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Response of a few thermotolerant bivoltine breeds and their hybrids to *Beauveria bassiana* (Bals.-Criv.) Vuill. infection in terms of yield and economic parameters of cocoon

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Abstract

Four thermotolerant bivoltine breeds *viz*., B1, B4, B6, B8 and their hybrids *viz*., B1× B4, B1× B6, B1× B8, B4× B1, B4× B6, B4× B8, B6× B1, B6× B4, B6× B8, B8× B1, B8× B4 and B8× B6, were topically inoculated with different dilutions of the fungal spore suspension of *Beauveria bassiana viz*., [stock (3.17 × 10^5 spores / ml), 10^{-2}, 10^{-4}, 10^{-6} and 10^{-8}]. The results revealed that the thermotolerant bivoltine silkworm breed B8 and hybrid B1× B8 performed significantly better than any breed and hybrid for all the eight parameters studied, *viz*., cocoon yield by number, cocoon yield by weight, single cocoon weight, pupal weight, shell weight, shell ratio, filament length and filament weight. While, the next better breed and hybrid was B1 and B1× B4 performing better for cocoon weight, pupal weight, shell weight and pupal weight. This study was conducted with an objective to screen whether thremotolerant bivoltine silkworm breeds and their hybrids can also tolerant white muscardine infections exhibiting dual stress tolerance.

Keywords: Silkworm, thermotolerance, bivoltine hybrids, white muscardine fungi, cocoon traits, filament traits

1. Introduction

The success of sericulture industry primarily depends on the successful harvest of cocoon crops. India being a tropical country where we encounter marginal sub-tropical and temperate sericulture zones, predominantly multivoltine × bivoltine hybrids are reared. But the raw silk produced from these hybrids do not satisfy the international standards as it is not as superior as that produce by bivoltine × bivoltine hybrids. Thus, there is great need and scope for improving the bivoltine sericulture in the country, and more emphasis needs to be given to bivoltine sericulture for producing international grade raw silk [3]. But the major problem for bivoltine sericulture is the high incidence of diseases. The major diseases affecting mulberry silkworm are muscardine, pebrine (both fungal disease), flacherie (bacterial diseases) and grasserie (viral diseases). Silkworm crop loss occurs in all the silkworm growing areas of the world, but the type of severity varies. They differ from region to region, crop to crop and even from farmer to farmer. Leaving aside minor variations, it has been found that crop loss is generally more in the tropics than in the temperate regions.

The magnitude of the disease damage is on the higher side in India. It is a general observation that out of 5-6 crops per year, two are usually lost due to diseases and other reasons and even the successful once are partially lost. Thus, the frequent outbreak of diseases is one of the main handicaps for the progress of sericulture industry. The reasons attributed, are poor hygienic conditions and continuous silkworm rearing all through the year and the climatic conditions that favour faster multiplication of disease causing germs. *Beauveria bassiana* (Bals) Vuill. is one of the most destructive fungal pathogen of silkworm *Bombyx mori* L. causing white muscardine disease. More than 40 per cent of crop losses in India are due to diseases and 10-40 per cent of crop loss has been accounted for white muscardine [2]. Further, silk yield is adversely affected by high temperature prevailing in tropical condition, especially in summer. Few thermotolerant breeds were evolved which are adaptable not only to high temperature but also its fluctuations. However, these breeds being suitable for summer rearing, their tolerance to white muscardine is not fully known.

Some of the thermotolerant bivoltine silkworm breeds have exhibited appreciable tolerance to muscardine infection in our earlier studies [8]. In the present study we intend to understand the response of the hybrids form those silkworm breeds.

2. Materials and Methods
2.1 Study location
Cocoon yield and economic traitsof thermotolerant bivoltine breeds and their hybrids as affected by white muscardine was studied at the Department of Sericulture, UAS, GKVK, Bengaluru during 2018-19.

