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Evaluation of Thermotolerant Bivoltine Silkworm Breeds through Cocoon Yield and Filament Characteristics against *Beauveria bassiana* (Bals-Criv.) Vuill. Inoculation

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Silkworm, *Bombyx mori* L. being a poikilothermic insect is susceptible to both biotic and abiotic factors. The present study was carried to assess the performance of few thermotolerant bivoltine silkworm breeds under high temperature treatment (36 ± 1º C for 6 hours) and *Beauveria bassiana* (Bals-Criv.) Vuill. inoculation (6.86×10^4 spores / ml @ 0.5 ml / silkworm). Seven thermotolerant bivoltine silkworm breeds *viz.,* B1, B2, B4, B6, B8, APS12, and APS45 and two popular bivoltine breeds, CSR2 and CSR4 breeds and one popular multivoltine breed Pure Mysore were utilized for the study. Among the thermotolerant breeds studied, the breed B4 was found to perform better with respect to cocoon yield by number, cocoon yield by weight, average filament length, filament weight

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under both high temperature treatment and *B. bassiana* inoculation. CSR4 breed was found to be least performer for all the parameters. Therefore, the breed B4 can be a better parent for hybridization and improvement under both the stress conditions.

Keywords: Bivoltine silkworm breeds; cocoon yield; filament length; high temperature treatment; Beauveria bassiana.

1. INTRODUCTION

Sericulture in India is being practiced predominantly in tropical regions and to limited extent in temperate region. The existing tropical situation in the country provides scope for the exploitation of multivoltine breeds / hybrids as these breeds show the inherent capacity to perform well under varied and / fluctuating environmental conditions. But the quality of multivoltine silk is low compared to the existing International Standards. To meet the International Standards, it is necessary to shift to bivoltine sericulture which assures the production of quantitatively and qualitatively superior cocoons. It is well established fact that, unlike multivoltine silkworms, bivoltines are more vulnerable to different stresses under tropical condition as these bivoltines have originated from temperate region. Therefore, it is imperative to evolve bivoltine silkworm breeds which can give stable yields under different stress conditions. Keeping this in view, the study was envisaged to assess of few thermotolerant bivoltine silkworm breeds under two different stress conditions *i. e.,* high temperature treatment and *Beauveria bassiana* infection. Ten thermotolerant silkworm breeds *viz.,* B1, B2, B3, B4, B5, B6, B8, APS12 and APS45 were evaluated under muscardine infection in our previous study and results revealed that, B4 breed performed better with respect to single cocoon weight, pupal weight, shell weight, cocoon shell ratio, filament length and filament weight, followed by B1 and B8 breeds [1].

2. MATERIALS AND METHODS

2.1 Locale of the Study

The investigation was carried out at the Department of Sericulture, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bengaluru-560 065. The experimental site is located in the eastern dry zone (zone 5) of Karnataka at 12º58’ N latitude and 77º35’ E longitude and at an altitude of 930 m above mean sea level.

2.2 Treatment Details

Assessment of ten selected silkworm breeds under high temperature treatment and *Beauveria bassiana* inoculation was carried out at the Department of Sericulture, UAS, GKVK, Bengaluru. Seven thermotolerant silkworm breeding lines namely, B1, B2, B4, B6 and B8 and APS12 and APS45 were procured from Central Sericultural Research and Training Institute, Mysuru and Andhra Pradesh State Sericulture Research and Development Institute, Hindupur, respectively. Along with these seven breeds, three popular silkworm breeds *viz.,* CSR2, CSR4 and Pure Mysore were also used for the investigation. The characteristic features of each breed and source of collection of their layings is detailed in Table 1. Silkworms were reared in bulk up to fourth moult following the standard rearing practices given by [2] and V-1 mulberry leaves were fed to silkworm till spinning.

Newly ecdysed fifth instar silkworms (50 silkworms per replication in 3 replication each) were used to impose the treatment. All the ten breeds were maintained in two sets for two different treatments *i. e.,* high temperature and *B. bassiana* inoculation. One set of all the 10 breeds were treated with high temperature *i. e.,* 36±1 ºC and 85±5 per cent relative humidity using BOD incubator. The treatment was given for first six days of fifth instar for duration of six hours daily (10.00 to 16.00 hours) [3] and the silkworms were fed twice a day. Another set of all the breeds were topically inoculated with *B. bassiana* spore suspension using an atomizer and LC_{50} of 68,625.71 spores per ml for thermotolerant breeds was used for the study [4] and silkworms were fed thrice a day. Simultaneously, control batch was also maintained.

