Concluded report

on

AIB 3547

DEVELOPMENT OF HIGH TEMPERATURE AND HIGH HUMIDITY TOLERANT BIVOLTINE BREEDS OF SILKWORM (*BOMBYX MORI* L.)

By

Principal Investigator: Dr. N. Chandrakanth, Scientist –B

Dr. N. Suresh Kumar, Scientist-D (up to May, 2016)

Co-Investigator :Dr. A. K. Verma, Scientist-D

Dr. A. K. Saha, Scientist-D (up to Dec., 2015)

Central Sericultural Research &Training Institute

Central Silk Board

Ministry of Textiles, Govt. of India

Berhampore - 742 101

Murshidabad District

West Bengal

July 2015- June 2017

i. Project code and title:

AIB 3547- Development of high temperature and high humidity tolerant bivoltine breeds of silkworm (*Bombyx mori* L.)

ii. Names of the Project Investigators (including coordinator in case of collaborative projects):

Investigators: N. Chandrakanth, N. Suresh Kumar (up to May 2016), A. K. Saha (up to Dec., 2015) and A. K. Verma

iii. **Duration (Date of Start)** – July 2015
(Scheduled Date of Completion)- June 2017

iv. **Name(s) of the Institute(s) and Address:** Central Sericultural Research & Training Institute, Berhampore - 742101 Dist.- Murshidabad, West Bengal, India

v. A list of Objectives / Goals

To develop thermotolerant bivoltine silkworm breeds with genetic plasticity to buffer against the adverse climatic conditions of West Bengal

vi. Introduction

Silkworm is a poikilothermic animal. Variation in temperature above 28°C and humidity above then 80% causes physiological deficiency resulting in the reduction of cocoon production. Therefore, development of suitable breeds for rearing under high temperature and high humidity conditions always been perceived as an extremely challenging task. As such, it is essential that the breeding strategies need to be directed towards the development of sustainable thermo-tolerant bivoltine breeds to produce quality raw silk to improve the unit production under tropical climate. Generally multivoltine breeds produce low quality silk but bivoltine produces good quality silk at congenial environment but in tropical condition when temperature and humidity are high and highly variable, the survival of bivoltine breed comes down to very low or nil. Therefore, Indian sericulture industry is multivoltine oriented and hence the quality of silk is of low grade. Quality silk can be produced only through bivoltines. However, the hot climatic conditions prevailing in India is not conducive to rear the bivoltines already available.

Moreover, in West Bengal, silkworm rearing for commercial purpose is practiced five times in a year at farms and farmer's level due to availability of huge mulberry leaves for high rainfall and fertility of soil. The climatic situation of West Bengal is broadly categorized into two *i.e.*, the favourable (November to March) and unfavourable (May to September). It has been observed that bivoltine P1 rearing to prepare multi x bi hybrid dfls for three commercial crop (June-July, August-September and November-December) is not successful as the P1 bivoltine rearing to prepare multi x bi layings for aforesaid commercial seasons fall under unfavourable season [high temperature (>35°C) and high humidity (>85-99%] which are not congenial for bivoltine silkworm rearing. Therefore, farmers are forced to restrict their rearing only with Nistari, the indigenous multivoltine strain having horizontal tolerant potentiality both at P1 and in commercial level during the adverse month. Now a day's multivoltine hybrid of Nistari is being widely reared at commercial level in West Bengal during adverse seasons though the production. Quality silk can be produced only through bivoltines. However, the hot climatic conditions prevailing in West Bengal is not conducive to rear the bivoltines already available due to lack of thermotolerant bivoltines. Therefore, there is an urgent need to develop high temperature and high humidity tolerant bivoltine breeds which can withstand the adverse climatic conditions of the tropics.

