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Evaluation of Silkworm Hybrids Tolerant to the High Temperature and High Humidity Conditions of West Bengal

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***Abstract*: West Bengal is one of the major mulberry silk producing states of India. The hot and humid climatic condition of West Bengal is the main factor restricting the bivoltine silkworm rearing during unfavourable seasons. This study aims to evaluate the twenty-five bivoltine hybrids (oval × dumbbell) identified as tolerant to high temperature and high humidity conditions of West Bengal. All the hybrids were reared at 25 ± 1°C till 5th instar 2nd day. On 3rd day of 5th instar, 100 larvae each of the twenty-five bivoltine hybrids were reared at 35 ± 1°C and 85 ± 5% RH with SK6 × SK7 and B.Con 1 × B.Con 4 as control hybrids for 6 hours every day to till spinning. Data on economically important rearing traits were collected. One sample t test revealed significant differences (p<0.01) among the traits. Based on the high pupation percentage at 35 ± 1°C and 85 ± 5% RH and low reduction in pupation percentage, HTH3 × HTH6 and HTH4 × HTH9 were identified as high temperature and high humidity tolerant hybrids in comparison with control hybrids. These hybrids also performed better in terms of cocoon characters in comparison to the control hybrids. Therefore, HTH3 × HTH6 and HTH4 × HTH9 are identified as promising hybrids that are suitable for rearing under the high temperature and high humidity conditions of West Bengal. However, field trial of these hybrids along with the control hybrids has to be done for confirming these findings.**

***Keywords*: High temperature, high humidity, pupation percentage, reduction in pupation percentage**

1. Introduction

India holds second position among the mulberry silk producing countries of the world with a bulk quantity raw silk contributed by the polyvoltine × bivoltine hybrids. Since, the quality of raw silk produced by polyvoltine × bivoltine is of inferior grade, there is necessity for the development of bivoltine sericulture in the country with more emphasis to improve qualitative bivoltine silk production. The main constrains in the development of bivoltine sericulture in the tropical regions is lack of high temperature and high humidity tolerant breeds because the rearing of silkworms at high temperature and high humidity conditions result in decline of the economically important qualitative and quantitative traits. This effect is more pronounced in bivoltines than multivoltines (Kumari et al., 2011). To overcome this drawback, compatible bivoltine hybrids for rearing under tropical conditions were developed (Suresh Kumar et al., 2002, 2006; Lakshmi et al., 2011) and selected for rearing in field conditions. However, the attempts to spread bivoltine silkworm breeds / hybrids throughout the sericulture belt of India resulted in extensive crop loss, especially in the hot and humid climatic conditions of tropics (Chavadi et al., 2006). West Bengal is one of the major mulberry silk producing states of India. The sericulture based climatic condition of West Bengal is broadly categorized into favorable (October to March) and unfavorable (April to September). The unfavorable climate is characterized by high temperature and high humidity conditions due to which the bivoltine rearing is not done during unfavorable seasons. Therefore, farmers are forced to restrict their rearing only with popular polyvoltines or poly x bi hybrids during adverse seasons though they produce inferior quality of silk. However, the hot climatic conditions prevailing in West Bengal is not conducive to rear the bivoltines already available due to lack of tolerance to high temperature and high humidity (Moorthy et al., 2007). Therefore, there is an urgent need to develop high temperature and high humidity tolerant bivoltine breeds / hybrids which can withstand the adverse climatic conditions of the tropics.

2. Materials and methods

A. *Silkworm rearing and thermal treatment*

Ten silkworm breeds were developed using thermo-tolerant parents by applying high temperature and high humidity treatment at alternative generations and selecting the survived and thermo-tolerant one for further line development. Likewise, up to F8 generations were done and 10 (5 oval - HTH1, HTH2, HTH3, HTH4, HTH5; 5 dumbbell - HTH6, HTH7, HTH8, HTH9 and HTH10) high temperature and high humidity tolerant bivoltine silkworm breeds were developed. Utilizing these breeds, all the possible twenty-five oval × dumbbell combinations were prepared and reared at 25 ± 1°C and 35 ± 1°C with 85 ± 5% humidity. Two hybrids namely SK6 × SK7 and B.Con 1 × B.Con 4 were considered as control hybrids to compare with the performance of newly developed bivoltine hybrids. Silkworm rearing was conducted following the standard method under recommended temperature and humidity conditions till 2nd day of 5th instar as suggested by Krishnaswami et al. (1973). From 3rd day 5th instar onwards the larvae of each hybrid (100 larvae) were given high temperature treatment in a SERICATRON (Environment chamber with temperature and humidity control) at 35 ± 1°C with 85 ± 5% humidity for 6 hours duration every day to till spinning. Silkworm rearing was continued as suggested by Kato et al. (1989) and Suresh Kumar et al. (2001). The larvae reared at 25 ± 1°C under normal conditions were considered as control. The experiment was performed in duplicate. The ripened larvae were mounted on plastic mount ages. On the 7th day of spinning, harvesting was done. Cocoons were de flossed and the defective ones were sorted out. Assessment of all the breeds was carried out on the same day of development.