Observations on cocoon yield by number (Number per 10,000 larvae), cocoon yield by weight (g per 10,000 larvae), filament length (m), filament weight (g) and denier were recorded. The data obtained were analysed using completely randomized block design [5].

Table 1. Characteristic features of the silkworm breeds utilized for the experiment

Sl. No.	Breeds	Larval marking	Cocoon colour	Cocoon shape	Source of Collection	Feature
1	B1	Plain	White	Oval	CSRTI, Mysore	Bivoltine, Thermotolerant
2	B2	Plain	White	Oval	CSRTI, Mysore	Bivoltine, Thermotolerant
3	B4	Plain	White	Oval	CSRTI, Mysore	Bivoltine, Thermotolerant
4	B6	Marked	White	Peanut / Dumbell	CSRTI, Mysore	Bivoltine, Thermotolerant
5	B8	Marked	White	Peanut / Dumbell	CSRTI, Mysore	Bivoltine, Thermotolerant
6	APS12	Plain	White	Peanut / Dumbell	APSSRDI, Hindupur	Bivoltine, Thermotolerant
7	APS45	Plain	White	Peanut / Dumbell	APSSRDI, Hindupur	Bivoltine, Thermotolerant
8	CSR2	Plain	White	Oval	CSRTI, Mysore	Bivoltine, Productive
9	CSR4	Plain	White	Peanut / Dumbell	CSRTI, Mysore	Bivoltine, Productive
10	Pure Mysore	Plain	Greenish yellow	Spindle	Seed Area, Kunigal	Multivoltine, Hardy

3. RESULTS AND DISCUSSION

3.1 Cocoon Yield by Number (Number per 10,000 Larvae)

After being subjected to thermal stress, the thermotolerant silkworm breeds showed significant difference for cocoon yield by number per 10,000 larvae. Significantly highest cocoon number was recorded in Pure Mysore breed (10,000 per 10,000 larvae) followed by CSR2, B4, B6 and APS12 breeds (9,111.11, 9,066.67 and 9,000.00 each per 10,000 larvae, respectively) and significantly lowest cocoon number was recorded in B2 breed (4,800 per 10,000 larvae). Highest reduction in cocoon yield by number was in B2 breed (52.00 %) followed by B8 breed (17.78 %) as against no change in Pure Mysore breed over their respective controls (Table 2).

Significant differences were recorded for cocoon yield by number among the thermotolerant silkworm breeds when inoculated with *B. bassiana* spores. Significantly highest cocoon yield by number was exhibited by Pure Mysore breed (10,000 per 10,000 larvae) followed by B2 breed (8,400.00 per 10,000 larvae) which was on par with B1 and B4 breeds (7,733.33 and 7,400.00 per 10,000 larvae, respectively). APS12 breed (4,888.89 per 10,000 larvae) showed significantly lowest cocoon yield by number followed by APS45 and B6 breeds (5,466.67 and 5,933.33 per 10,000 larvae, respectively). The per cent decrease in cocoon number was maximum in APS12 breed (51.11%) as against no change in Pure Mysore breed over their respective controls (Table 2).

Kumari et al. [6] screened twenty silkworm breeds for thermotolerance at 36±1º C and results indicated that, the cocoon yield by number per 10,000 larvae ranged from 2191 to 7190 per 10,000 larvae and in the present finding the same was in the range from 4,800.00 to 10,000.00 cocoons per 10,000 larvae. Lakshmi et al. [7] recorded 9,200 cocoons per 10,000 larvae at 32±1ºC in APS12 thermotolerant bivoltine silkworm breed. At high temperature treatment of 36±1º C, significantly highest cocoon yield by number was noticed in the breed APS45 (880.00 per 1,000 worms) followed by APS12 and B4 breeds (853.33 and 846.67 Number per 1,000 worms, respectively) [8]. In the present finding, APS12 recorded 9,000.00 cocoons per 10,000 larvae followed by B4 breed (9,066.67 cocoons per 10,000 larvae) which is in line with the above findings.