In this context, the Phase I of this project AIB-3496 was made and as a result ten bivoltine silkworm breeds tolerant to high temperature (35 ± 1°C) and high humidity (85 ± 5%) were shortlisted as breeding resource material by screening 38 existing thermo-tolerant silkworm breeds from different sericultural research stations.

vii. Methodology Adopted

1. Breeding resource material

The following 10 bivoltine silkworm breeds found to be tolerant to high temperature (35 ± 1°C) and high humidity (85±5%) conditions were selected as breeding resource material

Table 1: Cocoon characters of the selected silkworm breeds.

#	Breeds	Cocoon characters
1	SK6	White dumbbell
2	SK7	White dumbbell
3	B.Con.1	White dumbbell
4	B.Con.4	White dumbbell
5	D6PN	White dumbbell
6	SK4C	White dumbbell
7	BHR2	White oval
8	BHR3	White oval
9	ATR29	White oval
10	GEN3	White oval

2. Initiation of cross

By utilizing the identified 10 bivoltine silkworm breeds tolerant to high temperature and high humidity conditions, 12 oval and 30 dumbbell foundation crosses were initiated.

3. Initial evaluation

Twelve oval and thirty dumbbell foundation crosses were screened by rearing at high temperature (35 ± 1°C) and high humidity (85 ± 5%) conditions.

4. Selection of lines

Based on the high pupation rate at high temperature and high humidity conditions, five oval and five dumbbell foundation crosses were short listed. These short listed lines were continued till F_8 generation with exposure to high temperature and high humidity at alternative generations.

5. Hybrid preparation

Likewise, after fixation of the desired traits, all the 25 new possible combinations of hybrids were prepared.

6. Hybrid evaluation

These newly prepared 25 hybrids were screened at high temperature and high humidity conditions along with the bi x bi combinations *viz.*, SK6 × SK7 and B.Con.1 × B.Con.4, as control.

7. Selection of hybrids

After evaluation, promising hybrids with high pupation rate in comparison to the other hybrids and controls *viz.*, SK6 × SK7 and B.Con.1 × B.Con.4 were selected.

viii.Observations / Results duly indicating the output in terms of adding to knowledge; know-how / new packages/ practices / processes / products / innovations developed and their utility and advantages, etc.,

1. Breeding resource material

As a result of the 1st phase of this project, 10 bivoltine silkworm breeds were found to be tolerant to high temperature (35 ± 1°C) and high humidity (85 ± 5%) conditions. These breeds were selected as breeding resource material for the present study.

Table 2: Performance of the selected bivoltine silkworm breeds at normal conditions.

#	Name of the breed	Fecundity	Pupation rate	SCW	SSW	Shell %
1	SK6	496	88.50	1.645	0.305	18.55
2	SK7	536	89.80	1.547	0.302	19.52
3	B.Con.1	587	84.35	1.485	0.280	18.85
4	B.Con.4	565	81.37	1.504	0.279	18.57
5	D6PN	485	87.10	1.464	0.283	19.33
6	SK4C	492	88.30	1.577	0.298	18.87
7	BHR2	524	80.60	1.661	0.309	18.59
8	BHR3	444	81.68	1.598	0.295	18.45
9	ATR29	499	94.80	1.341	0.272	20.3
10	GEN3	452	75.60	1.515	0.305	20.1
Minimum		**444**	**75.60**	**1.341**	**0.272**	**18.45**
Maximum		**587**	**94.80**	**1.661**	**0.309**	**20.30**
Average		**508**	**85.21**	**1.5337**	**0.292**	**19.11**

2. Initiation of cross and evaluation

Table 3: Performance of 12 oval foundation crosses at 35±1°C and 85 ± 5% RH condition.

#	Combinations	Pupation rate
1	**BHR2 x BHR3**	**65.8%**
2	BHR2 X ATR29	50.7%
3	**BHR2 x GEN3**	**64.7%**
4	BHR3 x BHR2	55.8%
5	BHR3 X ATR29	57.6%
6	**BHR3 x GEN3**	**65.3%**
7	ATR29 x BHR2	53.5%
8	**ATR29 x BHR3**	**66.4%**
9	ATR29 x GEN3	59.1%
10	GEN3 x BHR2	56.7%
11	GEN3 x BHR3	54.5%
12	**GEN3 x ATR29**	**65.7%**

Table 4: Performance of 30 dumbbell foundation crosses at 35±1°C and 85 ± 5% RH condition.

