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Post Cocoon Traits of Thermotolerant Bivoltine Silkworm Breeds as Affected by White Muscardine

A. Keerthana, Manjunath Gowda, K. C. Narayanaswamy and N. Amarnatha
Department of Sericulture, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
E-mail : mgowda_uas@rediffmail.com

Abstract

Ten thermotolerant silkworm breeds *viz*., B1, B2, B3, B4, B5, B6, B7, B8, APS12 and APS45 along with CSR_2 as control were topically inoculated with different dilutions of the fungal spore suspension of *Beaveria bassiana viz.,* stock (1.45×10^5) to 10^{-5} to know their performance under muscardine infection. The results revealed that the thermotolerant bivoltine silkworm breed B4 performed significantly better than any breed at 10^{-3} fungal spore dilution for all the six parameters studied, *viz*., single cocoon weight, pupal weight, shell weight, shell ratio, filament length and filament weight. However, at 10^{-4} and 10^{-5} fungal spore dilutions, B4 performed better for all the cocoon and filament characters studied. While the next better breeds were B1 performing better for single cocoon weight, shell weight, pupal weight and filament weight and B8 for shell ratio and filament length and weight.

Keywords: Silkworms, Thermotolerance, Bivoltine, Muscardine, Cocoon traits, Filament traits

The Indian sericulture industry is facing a stiff challenge from imported silk mainly from China, which is not only superior in quality but also cheaper in cost. Therefore, it is necessary to improve the quality and reduce the cost of production of indigenous silk. Hence, rearing of bivoltine silkworm breeds / hybrids is the way to produce competitive quality silk. However, due to demanding environmental and rearing conditions under tropics, evolving bivoltine silkworm breeds which can tolerate high temperature and disease incidence becomes imperative. In tropical countries, mulberry silkworm is continuously reared and this makes it highly susceptible to pathogens and hence occurrence of diseases is a major constraint. The diseases of silkworm which caused heavy loss in the past are now under control in China through proper forecasting and integrated management. But in India, more than 40 per cent of crop losses still occurs due to these diseases and 10-40 per cent of crop loss has been accounted for white muscardine of the total loss due to diseases (Chandrasekharan & Nataraju, 2008). Further silk yield is adversely affected by high temperature prevailing in tropical condition, especially in summer. Few thermotolerant bivoltine breeds were evolved which are adaptable to temperature fluctuations. However, these breeds being suitable for summer rearing, their tolerance to white muscardine is unknown. Tolerance to muscardine is known to be determined by the recessive gene, mus and cal (Takasaki, 1958) and Japan bivoltine are suggested to be tolerant. The bivoltine silkworm for tolerant to high temperature enhanced in India are of Japanese origin. Hence, it is envisaged to identify their tolerance *vis-a-vis* susceptibility to white muscardine, through assessing cocoon and filament traits in this paper.

Material and Methods

Cocoon and filament traits of thermotolerant bivoltine silkworm breeds affected by muscardine was studied at the Department of Sericulture, UAS, GKVK, Bengaluru during 2017-18. Ten thermotolerant bivoltine silkworm breeds (Eight *viz*., B1, B2, B3, B4, B5, B6, B7 and B8 from CSRTI, Mysore and two breeds *viz*., APS12 and APS45 from APSSRDI, Hindupur) along with CSR_2 as control were utilized for conducting experiments. Bulk rearing was conducted up to fourth instar by following standard rearing practices feeding V1 mulberry variety (Dandin *et al*., 2001). Newly ecdysed fifth instar larvae (50 worms per replication in three replications each) were topically inoculated with different dilutions of the fungal spore suspension *i.e.*, stock (1.45 × 10^5), 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5} at the rate of 0.5 ml per worm by spraying with an automizer (Venkataramana Reddy, 1978). High relative humidity of 95±5 per cent and a temperature of 25±1 ºC was maintained in the rearing room. Control batch was also maintained by spraying with distilled water. The surviving and ripe silkworms were shifted to the mountages for spinning at ambient temperature of 25±1 ˚C and 65±5 per cent RH.