Among the bivoltine breeds, B2, B1 and B4 yield highest number of good cocoons under *B. bassiana* inoculation and it was least in CSR4 breeds [9]. Keerthana et al. [8] recorded significantly highest number of cocoons in breed B4 (620 per 1,000 worms) followed by B1 (500.00 per 1,000 worms) under *B. bassiana* inoculation. The present findings are in line with the above findings where B1 and B4 breed recorded maximum cocoon yield by number than any other thermotolerant silkworm breeds under *B. bassiana* infected condition. In the present study B4 breed alone could perform better with respect to cocoon yield by number under both thermal stress condition and *B. bassiana* inoculation.

3.2 Cocoon Yield by Weight (g per 10,000 Larvae)

The thermotolerant silkworm breeds showed significant variation for cocoon yield by weight under thermal treatment. CSR2 breed showed significantly highest (17,873.33 g per 10,000 larvae) cocoon yield by weight per 10,000 larvae followed by B4 and APS45 breeds (17,556.67 and 17,256.67 g per 10,000 larvae, respectively). Significantly lowest cocoon yield by weight was noticed in Pure Mysore breed (12,053.33 g per 10,000 larvae) followed by B8 and CSR4 breeds (14,016.67 and 15,216.67 g per 10,000 larvae, respectively). Highest reduction in cocoon yield by weight was observed in CSR4 breed (9.46%) and it was least in the breed B8 (1.06%) as compared to their controls (Table 2).

B. bassiana inoculation to all the ten silkworm breeds showed significantly different results for cocoon yield by weight per 10,000 larvae. Significantly highest cocoon yield by weight was recorded in Pure Mysore breed (9,320.67 g per 10,000 larvae) followed by B4 and B1 breeds (8,466.80 and 7,997.92 g per 10,000 larvae, respectively). APS12 breed exhibited significantly lowest value (4,130.95 g per 10,000 larvae) for cocoon yield by weight which was on par with CSR4 and APS45 breeds (4,222.57 and 4,643.93 g per 10,000 larvae, respectively). Highest reduction in cocoon yield was observed in APS12 breed (70.55%) followed by APS45, B6 and CSR4 breeds (67.42, 65.83 and 64.30%, respectively) Least reduction in cocoon yield by weight was observed in Pure Mysore (12.02%) followed by B2 (51.20%), B1 (54.29%) and B8 (54.51%) (Table 2).

Earlier findings on the effect of high temperature treatment in CSR18 and CSR19 thermotolerant silkworm breed reveal yields of 823 g per 1,000 worms and 793 g per 1,000 worms, respectively at 36±1º C and relative humidity 85±5 per cent [10,11]. SR1 and SR4 thermotolerant breeds could produce cocoon yield of 1,353 g per 1,000 worms and 1,381 g per 1,000 worms, respectively at 36±1º C and 85±5 per cent [3]. Lakshmi et al. [7] recorded cocoon yield of 1,490 g per 1,000 larvae in APS12 breed at 32±1º C. APS45, B4 and B8 breeds showed maximum cocoon yield by weight (1,409.80, 1,387.33 and 1,370.33 g per 1,000 worms, respectively) under high temperature treatment of 36±1ºC [8]. The present findings are in line with the above with highest cocoon yield in CSR2, B4 and APS45 breeds.

Keerthana et al. [8] recorded highest cocoon yield by weight under *B. bassiana* inoculation in breed B4 (710.93 g per 1000 worms). In the present study B4 and B1 breeds showed maximum cocoon yield by weight after being treated with *B. bassiana* spores. Thus, the B4 breed was observed to be better performer under both high temperature treatment and *B. bassiana* inoculation with respect to cocoon yield by weight.

3.3 Average Filament Length (m)

The thermotolerant silkworm breeds showed significant difference with respect to average filament length after being treated at high temperature (36±1ºC). CSR2 breed recorded significantly longest filament length of 1272. 60 m followed by APS12 breed (1120.15 m) which was on par with APS45, B2, B4 and B1 breeds (1115.00, 1111.13, 1102.50 and 1088.10 m, respectively). Significantly lowest filament length was recorded in Pure Mysore breed (493.13 m) followed by CSR4 breed (829.50 m). Highest per cent reduction over control in filament length when exposed to high temperature was observed in B4 breed (15.57%) and it was least in CSR2 and APS12 breeds (1.30 and 1.91%, respectively) (Table 3).