2.2 Experimantal Material
Four thermotolerant bivoltine silkworm breeds *viz*., B1, B4, B6 and B8 from CSRTI, Mysore which showed better tolerance to white muscardine caused by *Beauveria bassiana* in there earlier studies [7, 8] were hybridized in a Diallele fashion to develop sixteen crosses comprising of four crosses as parents and 12 as hybrids *viz*., B1, B4, B6, B8, B1× B4, B1× B6, B1× B8, B4× B1, B4× B6, B4× B8, B6× B1, B6× B4, B6× B8, B8× B1, B8× B4 and B8× B6. Bulk rearing was conducted up to fourth instar by following standard rearing practices feeding V1 mulberry variety [4]. Newly ecdysed fifth instar larvae of all the crosses were (50 worms per replication in three replications each) topically inoculated with different dilutions of the fungal spore suspension *i.e*., stock (3.17×10^5 spores / ml), 10^{-2}, 10^{-4}, 10^{-6} and 10^{-8} dilutions, at the rate of 0.5 ml per worm by spraying with an automizer [17]. High relative humidity of 95±5 per cent and temperature of 25±1°C were maintained in the rearing room. Control batch without any fungal inoculation was also maintained.

2.3 Data and analysis
Observations on LC_{50} [14] and cocoon parameters *viz*., cocoon yield by number, cocoon yield by weight, single cocoon weight, pupal weight, shell weight, shell ratio, filament length and filament weight were recorded. The data so obtained were analysed using completely randomized design [15]. 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 concentration was analysed after normalizing the distribution by $\sqrt{x+1}$ transformation. The mean values of the experiments were compared by Duncan's Multiple Range Test [5].

3. Results and Discussion
LC_{50}
Four thermotolerant silkworm breeds and their hybrids when treated immediately after fourth moult with different dilutions of *Beauveria bassiana* spores, B1 × B8 hybrid showed highest LC_{50} value (9.04×10^4 spores / ml), followed by B1×B4 (7.41×10^4 spores / ml) and B8 (7.12×10^4spores / ml). Whereas, B6 (3.91×10^4) and B6 × B8 (3.98×10^4 spores/ml) showed lowest LC_{50} value. The LC_{50} estimation of thermotolerant bivoltine silkworm hybrids revealed that, the hybrid B1×B8 (9.04×10^4 spore per ml) was relatively more tolerant to *B. bassiana* infection among all the hybrids studied (Fig 1).
The lethal concentration of the fungus, *B. bassiana* required for 50 per cent mortality was maximum in C-nichi during both fourth (7.71×10^2 spores / ml) and fifth (4.73×10^2 spores / ml) instars, while the same was minimum in NB_{18} (1.66×10^2 and 0.65×10^2 spores / ml during fourth and fifth instars, respectively) indicating their varied degree of susceptibility to the infection [13]. Three Indian silkworm strains when infected with *B. bassiana* during fifth instar showed 7 fold differences in LC_{50} values between most susceptible and tolerant strains [11]. In the present study, the thermotolerant bivoltine hybrids revealed varied degree of tolerance to *B. bassiana* being 2.3 folds more tolerance in the hybrid B1×B8 and 1.2 fold in B1×B4 hybrid compared to most susceptible B6 breed. Thus indicating the thermotolerant hybrids B1×B8 and B1×B4 could also be tolerant to the fungal infection.

