.26	1.800	0.402	22.35 (28.22)
F12	448	---	---	---	---	---	---	448	144	91.4 (72.9)	18.12	1.720	0.388	22.56 (28.36)
Mean	499	133	67.66	15.239	1.584	0.328	20.737	499	145.00	92.0	18.10	1.784	0.402	22.52
F-test	*	ns	***	**	ns	ns	ns	*	ns	ns	*	**	**	ns
CDat5%	3,10	---	15.02	0.79	---	---	---	3,10	---	---	0.74	0.09	0.02	---
CV%	19.66	1.14	17.57	4.32	2.28	3.56	3.91	19.66	1.69	1.475	2.97	4.14	4.35	1.26

*, **, *** Denote significant difference at 5%, 1% and 0.1% level respectively.
ns Denote non significant, Values in parenthesis are angular transformed.

Table 2. Generation wise mean performance for reeling of HH8 at two different temperatures

Generation	40 ± 1°c and 85 ± 5%RH						25 ± 1°c and 65 ± 5%RH					
	Reelability %	Filament length(m)	Renditta	Raw silk %	Filament size(d)	Neatness (p)	Reelability %	Filament length(m)	Renditta	Raw silk %	Filament size(d)	Neatness (p)
F1	82.00 (64.90)	757	6.59	15.19 (22.94)	2.42	85.00 (67.21)	86.00 (68.03)	981	5.72	17.48 (24.71)	2.83	92.33 (73.93)
F2	82.00 (64.90)	796	6.79	14.76 (22.59)	2.44	87.00 (68.87)	84.67 (66.95)	980	5.56	17.98 (25.09)	2.51	91.00 (72.60)
F3	80.00 (63.44)	825	6.68	15.01 (22.79)	2.29	86.00 (68.03)	86.67 (68.58)	1023	5.63	17.78 (24.94)	2.86	92.00 (73.57)
F4	81.00 (64.16)	808	6.66	15.02 (22.80)	2.50	88.67 (70.34)	85.33 (67.49)	1016	5.47	18.27 (25.31)	3.00	92.67 (74.30)
F5	80.67 (63.92)	879	6.76	14.79 (22.62)	2.42	87.00 (68.87))	85.00 (67.21)	1013	5.58	17.94 (25.06)	2.98	90.67 (72.23)
F6	---	---	---	---	---	---	86.33 (68.31)	1021	5.64	17.73 (24.90)	2.91	92.33 (73.93)
F7	80.67 (63.92)	898	6.63	15.11 (22.87)	2.46	90.67 (72.23)	86.00 (68.04)	1030	5.63	17.77 (24.93)	2.88	91.67 (73.26)
F8	---	---	---	---	---	---	86.33 (68.31)	993	5.58	17.93 (25.05)	2.89	91.33 (72.90)
F9	81.00 (64.16)	878	6.38	15.69 (23.33)	2.36	90.00 (71.57)	85.33 (67.49)	1033	5.59	17.88 (25.01)	2.97	92.33 (73.93)
F10	---	---	---	---	---	---	86.33 (68.31)	1106	5.68	17.61 (24.81)	2.87	91.00 (72.60)
F11	80.33 (63.68)	919	6.50	15.41 (23.11)	2.38	90.00 (71.57)	86.33 (68.31)	1007	5.66	17.66 (24.85)	2.87	92.33 (73.93)
F12	---	---	---	---	---	---	86.67 (68.59)	1021	5.57	17.95 (24.07)	2.89	92.00 (73.59)
Mean	80.96	845	6.62	15.12	2.41	88.04	85.92	1019	5.61	17.83	2.87	91.81
F-test	**	***	ns	ns	***	ns	**	***	ns	ns	***	ns
Cdat5%	0.87	33.33	---	---	0.09	---	0.97	43.90	---	---	0.08	---
CV%	1.00	6.70	4.12	4.08	3.11	2.37	0.94	3.77	1.78	1.79	4.45	1.19

*, **, *** Denote significant difference at 5%, 1% and 0.1% level respectively.

ns Denote non significant Values in parenthesis are angular transformed.