Average filament length was significantly affected in thermotolerant silkworm breeds after being treated with *B. bassiana* spores on first day of fifth instar. Significantly longest filament length was exhibited by the breed B4 (903.23 m) followed by CSR2, APS45 and B1 breeds (770.48, 709.91 and 695.25 m, respectively). CSR4 breed recorded significantly shortest filament length of 449.83 m which was on par with Pure Mysore and APS12 breeds (461.46 and 463.51 m, respectively). Highest reduction in filament length over control was observed in APS12 breed (59.41%) followed by the B2 (48.75%) and CSR4 (47.25%) breeds and least reduction was observed in Pure Mysore (10.21%) and B4 (30.83%) (Table 3).

Table 2. Cocoon yield in thermotolerant bivoltine silkworm breeds subjected to thermal stress and *B. bassiana* inoculation

Breeds	Cocoon yield per 10000 larvae					
	By number (No.)			By weight (g)		
	Control	Thermal treated	*B. bassiana* infected	Control	Thermal treated	*B. bassiana* infected
B1	10,000.00	8,333.33[cd] (-16.67)	7,733.33[bc] (-22.67)	16,920.00[ab]	15,893.33[cd] (-6.07)	7,997.92[b] (-54.29)
B2	10,000.00	4,800.00[e] (-52.00)	8,400.00[b] (-16.00)	17,213.33[ab]	16,580.00[cd] (-3.68)	7,393.64[b] (-51.20)
B4	10,000.00	9,066.67[b] (-9.33)	7,400.00[bc] (-26.00)	18,423.33[a]	17,556.67[ab] (-4.70)	8,466.80[ab] (-59.83)
B6	10,000.00	9,000.00[bc] (-10.00)	5,933.33[def] (-40.67)	17,366.67[ab]	15,916.67[cd] (-8.35)	5,895.44[cd] (-65.83)
B8	10,000.00	8,222.22[d] (-17.78)	6,444.44[cde] (-35.56)	14,166.67[c]	14,016.67[e] (-1.06)	5,323.11[cde] (-54.51)
APS12	10,000.00	9,000.00[bc] (-10.00)	4,888.89[f] (-51.11)	16,600.00[b]	15,400.00[cd] (-7.23)	4,130.95[e] (-70.55)
APS45	10,000.00	8,666.67[bcd] (-13.33)	5,466.67[ef] (-45.33)	16,780.00[b]	17,256.67[ab] (+2.84)	4,643.93[de] (-67.42)
CSR2	10,000.00	9,111.11[b] (-8.89)	7,083.33[bcd] (-29.17)	17,390.00[ab]	17,873.33[a] (+2.78)	6,051.76[c] (-59.27)
CSR4	10,000.00	8,533.33[bcd] (-14.67)	6,000.00[def] (-40.00)	16,806.67[b]	15,216.67[d] (-9.46)	4,222.57[e] (-64.30)
Pure Mysore	10,000.00	10,000.00[a] (-0.00)	10,000.00[a] (-0.00)	11,366.67[d]	12,053.33[f] (+6.04)	9,320.67[a] (-12.02)
F-test	NA	*	*	*	*	*
SEm±	0.00	200.18	443.53	446.33	387.14	422.50
CD at 5%	0.00	590.52	1,308.41	1,316.66	1,142.06	1,246.36
CV (%)	0	4.09	11.08	4.74	4.25	11.53

✓ *Positive and negative figures in the parentheses indicate per cent increase or decrease over control, respectively.*

✓ **- Significant at 5 %; NA - Not analysed; Figures with same superscript are statistically on par.*

✓ *B. bassiana inoculation @ 6.86 X 10^4 spores per ml @ 0.5 ml per worm; High temperature treatment @ 36±1º C for 6 h per day from 1^{st} to 6^{th} day of fifth instar.*

In the earlier studies rearing thermotolerant bivoltine silkworm breeds at high temperature of 36±1º C, produced filament length of 1112 m and 964 m, respectively [11] and CSR46 and CSR47 yielded filament length of 1200 m and 1005 m, respectively [12]. Lakshmi et al. [7] recorded filament length of 922 m in thermotolerant bivoltine silkworm breed APS12 at 32±1º C and the breeds HTO5 and HTP5 could produce filament length of 934 m and 936 m, respectively [13]. Filament length ranging from 623 m to 1,022 m to 1,022 m was recorded among 25 silkworm genotypes when screened at high temperature of 36±1ºC [6]. In the present study, B4 and APS45 breeds showed maximum and on par results with respect to filament length, which is in line with the findings of [8] who recorded maximum filament length in B4 breed (887.67 m) and APS45 breed (871.53 m) by exposing the breeds to 36±1ºC during fifth instar.