3.1 Cocoon yield by number (No. / 1000 worms)
Cocoon yield by number showed significant differences among the thermotolerant bivoltine silkworm hybrids inoculated with different spore dilutions of *B. bassiana* (Table 1). At stock concentration, cent per cent mortality was noticed in B6 breed and B6×B1 and B6×B4 hybrids and hence cocoon yield by number could not be recorded. However, the breed B8 showed significantly highest cocoon yield by number at stock and all the other dilutions of *B. bassiana* (333.33 / 1000 worms at stock, 406.67 / 1000 worms at 10^{-2}, 446.67 / 1000 worms at 10^{-4}, 526.67 / 1000 worms at 10^{-6} and 613.33 / 1000 worms at 10^{-8} dilution). Similarly, among hybrids B1 × B8 showed significantly highest cocoon yield by number at stock and all the other fungal dilutions (420.00 / 1000 worms at stock, 473.33 / 1000 worms at 10^{-2}, 526.67 / 1000 worms at 10^{-4}, 600.00 / 1000 worms at 10^{-6} and 660.00 / 1000 worms at 10^{-8} dilution). However, significantly least cocoon yield by number was recorded in B8×B1 (239.99/ 1000 worms) followed by B6 ×B8 (250.67 / 1000 worms) over the dilutions. In all the non-inoculated control batches 1000 cocoons per 1000 worms were recovered.
In earlier studies, when eleven thermotolerant bivoltine breeds were treated with different dilutions of fungal spore suspension (stock to 10^{-5}) highest percentage of cocoon formation was observed in B8 (286.66 / 1000 worms) at 10^{-5} spore concentration and no cocoons were formed at stock, 10^{-1} and 10^{-2} spore dilutions [8]. It was noticed that considerable reduction in the cocoon formation among the breeds as the concentration of dosage increased. In the present study similar trend was observed. Among parents B8 (613.33/1000 worms) and among hybrids B1×B8 (660.00 / 1000 worms) recorded significantly highest cocoon yield by number at 10^{-8} spore concentration and no cocoons were formed at stock in B6, B6×B1 and B6×B4.

3.2 Cocoon yield by weight (g / 1000 worms)
Significant difference was noticed for cocoon yield by weight when thermotolerant bivoltine silkworm hybrids were treated with different spore dilutions of *B. bassiana* (Table 1). At stock concentration, cent per cent mortality was noticed in B6 breed and B6×B1 and B6×B4 hybrids and hence cocoon yield by weight could not be recorded. The breed B1 recorded significantly highest cocoon yield by weight at 10^{-4} and 10^{-8} dilution (498.92 and 867.00 g / 1000 worms, respectively), while at stock and other dilutions, the cocoon yield by weight was highest in B8 breed (306.41 g / 1000 worms at stock, 412.27 g / 1000 worms at 10^{-2} and 649.93 g / 1000 worms at 10^{-8} dilution). Similarly, among hybrids B1 × B4 (637.67 g / 1000 worms) showed significantly highest cocoon yield by weight at 10^{-4} dilution, while at stock and other dilutions it was highest in the hybrid B1 × B8 (392.73 g / 1000 worms at stock, 480.07 g / 1000 worms at 10^{-2}, 767.87 g / 1000 worms

at 10^{-6} and 960.47 g / 1000 worms at 10^{-8} dilution). Significantly least cocoon yield by weight was recorded in B6 × B8 (250.77 g / 1000 worms), followed by B8 × B4 (259.43 g / 1000 worms) over the dilutions. In control batch, significantly highest cocoon yield by weight of 1787.28 and 1807.58 g / 1000 worms was recorded in B1 breed and B1×B4 hybrid, respectively, while least cocoon yield by weight was recorded in B6×B8 (1646.01 g / 1000 worms), followed by B8 × B6 (1673.33 g / 1000 worms).

When eleven thermotolerant breeds were treated with different dilutions of fungal spore (stock to 10^{-5}) highest cocoon yield by weight / 1000 worms was recorded in B8 (306.13 g / 1000 worms) at 10^{-5} spore concentration and lowest cocoon yield was recorded in CSR_2 (26.93 g / 1000 worms) at 10^{-3} spore concentration and no cocoons were formed at stock, 10^{-1} and 10^{-2} spore concentrations. Cocoon weight was higher at low fungal spore concentration [8]. These observations are in conformity with the present findings, that inoculation of higher dose of fungal spores to the thermotolerant bivoltine breeds and hybrids reduced their cocoon yield. Whereas, significantly highest cocoon yield by weight was recorded in B1 (867.00 g / 1000 worms) among parents and in B1×B8 (960.47 g / 1000 worms) among hybrids at 10^{-8} fungal spore dilution. Lowest cocoon yield by weight was recorded in B4 (139.43 g / 1000 worms) among parents and B8×B6 (19.88 g / 1000 worms) among hybrids at stock.