Table 3. Generation wise mean performances for rearing of HH10 at two temperature conditions

Generation	40 ± 1ºc and 85 ± 5%RH							25 ± 1ºc and 65 ± 5%RH						
	Fecundity (No)	V age larval span(hrs)	Pupation rate (%)	Yield/ 10,000 larvae(kg)	Cocoon Wt.(g) (g)	Shell Wt.(g) (g)	Cocoon Shell%	Fecundity (No)	V age larval span(hrs)	Pupation rate (%)	Yield/ 10,000 larvae(kg)	Cocoon Wt.(g) (g)	Shell Wt.(g) (g)	Cocoon Shell%
F1	582	130	59.0 (50.7)	15.18	1.601	0.327	20.42 (26.86)	582	148	93.0 (74.6)	19.03	1.808	0.401	22.20 (28.11)
F2	502	134	63.3 (52.8)	14.74	1.521	0.312	20.53 (26.94)	502	144	92.8 (74.4)	18.77	1.784	0.395	22.13 (28.06)
F3	465	134	62.0 (52.1)	15.10	1.590	0.328	20.65 (27.03)	465	144	93.5 (75.2)	18.72	1.650	0.364	22.07 (28.02)
F4	435	134	77.7 (61.8)	16.39	1.542	0.318	20.68 (27.04)	435	144	91.6 (73.1)	16.75	1.851	0.401	21.68 (27.75)
F5	420	134	78.0 (62.0)	14.87	1.543	0.324	21.02 (27.29)	420	150	92.2 (73.7)	19.41	1.901	0.408	21.48 (27.62)
F6	485	---	---	---	---	---	---	485	144	92.5 (74.1)	18.37	1.825	0.391	21.39 (27.54)
F7	618	134	87.7 (70.3)	15.32	1.566	0.320	20.44 (26.88)	618	150	92.9 (74.5)	18.93	1.837	0.404	22.00 (27.97)
F8	440	---	---	---	---	---	---	440	144	92.0 (73.5)	18.87	1.806	0.398	22.02 (27.98)
F9	600	132	82.0 (64.9)	15.40	1.575	0.342	21.74 (27.79)	600	144	91.9 (73.4)	18.75	1.828	0.404	22.10 (28.04)
F10	453	---	---	---	---	---	---	453	144	92.0 (73.5)	18.73	1.791	0.397	22.16 928.08)
F11	619	132	80.7 (63.9)	15.47	1.596	0.329	20.61 (27.00)	619	144	92.7 (74.3)	18.63	1.825	0.404	22.14 (28.07)
F12	458	---	---	---	---	---	---	458	144	93.3 (75.0)	18.07	1.781	0.397	22.29 (28.17)
Mean	506	133	73.80	15.487	1.567	0.324	20.762	506	145.00	92.5	18.59	**1.807**	**0.397**	**21.97**
F-test	ns	ns	*	**	ns	ns	ns	ns	ns	ns	***	*	**ns**	**ns**
Cdat5%	---	---	19.3	1.07	---	---	---	---	---	---	0.76	**0.10**	---	---
CV%	15.06	1.14	14.57	5.57	3.21	3.97	4.08	15.06	1.69	1.24	4.00	**4.18**	**4.03**	**2.432**

*, **, *** Denote significant difference at 5%, 1% and 0.1% level respectively.

ns Denote non significant Values in parenthesis are angular transformed.

Table 4. Generation wise mean performance for reeling of HH10 at two different temperatures