Observations on cocoon parameters *viz.,* single cocoon weight, pupal weight, shell weight, shell ratio, filament length and filament weight were recorded. The data obtained were analysed using completely randomized design (Sundarraj *et al*., 1972). The per cent data was analysed after transformation by using the formula $\sin^{-1}\sqrt{p/100}$. The zero values in the data obtained when treated with different spore concentrations were normalized for $\sqrt{x+1}$ transformation, before analysis.

RESULTS AND DISCUSSION

Single cocoon weight (g)

At the stock, 10^{-1} and 10^{-2} fungal spore dilutions the silkworms of all the breeds showed 100 per cent mortality and hence, cocoon weight could not be recorded (Table 1). At 10^{-3} spore dilution, survivors were observed in B1, B4, B5, B6, B7, B8 and CSR_2 breeds. Significantly highest single cocoon weight of 1.22 g was observed in B4 breed, followed by B1 (1.17 g) and B5 (1.16 g). Similarly, least single cocoon weight was recorded in breed CSR_2 (0.97 g), followed by B7 (0.93 g). At 10^{-4} fungal spore dilution, all the breeds showed survival except APS45 breed and B4 breed which showed significantly highest single cocoon weight (1.33 g) followed by B3 and B1 (1.24 g and 1.20 g, respectively). Lowest single cocoon weight was noticed in breed B5 (1.02 g), followed by CSR_2 (0.92 g). At 10^{-5} fungal spore dilution, though survivors were observed in all the breeds, the breeds showed non-significant differences. However, the maximum single cocoon weight was reported in breed B4 (1.25 g) followed by B1 (1.15 g) and lowest single cocoon weight was noticed in APS45 (0.97 g), followed by APS12 (0.99 g). In non-inoculated control batches, significantly highest cocoon weight of 1.91 g was observed in CSR_2 followed by B4 (1.87 g) and both APS12 and APS45 (1.84 g). Significantly lowest cocoon weight was reported in both B5 and B7 (1.69 g) breeds, followed by B3 (1.70 g).

Spore dosage drastically affecting the cocoon weight with lighter cocoons (0.476 g) being in the larvae inoculated with 10^6 spores / ml was noticed compared to those infected with 10^3 spores / ml (1.057 g) and uninfected (1.417 g) has been reported (1986). They also observed that, NB_7 formed cocoons with maximum weight (1.027 g) compared to NB_{18} (0.940). On the same note, Rajitha and Savithri (2015) reported significant reduction in cocoon weight in PM×CSR_2 (0.72 g) when infected with *B. bassiana* spores at 2.15×10^6 dilution on first day of fifth instar. The reduction in cocoon characters could be attributed to loss of appetite, lethargic conditions and physiological stress induced by the fungal pathogen (Lakshmi *et al*., 2013). In the present study, B4 breed produced higher cocoon weight at all the fungal spore concentrations studied, indicating its superiority over other breeds. APS45 showed significantly lowest cocoon weight at all treated spore dilutions of *B.bassiana*. Lowest cocoon weight may be due to infected larvae failing to spin complete cocoon thus, resulting in flimsy cocoons.

Pupal weight (g)

At the fungal spore dilutions of stock, 10^{-1} and 10^{-2} pupal weight was not recorded caused 100 per cent mortality in all the breeds. (Table 1). At 10^{-3} spore dilution significantly highest pupal weight was recorded in breed B4 (1.00 g) followed by B1 (0.99 g) and B5 (0.98 g) and significantly lowest pupal weight was recorded in B7 (0.79 g), followed by CSR_2 (0.83 g). At 10^{-4} spore dilution, breed B3 recorded significantly highest pupal weight (1.07 g), followed by B4 and B1 (1.04 g and 0.99 g, respectively), significantly lowest pupal weight was observed in APS12 (0.36 g), followed by CSR_2(0.74 g). Non-significant difference in pupal weight was evident among the thermotolerant silkworm breeds when treated with dilution of 10^{-5} spores / ml. However, higher pupal weight was recorded in B4

TABLE 1

Single cocoon weight (g) and pupal weight (g) of thermotolerant bivoltine silkworm breeds inoculated by different doses of *B. bassiana* spores.