3.3 Single cocoon weight (g)

At stock concentration, cent per cent mortality was noticed in B6 breed and B6×B1 and B6×B4 hybrids and hence cocoon weight could not be recorded (Table 2). The breed B1 showed significantly highest single cocoon weight (0.92 g) at stock concentration, while at 10^{-2} and 10^{-8} dilution, cocoon weight was highest in both B1 and B8 breeds (1.01 and 1.37 g each, respectively). The B8 breed showed significantly highest cocoon weight at 10^{-4} (1.12 g) and 10^{-6} dilution (1.23 g). Similarly among hybrids, both B1×B4 and B1×B8 recorded significantly highest single cocoon weight (1.28 g each) at 10^{-6} dilution, while at 10^{-4} dilution it was highest in B1×B4 (1.06 g). At stock, 10^{-4} and 10^{-8} dilutions, cocoon weight was significantly highest in the hybrid B1×B8 (0.94 g, 1.21 g and 1.46 g, respectively). Significantly lowest single cocoon weight was recorded in B6 breed (0.79g), followed by B6×B8 (0.92 g) hybrid over the dilutions. In non-inoculated control batches, among parents significantly highest cocoon weight of 1.81 g was recorded in B1and 1.82 g in B1×B4 among hybrids and lowest cocoon weight was recorded in B6×B8 (1.63 g).

Significant reduction in cocoon weight was observed in earlier studies in the silkworm PM × CSR_2 hybrid (0.72 g) when infected with *B. bassiana* spore at 2.15 × 10^6 dilution on first day of fifth instar compared to control (1.44 g) [12]. The reduction in cocoon characters could be attributed to loss of appetite, physiological stress and lethargic conditions induced by the fungal pathogen [10]. In the present findings also significant reduction in cocoon weight was noticed in experimental silkworms compared to control. Among most tolerant parent B8 cocoon weight was reduced from 1.74 g (control) to 0.86 g (stock: 3.17 × 10^5) and among most susceptible breed B6 cocoon weight was reduced from 1.6 g (control) to 0.83 g (10^{-2}) and in the most tolerant hybrid B1×B8 cocoon weight was reduced from 1.77 g (control) to 0.94 g (stock) and in the most susceptible hybrid B6×B8 cocoon weight was reduced from 1.63 g (control) to 0.66 g (stock).

3.4 Pupal weight (g)

At stock concentration, cent per cent mortality was noticed in B6 breed and B6×B1 and B6×B4 hybrids and hence pupal weight could not be recorded (Table 2). The breed B8 recorded significantly highest pupal weight at stock, 10^{-6} and 10^{-8} dilutions (0.75g, 1.00g and 1.15g, respectively), while at 10^{-2} and 10^{-4} dilutions, pupal weight was significantly highest in both B1 and B8 breeds (0.83g and 0.91g each, respectively). Similarly among hybrids, B1×B8 recorded significantly highest pupal weight at stock concentration, 10^{-4} and 10^{-8} dilution (0.76g, 0.98g and 1.18g, respectively) while, at 10^{-4} and 10^{-6} dilution the pupal weight was significantly highest in B1×B4 hybrid (0.88g and 1.04g, respectively). Significantly least pupal weight was observed in both B6×B8 and B8×B6 (0.76g each) over the dilutions. In non-inoculated control batches, among parents significantly highest pupal weight of 1.43 g was recorded in B1 and 1.46 g in B1×B4 among hybrids and lowest pupal weight was recorded in B6 (1.33 g).

Pupae of the silkworms were reported to be susceptible, but comparatively less than the larvae, due to pupal cuticular antifungal agents such as saturated fatty acids, namely, capric acid and caprylic acid [9, 2]. Silkworm hybrid PM × CSR_2 when treated with sub lethal concentration of *B. bassiana* conidial suspension (2.15 × 10^6 spores / ml), exhibited significant reduction in pupal weight, wherein the treated silkworm showed lowest pupal weight of 0.63 g compared to control (1.2 g). Significant reduction in pupal weight was also observed when thermotolerant bivoltine breeds were treated with different spore dilution of *B.bassiana* wherein, the breeds B3 (1.07 g at 10^{-4}) and B4 (1.00 g at 10^{-3}) showed significantly higher pupal weight even when challenged with fungal infection [8]. In the present study also significant reduction in pupal weight was observed from minimum of 0.50 g (stock: 3.17 × 10^5 spores / ml) in B8×B6 to maximum of 1.44 g (10^{-8}:3.8 × 10^3 spores / ml) in both B1×B8 and B4 × B1.