#	Combinations	Pupation rate	#	Combinations	Pupation rate
1	**SK6 x SK7**	**65.7%**	16	B.Con.4 x SK6	55.4%
2	SK6 x B.Con.1	48.7%	17	B.Con.4 x SK7	53.7%
3	**SK6 x B.Con.4**	**62.4%**	18	B.Con.4 x B.Con.1	51.7%
4	SK6 x D6PN	50.1%	19	B.Con.4 x D6PN	52.4%
5	SK6 x SK4C	49.8%	20	B.Con.4 x SK4C	50.9%
6	SK7 x SK6	50.4%	21	D6PN x SK6	58.6%
7	**SK7 x B.Con.1**	**63.8%**	22	D6PN x SK7	52.4%
8	SK7 x B.Con.4	52.7%	23	D6PN x B.Con.1	51.4%
9	SK7 x D6PN	54.5%	24	**D6PN x B.Con.4**	**64.3%**
10	SK7 x SK4C	52.4%	25	D6PN x SK4C	51.7%
11	B.Con.1 x SK6	53.7%	26	SK4C x SK6	52.4%
12	B.Con.1 x SK7	50.8%	27	SK4C x SK7	53.4%
13	**B.Con.1 x B.Con.4**	**68.7%**	28	SK4C x B.Con.1	54.5%
14	B.Con.1 x D6PN	49.5%	29	SK4C x B.Con.4	56.7%
15	B.Con.1 x SK4C	50.1%	30	SK4C x D6PN	58.4%

4. Selection of lines

Five oval and five dumbbell foundation crosses based on the high pupation rate at high temperature and high humidity were selected. These lines were continued till F_8 generation with exposure to high temperature and high humidity at alternative generations.

Table 5: Short listed foundation crosses (FCs)

#	Oval FCs	F_8 generation
1	BHR2 x GEN3	HTH1
2	BHR2 x BHR3	HTH2
3	BHR3 x GEN3	HTH3
4	ATR29 x BHR3	HTH4
5	GEN3 x ATR29	HTH5
Dumbbell FCs		
1	SK6 x SK7	HTH6
2	B.Con.1 x B.Con.4	HTH7
3	D6PN x B.Con.4	HTH8
4	SK6 x B.Con.4	HTH9
5	SK7 x B.Con.1	HTH10

- The newly developed breeds were reared at normal temperature and were also subjected to high temperature and high humidity conditions.

Table 6: Rearing performance of newly evolved breeds at normal condition.

#	Breed	Fecundity (No)	ERR (No)	ERR Wt (kg)	Single Cocoon Wt. (g)	Single Shell Wt.(g)	Shell (%)
Oval lines							
1	HTH-1	433	8520	11.200	1.302	0.214	16.43
2	HTH-2	543	9200	12.440	1.463	0.272	18.59
3	HTH-3	580	9420	13.840	1.512	0.281	18.58
4	HTH-4	518	9600	11.960	1.315	0.258	19.60
5	HTH-5	573	9540	13.320	1.472	0.276	18.75
Dumbbell lines							
1	HTH-6	540	8840	11.360	1.357	0.240	17.68
2	HTH-7	516	8580	13.000	1.549	0.248	16.01
3	HTH-8	486	8690	11.120	1.458	0.262	17.96
4	HTH-9	513	9540	13.160	1.439	0.262	18.20
5	HTH-10	461	9120	11.840	1.301	0.218	16.75
Average		**516**	**9105**	**12.324**	**1.417**	**0.253**	**17.86**
CD 5%		**33**	**301**	**0.694**	**0.065**	**0.017**	**0.82**
CV%		**9.01**	**4.62**	**7.870**	**6.42**	**9.13**	**6.39**

Table 7: Rearing performance of newly evolved breeds at 35 ± 1°C and 85 ± 5% RH condition.