Breeds	Single cocoon weight(g)							Pupal weight (g)						
	Stock	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	Control	Stock	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	Control
B1	0	0	0	1.17 d (1.29)	1.20 c (1.30)	1.15 b	1.74 ab	0	0	0	0.99 f (1.22)	0.99 c (1.22)	0.91 ab	1.40 ab
B2	0	0	0	0 a (0.70)	1.18 c (1.29)	1.09 ab	1.76 abc	0	0	0	0 a (0.70)	0.99 c (1.22)	0.91 ab	1.42 ab
B3	0	0	0	0 a (0.70)	1.24 c (1.31)	1.06 a	1.70 a	0	0	0	0 a (0.70)	1.07 c (1.25)	0.87 ab	1.36 a
B4	0	0	0	1.22 d (1.31)	1.33 c (1.35)	1.25 b	1.87 cd	0	0	0	1.00 f (1.22)	1.04 c (1.24)	0.99 b	1.47 bc
B5	0	0	0	1.16 c (1.28)	1.02 c (1.23)	1.13 a	1.69 a	0	0	0	0.98 ef (1.21)	0.83 c (1.15)	0.83 ab	1.39 ab
B6	0	0	0	1.07 c (1.25)	1.05 c (1.24)	1.07 ab	1.81 abc	0	0	0	0.89 cd (1.17)	0.86 c (1.16)	0.87 ab	1.49 ab
B7	0	0	0	0.93 b (1.19)	1.07 c (1.25)	1.08 a	1.69 a	0	0	0	0.79 b (1.13)	0.89 c (1.17)	0.88 ab	1.40 ab
B8	0	0	0	1.08 c (1.25)	1.10 c (1.26)	1.06 a	1.80 abc	0	0	0	0.90 de (1.18)	0.91 c (1.18)	0.87 ab	1.46 ab
APS12	0	0	0	0 a (0.70)	0.43 b (0.91)	0.99 a	1.84 bcd	0	0	0	0 a (0.70)	0.36 b (0.89)	0.80 ab	1.50 ab
APS45	0	0	0	0 a (0.70)	0 a (0.70)	0.97 a	1.84 bcd	0	0	0	0 a (0.70)	0 a (0.70)	0.78 a	1.47 ab
CSR_2(Control)	0	0	0	0.97 b (1.21)	0.92 c (1.19)	1.05 a	1.91 d	0	0	0	0.83 bc (1.15)	0.74 c (1.11)	0.87 ab	1.53 bc
F-test	NA	NA	NA	*	*	NS	*	NA	NA	NA	*	*	NS	NS
SEm±	-	-	-	0.01	0.06	-	0.04	-	-	-	0.01	0.05	-	-
CD at 5%	-	-	-	0.04	0.19	-	0.13	-	-	-	0.04	0.17	-	-
CV (%)	-	-	-	2.26	9.8	10.34	4.41	-	-	-	2.34	9.16	14.01	6.00

*- Significant at 5%; NS-Non significant; NA-Not analysed; $-Figures in parentheses are transformed values; Stock- 1.45×10^5 spores / ml

Note: *B.bassiana* infection was done immediately after fourth moult. Each treatment comprised of three replications with 50 silkworms each.

(0.99 g), followed by both B1 and B2 (0.91 g) and least pupal weight of 0.78 g was recorded in APS45 followed, by APS12 (0.80 g). In control batches *i.e.,* without any fungal treatment non-significant difference was observed for pupal weight and it was highest in CSR_2 (1.53 g), followed by APS12 (1.50 g) and minimum pupal weight was observed in B3 (1.36 g), followed by B5 (1.39 g).

Silkworm pupae were reported to be less susceptible, compared to larvae, due to pupal cuticular antifungal agents such as saturated fatty acids like cupric acid and caprylic acid. Rajitha and Savithri (2015) reported that, silkworm hybrid PM × CSR_2 treated with sub lethal concentration of *B.bassiana* conidial suspension (2.15×10^6 spores / ml), exhibited significant reduction in pupal weight, (0.63 g) compared to control (1.2 g). In the present study similar trend in reduction of pupal weight was observed in all the breeds at different fungal spore dilutions. Further, it was clear that the breeds B3 and B4 showed significantly higher pupal weight even when challenged with fungal infection.