3.5 Shell weight (g)

Weight of single shell showed significant difference among the thermotolerant bivoltine silkworm hybrids treated with different dilutions of *B. bassiana* spores (Table 3). At stock concentration, cent per cent mortality was noticed in B6 breed and B6×B1 and B6×B4 hybrids and hence shell weight could not be recorded. The breed B8 recorded significantly highest shell weight at stock, 10^{-2}, 10^{-4} and 10^{-6} dilution (0.17g, 0.19g, 0.21g and 0.24g, respectively) while, at 10^{-8} dilution shell weight was significantly higher in both B8 and B1 breeds (0.26g each). Similarly among hybrids, B1×B8 showed significantly highest shell weight at stock, 10^{-4}, 10^{-6} and 10^{-8} dilution (0.18g, 0.23g, 0.25g and 0.28g, respectively) while, at 10^{-2} shell weight was highest in both B1×B8 and B1× B4 hybrids (0.19g each). Significantly lowest shell weight was recorded in B6 × B4 (0.13g), followed by B8 × B1 (0.14g) over the dilutions. In non-inoculated control batches, among parents significantly highest shell weight of 0.37 g was recorded in B1 and 0.36 g in B1×B4 among hybrids and lowest shell weight was recorded in B6×B8 (0.27 g).

Silkworm hybrid PM × CSR_2 when treated with sub lethal concentration of *B. bassiana* conidial suspension (2.15 × 10^6

spores / ml), exhibited significant reduction in shell weight, wherein the treated silkworm showed lowest shell weight of 0.09 g compared to control 0.24 g [12]. *Beauveria bassiana* pathogen causes mutilation during its growth and development in 5th instar silkworm. On the 4th day of inoculation, secretory cells in the glandular layer were filled with mycelia. Shrinkage of silkgland tissue was observed on 5th and 6th days of post - inoculation. This caused irrepairable architectural changes in middle region of silkgland and hence production of good quality cocoons was severely affected [16]. In the present findings also significant reduction in shell weight was noticed in treated batches compared to control batches, which could be attributed to the above findings.

3.6 Shell ratio (g)

Significant difference for shell per cent was observed among the thermotolerant bivoltine silkworm hybrids treated with different dilutions of *B. bassiana* (Table 3). At stock concentration, cent per cent mortality was noticed in B6 breed and B6×B1 and B6×B4 hybrids and hence shell ratio could not be recorded. The breed B8 recorded significantly highest shell ratio at stock concentration and all the other dilutions (18.47% at stock, 18.49% at 10^{-2}, 19.19% at 10^{-4}, 19.18% at 10^{-6} and 19.22% at 10^{-8} dilution). Similarly among hybrids, B1×B8 recorded significantly highest shell ratio at stock and all the other dilutions (19.41% at stock, 18.96% at 10^{-2}, 19.41% at 10^{-4}, 19.17% at 10^{-6} and 19.07% at 10^{-8} dilution). Significantly lowest shell ratio of 15.17 per cent was noticed in B8 × B1, followed by B6 (15.97%) breed over all the dilutions. In non-inoculated control batches, significantly highest shell ratio of 20.53 per cent was recorded in B1 among parents and 19.92 per cent shell ratio in B1×B4 among hybrids and lowest shell ratio was recorded in B6×B8 hybrid (16.74%).

The shell content 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. 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 recorded highest shell ratio of 22.75 per cent at 10^2 spore dilution [17]. The hybrid PM × CSR_2 (12.80%) breed showed reduction in shell ratio when treated at 2.15 × 10^6 spores / ml of *B. bassiana* conidial suspension compared to control (16.43%) [12]. Even in earlier studies, significant reduction in cocoon shell ratio among thermotolerant bivoltine silkworm breeds was noticed when inoculated with different dilutions of *B. bassiana*, shell ratio being highest in B4 (21.22%) at 10^{-5} and lowest in CSR_2 (14.45%) at 10^{-3} spore dilution [8]. Even in the present study, at different dilutions of *B. bassiana* (stock to 10^{-8} dilution) highest shell ratio of 19.22 per cent was recorded in B8 at 10^{-8} spore dilution and lowest of 13.31 per cent in B8×B1at stock.