Under *B. bassiana* inoculation, [8] recorded significantly longest filament length in B4 breed (695.47 m), followed by B8 (657.47 m) and B7 (629.33 m) and significantly lowest filament length was noticed in B2 breed (480.00 m). In the present study B4 breed showed highest value for average filament length under *B. bassiana* infected condition. Under both high temperature treatment and fungal inoculation, the breed B4 alone could produce longer filament length than any other breeds utilized for the study.

3.4 Filament Weight (g)

Filament length was significantly affected due to high temperature treatment among the thermotolerant silkworm breeds. The breed B1 (0.33 g) exhibited significantly highest filament weight followed by B4 breed (0.32 g). Significantly lowest filament weight was recorded

Table 3. Filament characteristics in thermotolerant bivoltine silkworm breeds subjected to thermal stress and *B. bassiana* inoculation

Breeds	Average filament length (m)			Filament weight (g)			Denier		
	Control	Thermal treated	*B. bassiana* infected	Control	Thermal treated	*B. bassiana* infected	Control	Thermal treated	*B. bassiana* infected
B1	1129.50^{b}	1088.10^{b} (-3.67)	695.25^{cd} (-38.45)	0.31^{b}	0.33^{a} (+5.26)	0.18^{cd} (-42.31)	2.47^{ab}	2.69^{a} (+9.06)	2.32^{bc} (-6.27)
B2	1314.00^{a}	1111.13^{b} (-15.44)	673.46^{cde} (-48.75)	0.38^{a}	0.30^{a} (-20.20)	0.20^{b} (-45.83)	2.59^{a}	2.43^{cd} (-6.01)	2.74^{a} (+5.68)
B4	1305.75^{a}	1102.50^{b} (-15.57)	903.23^{a} (-30.83)	0.37^{a}	0.32^{a} (-14.23)	0.23^{a} (-37.93)	2.55^{ab}	2.60^{ab} (+2.11)	2.29^{bc} (-10.27)
B6	964.50^{c}	917.85^{c} (-4.84)	656.88^{de} (-31.89)	0.26^{c}	0.24^{b} (-6.30)	0.19^{bc} (-27.27)	2.41^{abc}	2.37^{bcd} (-1.63)	2.57^{ab} (+6.79)
B8	941.25^{c}	874.88^{cd} (-7.05)	636.41^{e} (-32.39)	0.24^{cd}	0.22^{bc} (-4.40)	0.15^{ef} (-34.62)	2.25^{bc}	2.32^{cd} (+2.90)	2.18^{cd} (-3.30)
APS12	1141.92^{b}	1120.15^{b} (-1.91)	463.51^{f} (-59.41)	0.29^{b}	0.30^{a} (+3.92)	0.14^{fg} (-50.96)	2.25^{bc}	2.38^{bcd} (+5.77)	2.28^{bc} (+1.31)
APS45	1149.38^{b}	1115.00^{b} (-2.99)	709.91^{c} (-38.24)	0.30^{b}	0.30^{a} (-0.81)	0.19^{bc} (-37.50)	2.38^{abc}	2.43^{bc} (+2.28)	2.40^{bc} (+1.19)
CSR2	1289.33^{a}	1272.60^{a} (-1.30)	770.48^{b} (-40.24)	0.31^{b}	0.32^{a} (+2.37)	0.16^{de} (-48.28)	2.18^{c}	2.26^{cd} (+3.88)	1.89^{de} (-13.44)
CSR4	852.75^{d}	829.50^{d} (-2.73)	449.83^{f} (-47.25)	0.21^{d}	0.20^{c} (-7.81)	0.13^{g} (-40.39)	2.25^{bc}	2.14^{d} (-5.18)	2.54^{ab} (+12.87)
Pure Mysore	513.94^{e}	493.13^{e} (-4.05)	461.46^{f} (-10.21)	0.10^{e}	0.10^{d} (0.00)	0.09^{h} (-6.90)	1.70^{d}	1.76^{e} (+3.83)	1.70^{e} (-0.11)
F-test	*	*	*	*	*	*	*	*	*
SEm±	20.02	28.10	12.25	0.01	0.01	0.01	0.09	0.09	0.10
CD at 5%	59.05	82.88	36.13	0.03	0.03	0.02	0.26	0.27	0.28
CV (%)	3.27	4.90	3.30	5.47	7.30	6.46	6.56	6.76	7.24