Shell weight (g)

Weight of single shell showed significant difference among the thermotolerant bivoltine silkworm breeds treated with different dilutions of *B. bassiana* spores (Table 2). At stock, 10^{-1} and 10^{-2} spore dilutions, no worms survived and hence shell weight was not recorded. At 10^{-3} fungal spore dilution, survivors were observed in B1, B4, B5, B6, B7, B8 and CSR_2. Significantly highest shell weight (0.22 g) was recorded in B4, followed by B5, B6 and B8 (0.18 g each). Significantly lowest shell weight was observed in B1 (0.17 g), followed by CSR_2 and B7 (0.14 g). At 10^{-4} spore dilution, thermotolerant bivoltine silkworm breed B4 recorded significantly highest shell weight (0.29 g), followed by B1 (0.22 g) and B8 (0.20 g) breeds while, lowest shell weight was observed in both CSR_2 and B5 (0.18 g) breeds, followed by B3 (0.17 g). At 10^{-5} spore dilution, significantly highest shell weight was noticed in breed B4 (0.25 g), followed by B1 (0.22 g). Significantly lowest shell weight was observed in B3, B5 and APS12 (0.18 g, each) followed by CSR_2 and B2 (0.17 g). In control batch, all breeds showed significant difference for shell weight and significantly highest shell weight was recorded in B4 (0.39 g), followed by CSR_2 (0.38 g) and least shell weight was recorded in B7 (0.28 g) followed by B5 (0.30 g).

In earlier literature, healthy NB_7 larvae spun the cocoons with maximum shell weight (0.234 g) compared to the surviving larvae infected with different doses of *B. bassiana* spore during fifth instar. In the present results the thermotolerant bivoltine breed B4 showed maximum shell weight followed by B1 when inoculated with different dilutions of *B.bassiana* spore, as they might have the ability to tolerate muscardine infection.

Shell ratio (%)

Significant difference for shell per cent was observed among the thermotolerant bivoltine silkworm breeds treated with different dilutions of *B. bassiana* (Table 2). At stock, 10^{-1} and 10^{-2} spore dilutions 100 per cent mortality was noticed and hence shell ratio was not recorded at these spore dilutions. At 10^{-3} dilution highest shell ratio of 17.98 per cent was observed in B4 breed, followed by B6 and B8 (16.90 % and 16.86 %, respectively). Significantly least shell ratio was observed in, CSR_2 (14.45 %) followed by B7 (15.39 %). At 10^{-4} spore dilution, significantly highest shell ratio of 21.62 per cent was observed in breed B4, followed by CSR_2 (19.40 %) and B8 (19.39 %) and least shell ratio of 5.17 per cent was recorded in APS12, followed by B3 (14.01 %). At 10^{-5} spore dilution, B4 breed recorded significantly highest shell ratio (20.27 %) followed by B1 (20.03 %) and APS45 (20.00 %) and significantly least shell ratio was recorded in CSR_2 (16.95 %) followed by B2 (16.58 %). In control batches, the breeds did not differ significantly for shell ratio though maximum shell ratio was recorded in B4 (21.22 %) followed by B3 (20.54 %) and CSR_2 (20.32 %) and minimum shell ratio was recorded in B7 (17.01 %) followed byB6 (17.81 %). The shell percentage of cocoons formed by the healthy larvae was significantly highest compared to the cocoons spun by the infected larvae and it decreased significantly with increased spore density.

TABLE 2

Shell weight (g) and shell ratio (%) of thermotolerant bivoltine silkworm breeds inoculated by different doses of *B. bassiana* spores.