3.7 Filament length (m)

Filament length showed significant variation among the thermotolerant bivoltine silkworm hybrids when inoculated with different doses of *B. bassiana* spores

(Table 4). As cent per cent mortality was noticed at stock concentration in B6 breed and B6×B1 and B6×B4 hybrids, filament length could not be recorded. The breed B8 recorded significantly longest filament length at stock concentration and all the other dilutions (461.67 m at stock, 512.79 m at 10^{-2}, 593.14 m at 10^{-4}, 691.64 m at 10^{-6} and 745.00 m at 10^{-8} dilution). Similarly among hybrids B1 × B8 recorded significantly longest filament length at stock and all the other dilutions (493.22 m at stock, 512.27 m at 10^{-2}, 643.10 m at 10^{-4}, 726.54 m at 10^{-6} and 816.55 m at 10^{-8} dilution). Significantly least filament length was observed in B8 × B4 (479.29 m), followed by B8 × B6 (482.76 m) over the dilutions. In non-inoculated control batches, significantly longest filament length of 992.03 m was recorded in B1 among parents and 1015.50 m in B1×B4 among hybrids and lowest shell ratio was recorded in B6 (897.17 m).

The silk filament length indicates the reelable length of silk filament from a cocoon. Generally, longer the non-breakable filament higher is the reelability. It is presumed that the physiological and biochemical stress induced by a fungal pathogen caused to exude uneven amounts of silk fluid in lumps [6]. Significant reduction in filament length in PM × CSR_2 hybrid (478.9 m) infected with *B. bassiana* conidia in contrast with the healthy larvae (671.6 m) was observed [12]. Those finding support the present study, wherein filament length was significantly reduced from 1015.50 m in control to 768.94 m at 10^{-8} dilution, to 726.54 m at 10^{-6} dilution, to 643.10 m at 10^{-4} dilution, to 512.79 m at 10^{-2} dilution and to 493.22 m at stock concentration.

3.8 Filament weight (g)

Filament weight was reported to show significant variation among the thermotolerant bivoltine silkworm breeds and hybrids when inoculated with different doses of *B. bassiana* spores (Table 4). In B6 breed and B6×B1 and B6×B4 hybrids concentration, cent percent mortality was noticed at stock concentration and hence filament weight could not be recorded. The breed B8 recorded significantly highest filament weight at stock concentration (0.13g) and at 10^{-4} dilution (0.17g) while, at 10^{-2} and 10^{-6} dilution filament weight was significantly highest in both B1 and B8 breeds (0.14 and 0.18g each, respectively). At 10^{-8} dilution it was highest in B1 breed (0.22g). Among hybrids B1 × B8 showed significantly highest filament weight at stock and all the other dilutions (0.14g at stock, 0.15g at 10^{-2}, 0.18g at 10^{-4}, 0.20g at 10^{-6} and 0.24g at 10^{-8} dilution).While, significantly least filament weight was recorded in B1 × B6, B8 × B1, B8 × B4 and B8 × B6 hybrids (0.14g each). In non-inoculated control batches, significantly highest filament weight of 0.28g was recorded in B1among parents and 0.29g in B1 ×B4 among hybrids and lowest shell ratio was recorded in both B6 breed and B6 × B8 hybrid (0.20g each).

Significantly lowest filament weight was recorded in breeds treated with different fungal doses compared to the control batches, as the infected silkworms spin flimsy cocoons, which yield shorter filament resulting in lesser filament weight. Silkworm hybrid PM × CSR_2 treated with sub lethal concentration of *B. bassiana* conidial suspension exhibited significant reduction in filament weight compared to control breeds [12]. Significant reduction in filament weight was recorded in thermotolerant bivoltine breeds when inoculated with different dilution of *B. bassiana* from 0.29 g in control to 0.20 g at 10^{-5} spore dilution, to 0.20 g at 10^{-4} dilution, to 0.16 g at 10^{-3} spore dilution [8]. In the present study also significant reduction in filament weight was observed under *B. bassiana* inoculation condition from 0.29 g in control to 0.24 g at 10^{-8} dilution, to 0.20 g at 10^{-6} dilution, to 0.18 g at 10^{-4} dilution, to 0.15 g at 10^{-2} dilution to 0.14 g at stock concentration.