✓ *Positive and negative figures in the parentheses indicate per cent increase or decrease over control, respectively.*

✓ **- Significant at 5 %; Figures with same superscript are statistically on par.*

✓ *B. bassiana inoculation @ 6.86 X 10^{4} spores per ml @ 0.5 ml per worm; High temperature treatment @ 36±1º C for 6 h per day from 1^{st} to 6^{th} day of fifth instar* in Pure Mysore (0.10 g) followed by CSR4 breed (0.20 g). Highest reduction in filament weight was recorded in B2 breed (20.20%) as against no change in Pure Mysore breed over control (Table 3).

B. bassiana inoculation to thermotolerant silkworm breeds resulted in significant variation with respect to filament weight. Significantly highest filament weight was noticed in the breed B4 (0.23 g) followed by B2 and APS45 breeds (0.20 and 0.19 g, respectively). Pure Mysore breed (0.09 g) recorded significantly lowest filament weight followed by CSR4 breed (0.13 g). Maximum reduction in filament weight over control was observed in APS12 breed (50.96%) and it was least in Pure Mysore breed (6.90%) (Table 3).

Filament weight ranged from 0.28 g to 0.26 g when different silkworm breeds were treated at high temperature treatment of 36±1ºC [6]. Keerthana et al. [8] recorded significantly highest filament weight in B4 thermotolerant bivoltine breed (0.23 g), followed by B8 (0.22 g) and APS45 (0.21 g) when fifth instar silkworms were exposed to 36±1º C. In the present finding, B1 and B4 breeds showed significantly highest filament weight.

Under *B. bassiana* inoculation, the breeds B4 and B8 recorded maximum filament weight of 0.18 g and 0.16 g, respectively [8]. In the present study B4, B2 and APS45 breeds showed maximum value for filament weight. Overall, the breed B4 could yield better filament weight under both the stress conditions.

3.5 Denier

Denier of the thermotolerant silkworm breeds treated with high temperature showed significant differences. Significantly highest value for denier was recorded in B1 breed (2.69) followed by B4 breed (2.60) and it was least in Pure Mysore and CSR4 breeds (1.76 and 2.14, respectively). Highest reduction in denier over control was observed in B2 breed (6.01%) followed by CSR4 breed (5.18%) and the reduction was observed to be the least in B6 breed (1.63%). Among the *B. bassiana* treated batch, significantly highest denier was noticed in B2 breed (2.74) followed by CSR4 breed (2.54) and it was least in Pure Mysore and CSR2 breeds (1.70 and 1.89, respectively). Per cent decrease in denier over control was found to be maximum in CSR2 breed (13.44%) followed by B4 breed (10.27%) and the least change was noticed in Pure Mysore breed (0.11%).

Under high temperature treatment for different silkworm breeds the denier was ranging from 1.9 to 3.1 [6] while in the present finding it ranged from 1.76 to 2.69. The performance of PM X CSR2 under muscardine inoculation and normal rearing was studied by [14,15] who recorded denier of 2.62 in the infected and 2.20 in healthy silkworms. In the present study, B2 breed was observed to show higher value for denier than any other breed under *B. bassiana* inoculation.

4. CONCLUSION

To meet the International Standards and to achieve the sustainability in sericulture, farmers should have silkworm breeds which can give stable yield under different stress conditions. In this context the present study was undertaken to study the performance of few thermotolerant bivoltine silkworm breeds under high temperature treatment and *B. bassiana* inoculation. The study results exhibited that, the thermotolerant bivoltine silkworm breed B4 can yield highest cocoon yield by number and weight, average filament length and filament weight compared to other thermotolerant breeds *viz.,* B1, B2, B6 and B8 under the aforementioned stress conditions. Therefore the breed, B4 can be exploited as a parent material for hybridization under both thermal stress and fungal infection conditions.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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