Generation	40 ± 1ºc and 85 ± 5%RH						25 ± 1ºc and 65 ± 5%RH					
	Reelability %	Filament length(m)	Renditta	Raw silk %	Filament size(d)	Neatness (p)	Reelability %	Filament length(m)	Renditta	Raw silk %	Filament size(d)	Neatness (p)
F1	82.33 (65.15)	852	6.61	15.15 (22.90)	2.38	85.00 (67.21)	86.00 (68.030	984	5.69	17.58 (24.59)	2.86	92.33 (73.93)
F2	81.33 (64.40)	764	6.68	14.99 (22.77)	2.45	86.33 (68.31)	84.67 (68.95)	967	5.71	17.52 (24.74)	2.54	91.67 (73.26)
F3	81.67 (64.65)	782	6.69	14.96 (22.76)	2.42	88.67 (70.34)	86.67 (68.59	1026	5.75	17.40 (24.65)	2.89	91.33 (72.90)
F4	81.67 (64.65)	868	6.70	14.98 (22.76)	2.54	87.00 (68.87)	85.33 (67.49)	1027	5.78	17.31 (24.58)	2.99	92.67 (74.30)
F5	81.00 64.16)	857	6.53	15.34 (23.05)	2.42	89.33 (70.95)	85.00 (67.21)	983	5.84	17.12 (24.44)	3.00	91.67 (73.23)
F6	---	---	---	---	---	---	86.33 (68.31)	1000	5.86	17.08 (24.41)	2.91	92.67 (74.30)
F7	81.00 (64.16)	968	6.73	14.86 (22.67)	2.46	90.67 (72.23)	86.00 (68.04)	1049	5.76	17.36 (24.62)	2.90	90.67 (72.23)
F8	---	---	---	---	---	---	86.33 (68.31)	993	5.72	17.48 (24.71)	2.85	91.00 (72.56)
F9	81.00 (64.16)	878	6.30	15.87 (23.48)	2.36	89.33 (70.95)	85.33 (67.49)	1033	5.68	17.60 (24.80)	2.97	92.33 (73.93)
F10	---	---	---	---	---	---	86.33 (68.31)	1106	5.65	17.70 (24.88)	2.87	91.00 (72.60)
F11	80.33 (63.68)	919	6.61	15.14 (22.90)	2.38	90.67 (72.22)	86.33 (38.31)	1007	5.66	17.67 (24.85)	2.87	90.67 (72.23)
F12	---	---	---	---	---	---	86.67 (68.59)	1084	5.68	17.60 (24.80)	2.87	91.00 (72.56)
Mean	81.29	861	6.61	15.16	2.43	88.38	85.92	1022	5.73	17.45	2.88	91.58
F-test	ns	ns	ns	ns	ns	ns	**	***	ns	ns	***	ns
CDat5%	---	---	---	---	---	---	0.97	50.26	---	---	0.05	---
CV%	0.99	7.72	4.28	4.21	3.82	2.34	0.94	4.65	2.51	2.47	4.03	1.24

*, **, *** Denote significant difference at 5%, 1% and 0.1% level respectively.
ns Denote non significant Values in parenthesis are angular transformed.

Table 5. Generation wise mean performances for rearing of HH112 at two temperature conditions

Generation	40 ± 1ºc and 85 ± 5%RH							25 ± 1ºc and 65 ± 5%RH						
	Fecundity (No)	V th age larval span(hrs)	Pupation rate (%)	Yield/ 10,000 larvae(kg)	Cocoon Wt.(g)	Shell Wt.(g)	Cocoon Shell%	Fecundity (No)	V th age larval span(hrs)	Pupation rate (%)	Yield/ 10,000 larvae(kg)	Cocoon Wt.(g)	Shell Wt.(g)	Cocoon Shell%
F1	600	130	53.8 (46.74)	16.04	1.600	0.325	20.33 (26.80)	600	148	91.6 (73.1)	18.76	1.756	0.382	21.77 (27.81)
F2	484	134	60.7 (51.2)	15.25	1.562	0.330	21.16 (27.29)	484	144	92.6 (74.2)	18.73	1.834	0.406	22.16 (28.08)
F3	470	134	53.0 (46.74)	14.77	1.521	0.334	21.96 (27.94)	470	144	94.4 (76.3)	18.88	1.821	0.407	22.32 (28.19)
F4	464	134	65.7 (54.1)	14.77	1.585	0.325	20.51 (26.92)	464	144	93.8 (75.5)	18.77	1.915	0.430	22.46 (28.29)
F5	450	134	56.3 (48.5)	15.93	1.571	0.329	20.96 (27.24)	450	150	92.7 (74.3)	19.81	1.947	0.438	22.50 (28.32)
F6	455	---	---	---	---	---	---	455	144	92.3 (73.8)	18.78	1.839	0.414	22.51 (28.32)
F7	625	134	77.7 (61.8)	13.74	1.579	0.336	21.30 (27.48)	625	150	91.1 (72.6)	18.94	1.823	0.415	22.75 (28.49)
F8	462	---	---	---	---	---	---	462	144	91.8 (73.3)	18.47	1.847	0.421	22.78 (28.51)
F9	632	132	83.7 (66.1)	16.42	1.598	0.327	20.46 (26.89)	632	144	92.5 (74.1)	19.27	1.863	0.424	22.74 (28.48)
F10	468	---	---	---	---	---	---	468	144	92.5 (74.1)	18.92	1.775	0.396	22.34 (28.21)
F11	610	132	83.3 (65.8)	15.94	1.569	0.327	20.83 (27.15)	610	144	93.6 (75.3)	18.71	1.808	0.411	22.72 (28.47)
F12	470	---	---	---	---	---	---	470	144	92.6 (74.2)	18.71	1.759	0.396	22.50 (28.31)
Mean	516	133	66.78	15.357	1.574	0.33	20.938	516	145.00	92.6	18.90	1.832	0.412	22.46
F-test	ns	ns	*	***	ns	ns	ns	ns	ns	ns	ns	*	**	ns
CDat5%	---	---	18.7	0.92	---	---	---	---	---	---	---	0.10	0.02	---
CV%	14.61	1.14	19.48	6.26	2.29	3.22	4.16	14.61	1.69	1.90	2.57	4.10	4.28	2.02