#	Breed	Fecundity	Pupation rate	Single cocoon wt. (g)	Single shell wt. (g)	Cocoon shell %
Oval lines						
1	HTH1	525	50.6	1.256	0.227	18.1
2	HTH2	505	52.4	1.254	0.225	17.9
3	HTH3	510	50.7	1.301	0.229	17.6
4	HTH4	495	50.4	1.265	0.225	17.8
5	HTH5	500	51.2	1.213	0.218	17.9
Dumbbell lines						
1	HTH6	515	50.8	1.245	0.209	16.8
2	HTH7	500	50.2	1.185	0.204	17.2
3	HTH8	505	51.6	1.205	0.208	17.3
4	HTH9	500	50.8	1.304	0.228	17.6
5	HTH10	505	50.2	1.267	0.225	17.8
Average		506	50.88	1.249	0.219	17.6
CD 5%		19.51	1.53	0.09	0.02	0.88
CV%		1.73	1.35	3.13	4.29	2.24

5. Hybrid preparation

After fixation of the desired traits, 25 possible combinations of hybrids were prepared.

Table 8: New 25 possible combinations of hybrids were prepared.

#	Hybrid	#	Hybrid	#	Hybrid	#	Hybrid
1	HTH1 x HTH6	8	HTH2 x HTH8	15	HTH3 x HTH10	22	HTH5 x HTH7
2	HTH1 x HTH7	9	HTH2 x HTH9	16	HTH4 x HTH6	23	HTH5 x HTH8
3	HTH1 x HTH8	10	HTH2 x HTH10	17	HTH4 x HTH7	24	HTH5 x HTH9
4	HTH1 x HTH9	11	HTH3 x HTH6	18	HTH4 x HTH8	25	HTH5 x HTH10
5	HTH1 x HTH10	12	HTH3 x HTH7	19	HTH4 x HTH9	C-1	SK6 x SK7 (Control)
6	HTH2 x HTH6	13	HTH3 x HTH8	20	HTH4 x HTH10	C-2	B.Con 1 x B.Con 4 (Control)
7	HTH2 x HTH7	14	HTH3 x HTH9	21	HTH5 x HTH6		

6. Hybrid evaluation

All the 25 new hybrids were screened at high temperature and high humidity conditions along with the bi x bi combinations *viz.*, SK6 × SK7 and B.Con.1 × B.Con.4, as control.

Table 9: Rearing performance of 25 new hybrids at 35 ± 1°C and 85 ± 5% RH conditions.