B. Rearing traits

During silkworm rearing, data on seven quantitative traits were collected separately for control and treatment batches. The traits like fecundity, hatching percentage, pupation percentage (%), ERR by weight (kg), single cocoon weight (g), single shell weight (g) and shell percent (%) were noted. The percentage change in the performance of the breeds in treated over control with respect to their pupation percentage was also calculated. This genetic trait was considered as the index of thermo-tolerance in silkworm. Percentage change / reduction in the pupation percentage was calculated following Kumari et al. (2011). One sample t test was performed to assess the significant differences between the means.

3. Results and discussion

Twenty-five hybrid combinations (oval × dumbbell) were reared for evaluating their performances under normal and, high temperature and high humidity conditions. Based on the pupation percentage at 25 ± 1°C and at 35 ± 1°C and 85 ± 5% RH, and percentage reduction in pupation percentage (Table 1), in comparison to the control hybrids (SK6 × SK7 and B.Con 1 × B.Con 4) and other test hybrids it was observed that HTH3 × HTH6 and HTH4 × HTH9 were more tolerant to high temperature and high humidity conditions. They also showed consistency in other quantitative parameters indicating better hybrid vigour. Many silkworm breeders in the sericultural countries succeeded in the development of bivoltine silkworm hybrids by exploiting the hybrid vigour that are reflected in the improvement of several qualitative and economic traits (Harada, 1961; Mano et al., 1982; He et al., 1991; Chen et al., 1994). Notable reduction in the rearing traits at 35 ± 1°C and 85 ± 5% in comparison to 25 ± 1°C was also observed (Table 2 and 3). During higher temperatures, evapotranspiration of water at body surfaces and respiratory epithelium of tracheal system of silkworm significantly increases (Rahmathulla, 2012). This problem in association with loss of water from mulberry leaves through evaporation resulting in poor moisture content leading to the faster drying of the same makes it difficult for the silkworm to ingest it. This results in non-feeding or poor feeding of leaves by silkworm, which negatively affects the growth and in turn the productivity of silkworm (Suresh Kumar et al., 2002). These processes jointly increase the vulnerability of other biological processes to heat stress resulting in decline in the performance of the silkworm (Kumari et al., 2011). In this study, the rearing traits were gradually decreased at high rearing temperature. Similar observation of decline in the rearing traits due to high temperature in silkworm was also reported by Kumar et al. (2002) and, Singh and Suresh Kumar (2010). The one sample t test revealed significant difference among all the combinations ($p<0.01$) for all the traits studied at 25 ± 1°C as well as 35 ± 1°C and 85 ± 5% RH. Earlier efforts of silkworm breeders of various sericulture institutions in India have resulted in the development of many bivoltine silkworm breeds with improved productivity and fiber quality (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 thermo-tolerant bivoltine breeds to high temperature at alternative generations. These newly developed breeds were better than their parents both in terms of thermo-tolerance 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 thermo-tolerance trait in silkworm is inherited genetically and can also be improved by applying appropriate selection environments and procedures. 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, high temperature and high humidity conditions, in comparison to the control hybrids and other test hybrids it can be observed that HTH3 × HTH6 and HTH4 × HTH9 were more tolerant to high temperature and high humidity conditions. However, field trial of these hybrids along with the control hybrids has to be performed for further confirmation of these findings.

4. Conclusion

This paper presented the evaluation of silkworm hybrids tolerant to the high temperature and high humidity conditions of West Bengal.

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Table 1
Percentage reduction in pupation percentage of 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

Table 2
Rearing performance of 25 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 3
Rearing performance of 25 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**