*, **, *** Denote significant difference at 5%, 1% and 0.1% level respectively.
ns Denote non significant
Values in parenthesis are angular transformed.

Table 6. Generation wise mean performance for reeling of HH12 at two different temperatures

Generation	40 ± 1ºc and 85 ± 5%RH						25 ± 1ºc and 65 ± 5%RH					
	Reelability %	Filament length(m)	Renditta	Raw silk %	Filament size(d)	Neatness (p)	Reelability %	Filament length(m)	Renditta	Raw silk %	Filament size(d)	Neatness (p)
F1	81.00 (64.17)	794	6.71	14.93 (22.72)	2.39	85.33 (37.49)	85.67 (67.76)	986	5.83	17.16 (24.47)	2.87	92.33 (73.93)
F2	80.67 (63.92)	763	6.53	15.33 (23.05)	2.45	86.33 (68.31)	84.67 (66.95)	982	5.69	17.58 (24.79)	2.63	92.00 (72.59)
F3	82.00 (64.91)	792	6.28	15.94 (23.53)	2.54	88.67 (70.34)	85.67 (67.76)	1077	5.70	17.5 (24.75)	2.88	92.33 (73.93)
F4	81.00 (64.16)	852	6.82	14.68 (22.52)	2.53	90.00 (71.61)	83.33 (65.91)	1013	5.70	17.55 (24.77)	3.01	91.67 (73.26)
F5	80.67 (63.92)	871	6.59	15.18 (22.93)	2.43	89.33 (70.95)	84.00 (66.42)	963	5.66	17.65 (24.84)	2.85	90.67 (72.23)
F6	---	---	---	---	---	---	86.33 (68.31)	981	5.64	17.73 (24.90)	2.82	91.33 (72.89)
F7	80.67 (63.92)	965	6.40	15.64 (23.30)	2.69	90.33 (71.89)	86.00 (68.04)	1057	5.57	17.94 (25.06)	2.84	90.67 (72.23)
F8	---	---	---	---	---	---	86.33 (68.31)	1037	5.53	18.08 (25.16)	2.81	91.00 (72.56)
F9	82.00 (64.91)	878	6.64	15.08 (22.84)	2.37	90.00 (71.57)	85.33 (37.49)	1027	5.57	17.95 (25.07)	2.90	92.33 (73.93)
F10	---	---	---	---	---	---	86.33 (68.31)	1024	5.62	17.79 (24.95)	2.88	92.00 (73.59)
F11	80.67 (63.92)	976	6.57	15.27 (23.00)	2.42	90.33 (71.89	86.33 (68.31)	1023	5.63	17.76 (24.92)	2.93	92.33 (73.93)
F12	---	---	---	---	---	---	86.67 (68.59)	1065	5.59	17.91 (25.03)	2.95	91.00 (72.60)
Mean	81.08	894	6.57	15.26	2.48	88.79	85.56	1020	5.65	17.72	2.86	**91.64**
F-test	ns	***	ns	ns	***	ns	***	*	ns	ns	***	**ns**
CDat5%	---	29.20	---	---	0.11	---	1.01	66.06	---	---	0.08	**---**
CV%	1.58	5.33	4.19	4.20	4.69	2.17	1.32	4.69	2.12	2.12	3.42	**1.17**

*, **, *** Denote significant difference at 5%, 1% and 0.1% level respectively.

ns Denote non significant

Values in parenthesis are angular transformed.