#	Breed	Fecundity (No.)	Hatching (%)	ERR (wt.) (Kg.)	Single cocoon Wt.(g)	Single shell Wt.(g)	Shell %
1	HTH 1 x HTH 6	495	86	6.133	1.344	0.228	17.45
2	HTH 1 x HTH 7	488	95	5.000	1.570	0.255	16.24
3	HTH 1 x HTH 8	497	96	7.233	1.509	0.264	17.50
4	HTH 1 x HTH 9	512	97	9.000	1.540	0.265	17.21
5	HTH 1 x HTH 10	513	97	8.100	1.516	0.265	17.48
6	HTH 2 x HTH 6	469	92	4.733	1.446	0.270	18.67
7	HTH 2 x HTH 7	510	95	6.200	1.440	0.258	17.92
8	HTH 2 x HTH 8	503	98	8.800	1.503	0.274	18.23
9	HTH 2 x HTH 9	461	96	6.933	1.364	0.253	18.55
10	HTH 2 x HTH 10	516	94	6.867	1.433	0.259	18.07
11	**HTH 3 x HTH 6**	**503**	**95**	**9.600**	**1.415**	**0.251**	**17.73**
12	HTH 3 x HTH 7	447	94	8.267	1.411	0.262	18.57
13	HTH 3 x HTH 8	462	96	7.733	1.402	0.259	18.47
14	HTH 3 x HTH 9	432	96	11.000	1.515	0.265	17.49
15	HTH 3 x HTH 10	485	97	9.600	1.405	0.233	16.58
16	HTH 4 x HTH 6	417	83	10.400	1.435	0.270	18.82
17	HTH 4 x HTH 7	429	94	9.100	1.515	0.272	17.95
18	HTH 4 x HTH 8	362	93	9.000	1.609	0.287	17.84
19	**HTH 4 x HTH 9**	**461**	**94**	**9.250**	**1.485**	**0.262**	**17.64**
20	HTH 4 x HTH 10	499	97	5.733	1.550	0.273	17.61
21	HTH 5 x HTH 6	489	89	7.150	1.456	0.252	17.31
22	HTH 5 x HTH 7	498	96	7.967	1.426	0.247	17.32
23	HTH 5 x HTH 8	501	98	8.950	1.433	0.264	18.42
24	HTH 5 x HTH 9	486	96	7.667	1.377	0.255	18.52
25	HTH 5 x HTH 10	491	67	9.150	1.450	0.238	16.41
Control	SK6 x SK7	521	92	7.600	1.272	0.205	16.12
Control	B.Con 1 x B.Con 4	504	94	6.733	1.336	0.235	17.59
Average		**479.6**	**93**	**7.922**	**1.450**	**0.256**	**17.693**
Standard deviation		**35.82**	**6.16**	**1.547**	**0.076**	**0.017**	**0.728**
t-value		**68.28****	**77.08****	**26.104****	**97.491****	**78.44****	**23.93****

** indicates $p<0.01$

Table 10: Rearing performance of 25 new hybrids at normal conditions.

#	Breed	ERR (wt.) (kg.)	Single cocoon Wt.(g)	Single shell Wt.(g)	Shell %
1	HTH 1 x HTH 6	9.333	1.544	0.286	18.52
2	HTH 1 x HTH 7	8.200	1.670	0.293	17.54
3	HTH 1 x HTH 8	10.433	1.609	0.302	18.77
4	HTH 1 x HTH 9	12.200	1.640	0.303	18.48
5	HTH 1 x HTH 10	11.300	1.616	0.303	18.75
6	HTH 2 x HTH 6	4.933	1.546	0.308	19.92
7	HTH 2 x HTH 7	9.400	1.540	0.296	19.22
8	HTH 2 x HTH 8	12.000	1.603	0.312	19.46
9	HTH 2 x HTH 9	10.133	1.464	0.291	19.88
10	HTH 2 x HTH 10	10.067	1.533	0.297	19.37
11	**HTH 3 x HTH 6**	**12.800**	**1.515**	**0.289**	**19.07**
12	HTH 3 x HTH 7	11.467	1.511	0.300	19.85
13	HTH 3 x HTH 8	4.933	1.502	0.297	19.77
14	HTH 3 x HTH 9	14.200	1.615	0.303	18.76
15	HTH 3 x HTH 10	13.800	1.505	0.271	18.01
16	HTH 4 x HTH 6	12.600	1.535	0.308	20.07
17	HTH 4 x HTH 7	12.300	1.615	0.310	19.20
18	HTH 4 x HTH 8	14.200	1.709	0.325	19.02
19	**HTH 4 x HTH 9**	**10.400**	**1.585**	**0.310**	**19.56**
20	HTH 4 x HTH 10	4.933	1.650	0.311	18.85
21	HTH 5 x HTH 6	10.350	1.556	0.290	18.64
22	HTH 5 x HTH 7	11.167	1.526	0.285	18.68
23	HTH 5 x HTH 8	14.150	1.533	0.302	19.70
24	HTH 5 x HTH 9	10.867	1.477	0.293	19.84
25	HTH 5 x HTH 10	12.750	1.550	0.276	17.81
Control	SK6 x SK7	10.800	1.372	0.243	17.71
Control	B.Con 1 x B.Con 4	9.933	1.436	0.273	19.01
Average		**10.728**	**1.554**	**0.295**	**19.017**
Standard deviation		**2.561**	**0.073**	**0.016**	**0.698**
t-value		**21.369****	**108.60****	**93.947****	**138.97****