	Shell weight (g)							Shell ratio (%)						
Breeds	Stock	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	Control	Stock	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	Control
B1	0	0	0	0.17 ^{d} (0.82)	0.22 ^{c} (0.84)	0.22 ^{b}	0.34 ^{bcd}	0	0	0	15.47 ^{cd} (3.98)	18.78 ^{c} (4.38)	20.03 ^{cd}	19.77 ^{ab}
B2	0	0	0	0 ^{a} (0.70)	0.18 ^{c} (0.82)	0.17 ^{a}	0.33 ^{bcd}	0	0	0	0 ^{a} (0.70)	15.90 ^{c} (4.04)	16.58 ^{a}	19.30 ^{ab}
B3	0	0	0	0 ^{a} (0.70)	0.17 ^{c} (0.82)	0.18 ^{a}	0.34 ^{bcd}	0	0	0	0 ^{a} (0.70)	14.01 ^{c} (3.80)	17.55 ^{ab}	20.54 ^{b}
B4	0	0	0	0.22 ^{e} (0.84)	0.29 ^{e} (0.88)	0.25 ^{c}	0.39 ^{de}	0	0	0	17.98 ^{e} (4.29)	21.62 ^{c} (4.70)	20.27 ^{d}	21.22 ^{b}
B5	0	0	0	0.18 ^{d} (0.82)	0.18 ^{c} (0.82)	0.18 ^{a}	0.30 ^{ab}	0	0	0	15.74 ^{b} (1.03)	18.45 ^{c} (4.35)	17.62 ^{ab}	18.00 ^{ab}
B6	0	0	0	0.18 ^{d} (0.82)	0.19 ^{c} (0.83)	0.19 ^{a}	0.32 ^{ab}	0	0	0	16.90 ^{de} (4.16)	18.61 ^{c} (4.37)	18.18 ^{ab}	17.81 ^{ab}
B7	0	0	0	0.14 ^{c} (0.80)	0.19 ^{c} (0.83)	0.19 ^{a}	0.28 ^{a}	0	0	0	15.39 ^{cd} (3.98)	18.30 ^{c} (4.33)	18.34 ^{bc}	17.01 ^{a}
B8	0	0	0	0.18 ^{d} (0.82)	0.20 ^{c} (0.83)	0.19 ^{a}	0.34 ^{bc}	0	0	0	16.86 ^{de} (4.16)	19.39 ^{c} (4.45)	18.19 ^{ab}	19.09 ^{ab}
APS12	0	0	0	0 ^{a} (0.70)	0.07 ^{b} (0.75)	0.18 ^{a}	0.34 ^{bcd}	0	0	0	0 ^{a} (0.70)	5.17 ^{b} (1.80)	18.90 ^{bcd}	18.45 ^{ab}
APS45	0	0	0	0 ^{a} (0.70)	0 ^{a} (0.70)	0.19 ^{a}	0.37 ^{cde}	0	0	0	0 ^{a} (0.70)	0 ^{a} (0.70)	20.00 ^{cd}	19.93 ^{ab}
CSR_2(Control)	0	0	0	0.14 ^{b} (0.79)	0.18 ^{c} (0.82)	0.17 ^{a}	0.38 ^{de}	0	0	0	14.45 ^{c} (3.85)	19.40 ^{c} (4.46)	16.95 ^{a}	20.32 ^{ab}
F-test	NA	NA	NA	*	*	*	*	NA	NA	NA	*	*	*	NS
SEm±	-	-	-	0.005	0.014	0.011	0.017	-	-	-	0.10	0.33	0.60	-
CD at 5%	-	-	-	0.016	0.04	0.03	0.05	-	-	-	0.29	0.98	1.78	-
CV (%)	-	-	-	1.24	3.03	10.12	8.80	-	-	-	6.15	15.43	5.73	10.60

*- Significant at 5%; NS-Non significant; NA-Not analysed; $-Figures in parentheses are transformed values; Stock- 1.45×10^5 spores / ml

Note: *B.bassiana* infection was done immediately after fourth moult. Each treatment comprised of three replications with 50 silkworms each.

In earlier studies, eight different bivoltine silkworm breeds when treated with different dilutions of 10^9 to 10^2 of *B. bassiana* spore, NB_4D_2 showed highest shell ratio of 22.75 per cent at 10^1 spore dilution and PM × CSR_2 breed showed reduction in shell ratio at 2.15 × 10^6 spores / ml of *B. bassiana* conidial suspension (Rajitha and Savithri, 2015). In the present study, B4, B8 and B1 breeds showed better performance for shell ratio when infected with different fungal spore dilutions.