the two temperature treatments. Since the larvae from the same layings were used for both the temperature treatments there was no difference in fecundity between treatments. The fecundity in HH8 ranged from 420 to 680 with the highest of 680 recorded at F1 and the lowest of 420 recorded at F4 generation (Table 1). At 40 ± 1°C, the larval duration ranged from 130 to 134 hrs with the longest duration of 134 hours was recorded for F2 to F5 and F7 and the shortest duration of 130 hrs duration was recorded at F1. At 25 ± 1°C, the larval duration ranged from 144 to 150 hrs with the longest duration was recorded at F5 and F7 and the shortest duration of 144 hrs was recorded at F2 to F4, F6 and F8 to F12. At 40 ± 1°C, the pupation ranged from 53.0 to 80.3% with the highest of 80.3% recorded at F9 and the lowest of 53.0% recorded at F1. At 25 ± 1°C, the pupation rate ranged from 90.9 to 94.1% with the highest of 94.1% recorded at F1 and the lowest of 90.9% recorded at F6. At 40 ± 1°C, the yield/10000 larvae ranged from 14.37 to 15.79 kg with the highest of 15.79 kg recorded at F9 and the lowest of 14.37 kg recorded at F7. At 25 ± 1°C, the yield/10000 larvae ranged from 17.23 to 18.58 kg with the highest of 18.58 kg recorded at F6 and the lowest of 17.23 kg recorded at F2. At 40 ± 1°C, the cocoon weight ranged from 1.562 to 1.607 g with the highest of 1.607 g recorded at F7 and the lowest of 1.562 g recorded at F2. At 25 ± 1°C, the cocoon weight ranged from 1.695 to 1.933 g with the highest of 1.933 g recorded at F5 and the lowest of 1.695 g recorded at F3. At 40 ± 1°C, the cocoon shell weight ranged from 0.316 to 0.342 g with the highest of 0.342 recorded at F9 and the lowest of 0.316 g recorded at F2. At 25 ± 1°C, the cocoon shell weight ranged from 0.379 to 0.440 g with the highest of 0.440 g recorded at F5 and the lowest of 0.379 g recorded at F3. At 40 ± 1°C, the cocoon shell percentage ranged from 20.26 to 21.42 g with the highest of 21.42 g recorded at F9 and the lowest of 20.26 g recorded at F2. At 25 ± 1°C, the cocoon shell percentage ranged from 22.19 to 22.81 g with the highest of 22.81 recorded at F4 and the lowest of 22.19 g recorded at F1.

Similarly, the reeling parameters also recorded difference in performance at two different temperature treatments (Table 2). At 40 ± 1°C, the reelability ranged from 80.0 to 82.0% with the highest of 82.0% recorded at F1and F2 and the lowest of 80.0% recorded at F3. At 25 ± 1°C, the reelability ranged from 84.67 to 86.67% with the highest of 86.67 % recorded at F3 and F12 and the lowest of 84.67 % recorded at F2. At 40 ± 1°C, the filament length ranged from 757 to 919 m with the highest of 916 m recorded at F12 and the lowest of 757 m recorded at F1. At 25 ± 1°C, the filament length ranged from 980 to 1106 m with the highest of 1106 m recorded at F10 and the lowest of 980 recorded at F2. At 40 ± 1°C, the renditta ranged from 6.39 to 6.79 with the highest of 6.79 recorded at F2 and the lowest of 6.39 recorded at F9. At 25 ± 1°C, the renditta ranged from 5.47 to 5.72 with the highest of 5.72 recorded at F1 and the lowest of 5.47 recorded at F4. At 40 ± 1°C, the raw silk percentage ranged from14.76 to 15.69% with the highest of 15.69% recorded at F9 and the lowest of 14.76% recorded at F2. At 25 ± 1°C, the raw silk percentage ranged from 17.48 to 18.27% with the highest of 18.27 recorded at F4 and the lowest of 17.48% recorded at F1. At 40 ± 1°C, the filament size ranged from 2.36 to 2.50 with highest of 2.50 recorded at F4 and the lowest of 2.36 recorded at F9. At 25 ± 1°C, the filament size ranged from 2.51 to 3.0 with the highest of 3.0 recorded at F4 and the lowest of 2.51 recorded at F2. At 40 ± 1°C, the neatness ranged from 85.0 to 90.67 with the highest of 90.67 recorded at F7 and the lowest of 85.0 recorded at F1. At 25 ± 1°C, the neatness ranged from 90.67 to 92.67 with the highest of 92.67 recorded at F4 and the lowest of 90.67 recorded at F5.