** indicates $p<0.01$

Table 11: **Percentage reduction of pupation rate of new hybrids in treated over control batches.**

#	Hybrid	25± 1°C & 65 ± 5 %	35 ± 1°C & 85 ± 5 %	Percentage reduction
1	HTH1 x HTH6	74	56	-24.32
2	HTH1 x HTH7	78	63	-19.23
3	HTH1 x HTH8	86	53	-38.37
4	HTH1 x HTH9	85	65	-23.52
5	HTH1 x HTH10	83	65	-21.68
6	HTH2 x HTH6	85	61	-28.23
7	HTH2 x HTH7	90	45	-50.00
8	HTH2 x HTH8	92	60	-34.78
9	HTH2 x HTH9	89	66	-25.84
10	HTH2 x HTH10	87	65	-25.28
11	**HTH3 x HTH6**	**92**	**77**	**-16.30**
12	HTH3 x HTH7	94	56	-40.42
13	HTH3 x HTH8	92	76	-17.39
14	HTH3 x HTH9	91	75	-17.58
15	HTH3 x HTH10	87	67	-22.98
16	HTH4 x HTH6	90	74	-17.77
17	HTH4 x HTH7	90	59	-34.44
18	HTH4 x HTH8	86	68	-20.93
19	**HTH4 x HTH9**	**91**	**76**	**-16.48**
20	HTH4 x HTH10	92	65	-29.34
21	HTH5 x HTH6	87	55	-36.78
22	HTH5 x HTH7	86	70	-18.60
23	HTH5 x HTH8	89	68	-23.59
24	HTH5 x HTH9	87	61	-29.88
25	HTH5 x HTH10	91	67	-26.37
Control	SK6 x SK7	88	72	-18.18
Control	B.Con 1 x B.Con 4	87	65	-25.28

7. Selection of hybrids

After evaluation, promising hybrids with high pupation rate in comparison to the other hybrids and controls *viz.*, SK6 × SK7 and B.Con.1 × B.Con.4 were selected. Two hybrids namely HTH3 × HTH6 and HTH4 × HTH9 were found to be more tolerant to high temperature and high humidity conditions when compared to other hybrids.

ix. Discussion

Efforts of silkworm breeders of various institutions in India from the 70s to 90s have resulted in the development of many bivoltine silkworm breeds *viz.* CSR2, CSR3, CSR4, CSR5, CSR6 *etc.* with improved productivity and fibre quality as part of breeding program that was initiated in the 90s in collaboration with Japanese breeders under JICA phase 1, using the Japanese hybrids as breeding resource materials (Krishnaswamy, 1983; Datta, 1984). Even though they are known for their productive merit, absence of genetic plasticity to buffer against the tropical environmental stresses acts as a constraint to tap the full economic potential of these hybrids. To overcome these drawbacks, Efforts made for the development of temperature tolerant bivoltine breeds has led to the development of robust bivoltine hybrids like CSR18 × CSR19, 5HT × 8HT and SR1 × SR5 for rearing in high temperature conditions of summer (Suresh Kumar *et al.*, 2002; Sudhakara rao *et al.*, 2006). Recently, Lakshmi *et al.* (2011) has developed new breeds tolerant to high temperature conditions by exposing the known thermotolerant bivoltine breeds to high temperature at alternative generations. These newly developed breeds were better than their parents both in terms of thermotolerance and productivity. Similarly, Moorthy *et al* (2007) developed two robust bivoltine silkworm breeds under North-Eastern regions by applying biochemical marker assisted selection. Therefore, the performance of silkworm breeds can be improved by selection in the environment in which it is subsequently exploited. However, Shirota (1992) and Tazima and Ohnuma (1995) confirmed that thermotolerance trait in silkworm is inherited genetically and can also be improved by applying appropriate selection environments and procedures.