Filament length (m)

Filament length was reported to show significant variation among the thermotolerant bivoltine silkworm breeds when inoculated with different doses of *B. bassiana* spores (Table 3). It was observed that all the selected breeds, showed 100 per cent mortality at stock, 10^{-1} and 10^{-2} dilutions of *B. bassinana* and hence, no filament length was recorded. At 10^{-3} dilution survivors were observed in B1, B4, B5, B6, B7, B8 and CSR_2 breeds and significantly highest filament length was observed in B4 (714.00 m) breed followed by B8 (706.34 m) and CSR_2 (656.33 m). Significantly least filament length of 238.33 m was reported in breed B5, followed by B7 (617.40 m) and B1 (642.00 m). At 10^{-4} spore dilution highest filament length was reported in breed B4 (798.67 m) followed by B8 (774.00 m) and B1 (767.00 m). Significantly least filament was reported in breed APS12 (238.00 m) followed by B3 (577.83 m) and B2 (579 m). Similarly, at 10^{-5} dilutions breed B4 produced highest filament length (806.22 m), followed by CSR_2 (803.18 m) and B8 (783.32 m) breeds. Significantly least filament length of 608.36 m was recorded in B3 followed by B2 (635.45m) and B5 (646.67 m). The non-inoculated control batches of thermotolerant bivoltine breeds showed significant differences with respect to the length of silk filament reeled from single cocoon. The productive bivoltine silkworm breed CSR_2 recorded longest filament length (1034.80 m) followed by B4 (1005.40 m) and B8 (972.40 m) breeds. However, the shortest filament length was reported in breed B5 (844.00 m) followed by B3 (858.13 m).

The silk filament length indicates the reelable length of silk filament from a cocoon. Generally, a longer non-breakable filament with less number of breaks, higher is the reelability. It is assumed that the physiological and biochemical stress induced by a fungal pathogen caused to exude uneven amounts of silk fluid in lumps. Accordingly in PM × CSR_2 breed yielded 478.90 m filament length under *B. bassiana* infection and 671.6 m in healthy silkworms (Rajitha and Savithri, 2015). In the present findings, the B4 and B8 breeds recorded significantly high filament length than other breeds at higher three dilutions of *B. bassiana* infections, indicating their ability to overcome fungal stress.

Filament weight (g)

At the stock, 10^{-1} and 10^{-2} dilutions of fungal spores, no worms survived and hence filament weight was not recorded (Table 3). However, at 10^{-3} spore dilution survivors were observed in B1, B4, B5, B6, B7, B8 and CSR_2 breeds. Significantly highest filament weight was recorded in breed B4 (0.18 g) at 10^{-3} spore dilution, followed by B1 and CSR_2 (0.16 g, each) whereas, significantly lowest filament weight was recorded in B6 and B7 (0.14 g), followed by B5 (0.06 g). At 10^{-4} spore dilution, silkworms survived in all the breeds except APS45, which showed cent per cent mortality. Significantly highest filament weight was recorded in breed B4 (0.20 g), followed by B8 (0.19 g) and significantly least filament weight was recorded in both B2 and B3 (0.14 g), followed by APS12 (0.06 g). At 10^{-5} spore dilution, significantly highest filament weight (0.20 g) was recorded in breed B4 followed by both B8 and APS45 (0.18 g). Significantly least filament weight was recorded in B3 (0.15 g).m In control batches, significantly highest filament weight was recorded in both B4 and CSR_2 (0.29 g) breeds, followed by B1, B7 and B8 (0.26 g each). Significantly lowest filament weight was recorded in B3 and B5 (0.18 g and 0.19 g, respectively), followed by APS12 (0.21 g).

Silkworm hybrid PM × CSR_2 treated with sub lethal concentration of *B. bassiana* conidial suspension exhibited significant reduction infilament weight

TABLE 3

Filament length (m) and filament weight (g) of thermotolerant bivoltine silkworm breeds inoculated by different doses of *B. bassiana* spores