The fecundity in HH10 ranged from 420 to 619 with the highest of 619 recorded at F11 and the lowest of 420 recorded at F5 generation (Table 3). At 40 ± 1°C, the larval duration ranged from 130 to 134 hrs with the longest duration of 134 hrs was recorded for F2 to F5 and F7 and the shortest duration of 130 hrs duration was recorded at F1. At 25 ± 1°C, the larval duration ranged from 144 to 150 hrs with the longest duration of 150 was recorded at F5 and F7 and the shortest duration of 144 hrs was recorded at F2 to F4, F6 and F8 to F12. At 40 ± 1°C, the pupation ranged from 59.0 to 87.7% with the highest of 87.7% recorded at F7 and the lowest of 59.0% recorded at F1. At 25 ± 1°C, the pupation rate ranged from 91.6 to 93.5% with the highest of 93.5% recorded at F3 and the lowest of 91.6% recorded at F4. At 40 ± 1°C, the yield/10000 larvae ranged from 14.74 to 16.39 kg with the highest of 16.39 kg recorded at F4 and the lowest of 14.74 kg recorded at F2. At 25 ± 1°C, the yield/10000 larvae ranged from 16.75 to 19. 41 kg with the highest of 19.41 kg recorded at F5 and the lowest of 16.75 kg recorded at F4. At 40 ± 1°C, the cocoon weight ranged from 1.521 to 1.601 g with the highest of 1.601 g recorded at F1 and the lowest of 1.521 g recorded at F2. At 25 ± 1°C, the cocoon weight ranged from 1.650 to 1.901 g with the highest of 1.901 g recorded at F5 and the lowest of 1.650 g recorded at F3. At 40 ± 1°C, the cocoon shell weight ranged from 0.312 to 0.342 g with the highest of 0.342 recorded at F9 and the lowest of 0.312 g recorded at F2. At 25 ± 1°C, the cocoon shell weight ranged from 0.364 to 0.408 g with the highest of 0.408 g recorded at F5 and the lowest of 0.364 g recorded at F3. At 40 ± 1°C, the cocoon shell percentage ranged from 20.42 to 21.74 g with the highest of 21.74 g recorded at F9 and the lowest of 20.42 g recorded at F1. At 25 ± 1°C, the cocoon shell percentage ranged from 21.39 to 22.29 g with the highest of 22.29 recorded at F12 and the lowest of 21.39 g recorded at F6.

Similarly, the reeling parameters also recorded difference in performance at two different temperature treatments (Table 4). At 40 ± 1°C, the reelability ranged from 80.33 to 82.33% with the highest of 82.33% recorded at F1 and the lowest of 80.33% recorded at F11. At 25 ± 1°C, the reelability ranged from 84.67 to 86.67% with the highest of 86.67% recorded at F3 and F12 and the lowest of 84.67% recorded at F2. At 40 ± 1°C, the filament length ranged from 764 to 968 m with the highest of 968 m recorded at F7 and the lowest of 764 m recorded at F2. At 25 ± 1°C, the filament length ranged from 967 to 1106 m with the highest of 1106 m recorded at F10 and the lowest of 967 recorded at F2. At 40 ± 1°C, the renditta ranged from 6.30 to 6.73 with the highest of 6.73 recorded at F7 and the lowest of 6.30 recorded at F9. At 25 ± 1°C, the renditta ranged from 5.65 to 5.86 with the highest of 5.86 recorded at F6 and the lowest of 5.65 recorded at F10. At 40 ± 1°C, the raw silk percentage ranged from 14.86 to 15.87% with the highest of 15.87% recorded at F9 and the lowest of 14.86% recorded at F7. At 25 ± 1°C, the raw silk percentage ranged from 17.08 to 17.70% with the highest of 17.70 recorded at F10 and the lowest of 17.08% recorded at F6. At 40 ± 1°C, the filament size ranged from 2.36 to 2.54 with highest of 2.54 recorded at F4 and the lowest of 2.36 recorded at F9. At 25 ± 1°C, the filament size ranged from 2.54 to 3.0 with the highest of 3.0 recorded at F5 and the lowest of 2.54 recorded at F2. At 40 ± 1°C, the neatness ranged from 85.0 to 90.67 with the highest of 90.67 recorded at F7 and F11 the lowest of 85.0 recorded at F1. At 25 ± 1°C, the neatness ranged from 90.67 to 92.67 with the highest of 92.67 recorded at F4 and F6 the lowest of 90.67 recorded at F7 and F11.