In this project five each of new oval and dumbbell bivoltine silkworm breeds were developed / evolved. Newly developed silkworm breeds exhibited considerable variations in the studied rearing traits both under normal conditions as well as high temperature and high humidity conditions which can be attributed to the variations in the genetic material, environment and G × E interactions. Utilizing the 10 new breeds, 25 different hybrid combinations were made. Out of them, two new hybrids *viz.* HTH3 × HTH6 and HTH4 × HTH9 showed superiority with higher survival than the control hybrids (SK6 × SK7 and B.Con 1 × B.Con 4) at 35 ± 1°C and 85 ± 5% RH conditions. Further, the higher survival recorded for the new hybrids, HTH3 × HTH6 and HTH4 × HTH9 compared to the parents corroborate the observations of Suresh Kumar and Yamamoto (1995) who indicated higher tolerance (survival) in hybrids than pure breeds. It is observed from the present study that there is considerable improvement in silk yield contributing traits compared to the control hybrids, SK6 × SK7 and B.Con 1 × B.Con 4 thus corroborate the earlier observations of Lakshmi *et al.*, (2011). Based on the rearing performance of the hybrids at normal and at 35 ± 1°C and 85 ± 5% RH conditions, in comparison to the control hybrids and other test hybrids it was observed that HTH3 × HTH6 and HTH4 × HTH9 were more tolerant to high temperature and high humidity conditions.

x. Inference / Recommendations

1. Two new hybrids namely HTH3 × HTH6 and HTH4 × HTH9 were found to be tolerant to high temperature and high humidity of 35 ± 1°C & 85 ± 5 % conditions. They were on par with the controls both in terms of tolerance and productivity merits.

2. Therefore, suggesting in house testing of the selected new hybrids along with the controls was proposed and approved for 2nd phase of this project in the 46th RAC.

xi. Applications made for patenting / commercialization if any

Nil

xii. References

Krishnaswami, S. (1978) New technology of silkworm rearing. Bulletin No.2, Central Sericultural Research and Training Institute, Mysore, Central Silk Board, India. 1 – 23.

Datta, R.K. (1984) Gudielines for bivoltine rearing. Bulletin of Central Silk Board, Bangalore.

Suresh Kumar N., Basavaraja, H.K., Kishor Kumar, C.M., Mal Reddy, N. and Datta, R.K. (2002) On the breeding of CSR18 x CSR19 a robust hybrid of silkworm, *Bombyx mori* L for tropics. *Int. J. Indus. Entomol.*5(2): 153 – 162.

Sudhakara Rao , P., Datta, R.K. and Basavaraja, H.K.(2006) Evolution of thermo tolerant bivoltine hybrids of the silkworm (*Bombyx mori* L.) for tropical climate. Indian J. Seric. 45(1): 15 – 20.

Lakshmi H, Chandrashekharaiah, Babu MR, Raju PJ, Saha AK and Bajpai AK (2011) HTO5 x HTP5, The new bivoltine silkworm (*Bombyx mori* L.) hybrid with thermo-tolerance for tropical areas. *Int. J. Pl. Ani. and Env. Sci.* 1, 88-104.

Moorthy, S.M., Das, S.K., Kar, N.B. and Raje Urs, S. (2007). Breeding of bivoltine breeds of *Bombyx mori* L. suitable for variable climatic conditions of the tropics. Int. J. Indust. Entomol. 14(2): 99 –105.

Shirota, T. (1992) Selection of healthy silkworm strain through high temperature rearing of fifth instar larvae. Reports of the Silk Sci. Res. Inst. 40: 33 – 40.

Tazima, Y and Ohnuma, A. (1995) Preliminary experiments on the breeding procedure for synthesizing a high temperature resistant commercial strain of the silkworm, *Bombyx mori* L. *Silk Sci. Res. Inst. Japan* 43: 1 – 16.