Breeds	Filament length (m)							Filament weight (g)						
	Stock	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	Control	Stock	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	Control
B1	0	0	0	642.00 [c] (25.34)	767.00 [c] (27.69)	719.00 [cd]	954.40 [cde]	0	0	0	0.16 [cd] (0.81)	0.19 [c] (0.82)	0.17 [d]	0.26 [cd]
B2	0	0	0	0 [a] (0.70)	579.00 [c] (24.06)	635.45 [ab]	936.53 [bcd]	0	0	0	0 [a] (0.70)	0.14 [c] (0.80)	0.16 [c]	0.24 [bcd]
B3	0	0	0	0 [a] (0.70)	577.83 [c] (24.03)	608.36 [a]	858.13 [a]	0	0	0	0 [a] (0.70)	0.14 [c] (0.80)	0.15 [b]	0.18 [a]
B4	0	0	0	714.00 [c] (26.73)	798.67 [c] (28.26)	806.22 [e]	1005.40 [ef]	0	0	0	0.18 [d] (0.82)	0.20 [c] (0.83)	0.20 [f]	0.29 [d]
B5	0	0	0	238.33 [b] (9.38)	622.72 [c] (24.96)	646.67 [ab]	844.00 [a]	0	0	0	0.06 [b] (0.74)	0.15 [c] (0.80)	0.14 [a]	0.19 [ab]
B6	0	0	0	637.23 [c] (25.23)	661.78 [c] (25.70)	684.75 [bc]	893.13 [ab]	0	0	0	0.14 [c] (0.79)	0.15 [c] (0.80)	0.16 [c]	0.22 [abc]
B7	0	0	0	617.40 [c] (24.84)	678.70 [c] (26.04)	724.86 [cd]	954.53 [cde]	0	0	0	0.14 [cd] (0.80)	0.17 [cd] (0.81)	0.17 [d]	0.26 [cd]
B8	0	0	0	706.34 [c] (26.56)	774.00 [c] (27.82)	783.32 [de]	972.40 [de]	0	0	0	0.15 [cd] (0.80)	0.19 [d] (0.83)	0.18 [e]	0.26 [cd]
APS12	0	0	0	0 [a] (0.70)	238.00 [b] (9.38)	728.00 [cd]	915.13 [bc]	0	0	0	0 [a] (0.70)	0.06 [b] (0.74)	0.17 [d]	0.21 [abc]
APS45	0	0	0	0 [a] (0.70)	0 [a] (0.70)	756.66 [de]	935.53 [bc]	0	0	0	0 [a] (0.70)	0 [a] (0.70)	0.18 [e]	0.24 [bcd]
CSR_2(Control)	0	0	0	656.33 [c] (25.62)	706.45 [c] (26.58)	803.18 [d]	1034.80 [f]	0	0	0	0.16 [cd] (0.81)	0.17 [cd] (0.82)	0.15 [b]	0.29 [d]
F-test	NA	NA	NA	*	*	*	*	NA	NA	NA	*	*	*	*
SEm±	-	-	-	2.64	2.65	23.75	19.13	-	-	-	0.012	0.012	0.006	0.021
CD at 5%	-	-	-	7.74	7.77	69.54	56.01	-	-	-	0.035	0.03	0.017	0.06
CV (%)	-	-	-	30.26	20.62	5.73	3.53	-	-	-	2.74	2.70	6.12	15.32

*- Significant at 5%; NS-Non significant; NA-Not analysed; $-Figures in parentheses are transformed values; Stock- 1.45 × 10^5 spores / ml

Note: *B.bassiana* infection was done immediately after fourth moult. Each treatment comprised of three replications with 50 silkworms each.

compared to control breeds (0.16 g) (Rajitha and Savithri, 2015). The lowest filament weight observed in breeds treated with different fungal infections compared to the control breeds, as the infected worms fail to spin the cocoons. Those which form thin shelled cocoons yield shorter filament length resulting in lesser filament weight. With similar effect, in the present study, it was noticed that the thermotolerant bivoltine breeds B4, B8, B6 and B1 resulted in better filament weight even under fungal inoculation indicating their ability to tolerate fungal stress better than other breeds.

The performance of the thermotolerant bivoltine silkworm for cocoon and filament traits under muscardine infection revealed that the breeds B4 performed better for all the traits studied, while B1 for cocoon, shell weight, cocoon shell ratio and filament length and filament weight. Hence, it may be concluded that, the breeds *viz.,* B4, B1 and B8 are tolerant to muscardine infection and result in better cocoon and filament traits.

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