The fecundity in HH12 ranged from 450 to 632 with the highest of 632 recorded at F9 and the lowest of 450 recorded at F5 generation (Table 5). At 40 ± 1°C, the larval duration ranged from 130 to 134 hours with the longest duration of 134 hours was recorded for F2 to F5 and F7 and the shortest duration of 130 hours duration was recorded at F1. At 25 ± 1°C, the larval duration ranged from 144 to 150 hrs with the longest duration of 150 was recorded at F5 and F7 and the shortest duration of 144 hrs was recorded at F2 to F4, F6 and F8 to F12. At 40 ± 1°C, the pupation ranged from 53.0 to 83.7% with the highest of 83.7% recorded at F9 and the lowest of 53.0% recorded at F3. At 25 ± 1°C, the pupation rate ranged from 91.1 to 94.4% with the highest of 94.4% recorded at F3 and the lowest of 91.1% recorded at F7. At 40 ± 1°C, the yield/10000 larvae ranged from 13.74 to 16.42 kg with the highest of 16.42 kg recorded at F9 and the lowest of 13.74 kg recorded at F7. At 25 ± 1°C, the yield/10000 larvae ranged from 18.47 to 19.81 kg with the highest of 19.81 kg recorded at F5 and the lowest of 18.47 kg recorded at F8. At 40 ± 1°C, the cocoon weight ranged from 1.521 to 1.600 g with the highest of 1.600 g recorded at F1 and the lowest of 1.521 g recorded at F3. At 25 ± 1°C, the cocoon weight ranged from 1.756 to 1.947 g with the highest of 1.947 g recorded at F5 and the lowest of 1.756 g recorded at F1. At 40 ± 1°C, the cocoon shell weight ranged from 0.325 to 0.336 g with the highest of 0.336 recorded at F7 and the lowest of 0.325 g recorded at F1 and F4. At 25 ± 1°C, the cocoon shell weight ranged from 0.382 to 0.438 g with the highest of 0.438 g recorded at F5 and the lowest of 0.382 g recorded at F1. At 40 ± 1°C, the cocoon shell percentage ranged from 20.33 to 21.96 g with the highest of 21.96 g recorded at F3 and the lowest of 20.33 g recorded at F1. At 25 ± 1°C, the cocoon shell percentage ranged from 21.77 to 22.78 g with the highest of 22.78 recorded at F8 and the lowest of 21.77 g recorded at F1.

Similarly, the reeling parameters also recorded difference in performance at two different temperature treatments (Table 6). At 40 ± 1°C, the reelability ranged from 80.67 to 82.00% with the highest of 82.00% recorded at F3 and F9 and the lowest of 80.67% recorded at F2, F5, F7 and F11. At 251°C, the reelability ranged from 83.33 to 86.67% with the highest of 86.67% recorded at F12 and the lowest of 83.33% recorded at F4. At 40 ± 1°C, the filament length ranged from 763 to 976 m with the highest of 976 m recorded at F11 and the lowest of 763 m recorded at F2. At 25 ± 1°C, the filament length ranged from 963 to 1077 m with the highest of 1077 m recorded at F3 and the lowest of 963 recorded at F5. At 40 ± 1°C, the renditta ranged from 6.28 to 6.82 with the highest of 6.82 recorded at F4 and the lowest of 6.28 recorded at F3. At 25 ± 1°C, the renditta ranged from 5.53 to 5.70 with the highest of 5.70 recorded at F3 and F4 and the lowest of 5.53 recorded at F8. At 40 ± 1°C, the raw silk percentage ranged from14.68 to 15.94% with the highest of 15.94% recorded at F3 and the lowest of 14.68% recorded at F4. At 25 ± 1°C, the raw silk percentage ranged from 17.16 to 18.08% with the highest of 18.08 recorded at F8 and the lowest of 17.16% recorded at F1. At 40 ± 1°C, the filament size ranged from 2.37 to 2.69 with highest of 2.69 recorded at F7 and the lowest of 2.37 recorded at F9. At 25 ± 1°C, the filament size ranged from 2.63 to 3.01 with the highest of 3.01 recorded at F4 and the lowest of 2.63 recorded at F2. At 40 ± 1°C, the neatness ranged from 85.33 to 90.33 with the highest of 90.33 recorded at F7 and F11 the lowest of 85.33 recorded at F1. At 25 ± 1°C, the neatness ranged from 90.67 to 92.33 with the highest of 92.33 recorded at F1, F3, F9 and F11 the lowest of

90.67 recorded at F5 and F7.