Suresh Kumar, N and Yamamoto, T. (1995) Maternal effect of resistance to high temperature in F1 hybrids between polyvoltine and bivoltine silkworm race. Paper presented at the Annual Conference held on 9/10-11-98 at *Nigata*, Japan

xiii. Papers Published

Nil

xiv. Summary

During the summer season, sericulturists in tropical areas like India face unfavourable environmental conditions that directly affect the silk production. Of them, the main factor in constraining silkworm growth and silk productivity is high temperature. A negative relationship is found between high temperature and silk yield. Rearing thermotolerant silkworm breeds is one of the most effective methods to increase silk productivity in summers. In the context, ten bivoltine silkworm breeds tolerant to high temperature (35±1°C) and high humidity (85±5%) were shortlisted as breeding resource material by screening 38 existing thermo tolerant silkworm breeds from different sericultural research stations. Breeding program was initiated by preparing 12 oval and 30 dumbbell foundation crosses from the identified breeding resource materials. Based on the high pupation rate at high temperature (35 ± 1°C) and high humidity (85 ± 5%) conditions, five oval and five dumbbell foundation crosses were short listed. These shortlisted foundation crosses were continued to F_8 generations with exposure to high temperature and high humidity at alternative generations. The selection was also based on the pupation rate at normal as well as high

temperature and high humidity conditions. Utilizing the new breeds, 25 new possible combinations of hybrids were prepared and were tested at 35 ± 1°C and 85 ± 5% RH with control hybrids (SK6 × SK7 and B.Con 1 × B.Con 4). Among them, two new hybrids namely HTH3 × HTH6 and HTH4 × HTH9 were found to be tolerant to high temperature and high humidity conditions. They were on par with the control hybrids both in terms of tolerance and productivity merits.

xv. Expenditure details

(In lakh Rupees)

ITEM				
	1ST Year	**2nd Year**	**3rd Year**	**Total**
A. Recurring	-	-	-	-
1. **Remuneration/salaries**	-	-	-	-
2. **Consumables**	0.06	0.06	0.06	0.18
3. **Travel** 4. **Contingency**	0.05	0.05	0.05	0.15
B. **Non-recurring** **Permanent equipment**	-	-	-	-
Grand Total (A+B)	**0.11**	**0.11**	**0.11**	**0.33**

xvi) CERTIFICATE

Certified that the study has been carried out and financial expenditure incurred for executing the study are in accordance with the declaration/certification unknotted at the time of submission of the proposal and sanction obtained from time to time thereafter as per the revisions made.

N. Chandrakanth 29/01/18

Signature of the Principal Investigator

श्री एन. चन्द्रकान्त/Shri N. Chandrakanth
वैज्ञानिक-बी / Scientist-B
के.रे.उ.अ.व.प्र.सं./CSR&TI
केन्द्रीय रेशम बोर्ड / Central Silk Board
बहरमपुर-742101/ Berhampore-742101
मुर्शिदाबाद (प.बं.)/ Murshidabad (W.B.)

29/01/18

Co-investigator(s)

Dr. A. K. Verma, M.Sc., Ph.D.
Scientist-D
CSR & TI, Central Silk Board
Ministry of Textiles, Govt. of India
Berhampore-742101, W.B.

Signature of Director

DIRECTOR'S COMMENT

Regarding this project, it was observed that the project was concluded as per the milestone successfully from July 2015 to June 2017. In this project a total of 10 new bivoltine breeds were developed and authorizing them. The two new hybrids viz. HTH-3 × HTH-6 & HTH-4 × HTH-9 tolerant to high temperature and high humidity were identified.

5/2/18

Signature of Director

(डॉ. कणिका त्रिवेदी)
(Dr. Kanika Trivedy)
निदेशक/Director
केन्द्रीय रेशम उत्पादन अनुसंधान
एवं प्रशिक्षण संस्थान, बहरमपुर
Central Sericultural Research &
Training Institute, Berhampore 742101