Discussion

The breeding of silkworm since long has been aimed towards evolving of superior and hardy breeds either by means of selection alone or by combining out-crossing or backcrossing with selection in the subsequent generations. The final aim of the breeder is primarily to evolve a breed which can give rise to stabilized crops and secondly to improve both quantity and quality of silk (Tazima, 1984). The breeding of silkworm races probably dates back to the beginning of the history of silkworm rearing, but it has made great progress rather recently (Hirobe, 1968). 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 correlation for few traits is negative and for some it is positive (Tsuchima and Kurashima, 1959 and 1960; Kurasawa, 1968a, 1968b; Ohi *et al.,* 1970; Gamo and Ichiba, 1971; Gamo, 1976). Therefore, during the course of breeding of new breeds, the breeder has to be aware of the response of certain characters in selection and its correlated changes with other economic traits. Inbreeding of hybrids to stabilize silkworm breeds which bred true is well documented (Osawa and Harada, 1944; Harada, 1952, 1953, 1956; Hirobe, 1956, 1967, 1968; Yokoyama, 1956, 1959, 1976, 1979; Gamo, 1976). Similarly, Kovalov (1970) is of the opinion that improvement of silkworm races is possible by outbreeding with exotic races and improvement of cocoon quality by repeated backcrossing (Tazima, 1964).

During the course of breeding varied responses for the traits analyzed from F1~F5 can be attributed to the transgressive segregation of large number of genes along with the influence of environmental effects. Systematic evaluation of major contributing traits of the population raised from F5 onwards made it possible to concentrate on each one of the character in order to follow high intensity of selection for the phenotypic target traits. During the breeding process, emphasis was laid for important aspects such as the number of generations required for segregating populations to regain from the loss of inbreeding and to excel the level of initial generations. The results obtained in the breeding experiments indicate that several important issues need to be addressed for interpretation. The selection response for various traits need to be focused first followed by the results obtained. The polygenic nature of the traits in question and the role of different intensities of selection in changing the mean expression of such characters have been demonstrated in plants and animals by several workers (Dickinson and Hazel, 1944: Bell *et al.,* 1955; Robertson, 1956; Clayton and Robertson, 1957; Clayton *et al.,* 1957; Falconer, 1981). Selection can not make new genes but it will alter the gene frequency in the existing population. It is an essential adjunct of the other systems as a means of improvement.

Geneticists and breeders of all the sericultural countries have experienced the influence of environment during the process of breeding. Shibukawa (1965) studied the silkworm viability and cocoon weight for 19 generations at two different temperature and humidity. He observed that the lines selected at high temperature and humidity perform better than the lines selected at normal temperature and humidity. The effect of high temperature more 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 silkworms as a main yardstick character for evaluating thermo-tolerance. Kato *et al.* (1989) conducted a series of experiments and concluded that the resistance to high temperature is a heritable character and it may be possible to breed silkworm races tolerant to high temperature. Shirota (1992) and Tazima and Ohnuma (1995) while attempting to synthesize high temperature resistant silkworm races confirmed the genetically heritable nature of thermo-tolerance by selection based on pupation rate of silkworm reared under high temperature conditions during 5^{th} instar.

The variations in the environmental conditions during rearing influence the expression of various economic traits (Watanabe, 1928; Hassanein and Sharawy, 1962; Kasivishwanathan *et al.,* 1970; Ueda *et al.,* 1969, 1971, 1975). Moreover, the genotypic differences among breeds due to variable gene frequencies at many loci make the respective breeds to respond differently to changing environmental conditions (Watanabe, 1918, 1919, 1961; Kogure, 1933; Nagatoma, 1942; Suzuki, 1954; Fukuda *et al.,* 1963; White and Richmond, 1963; Narayanan *et al.,* 1967; Morohoshi, 1969; Sengupta, 1969, 1988; Subramanya and Reddy, 1986; Ueda *et al.,* 1969; Singh *et al.,* 1990, 1992, 1998; Reddy *et al.,* 1992; Radhakrishna *et al.*, 2001; Raju *et al.,* 2001; Rao, 2003).

Silkworm breeds 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 low 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 Rao (2003). Nagaraju *et al.* (1996) observed 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. Kumar *et al.* (2003) reported the deleterious effect of high temperature and high humidity on quantitative traits of parents, foundation crosses, single and double hybrids of bivoltine silkworm breeds of *Bombyx mori* L.

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