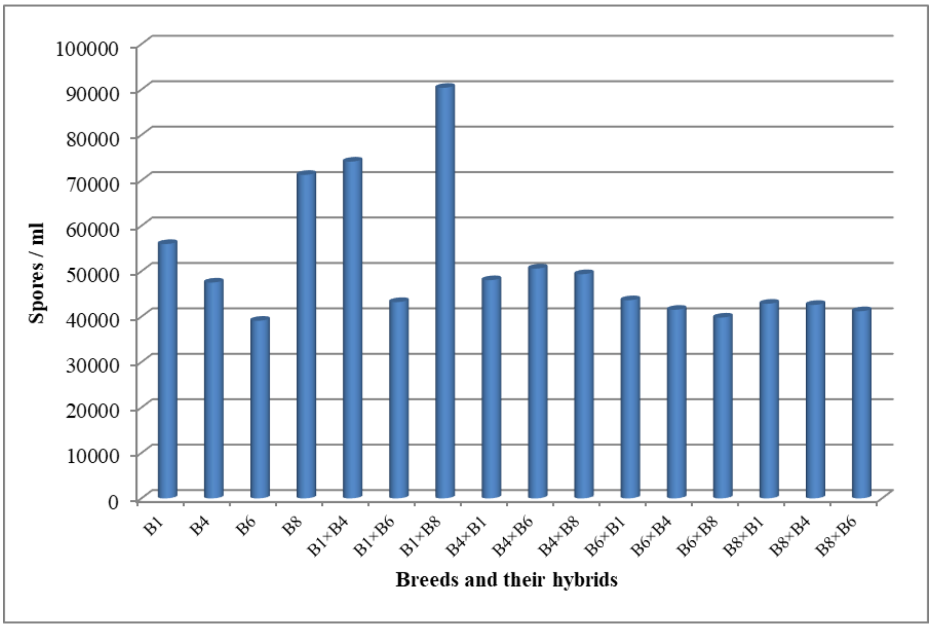

Fig 1: LC_{50} values for *B. bassiana* infection among thermotolerant bivoltine silkworm breeds and hybrids.

The LC_{50} was calculated by Reed and Muench (1938) method for each of the breed and the hybrid. The silkworms were inoculated in the beginning of the V instar and total larval mortality (mean of three replications with 50 worms in each) in the V instar till the worms entered cocoon spinning stage was recorded and used for the calculation.

Table 1: Cocoon yield response of thermotolerant bivoltine silkworms to *B. bassiana* infection

Cocoon yield by number per 1000 worms							
Parents/ hybrids	**Stock**	**10^{-2}**	**10^{-4}**	**10^{-6}**	**10^{-8}**	**Mean**	**control**
B1	220.00^{efg}(14.84)	306.67^{cd}	340.00^{bcd}	453.33^{bcd}	480.00^{abc}	360.00	1000
B4	173.33^{cdefg}(13.10)	246.67^{abc}	400.00^{de}	400.00^{ab}	526.67^{cd}	349.33	1000
B6	0.00^{a}(0.71)	193.33^{abc}	240.00^{ab}	333.33^{a}	426.67^{ab}	298.33	1000
B8	333.33^{g}(18.26)	406.67^{de}	446.67^{def}	526.67^{cde}	613.33^{de}	465.33	1000
B1×B4	326.67^{fg}(18.07)	413.33^{de}	486.67^{ef}	540.00^{de}	600.00^{de}	473.33	1000
B1×B6	46.67^{abc}(6.62)	193.33^{abc}	260.00^{abc}	333.33^{a}	433.33^{ab}	253.33	1000
B1×B8	420.00^{g}(20.48)	473.33^{e}	526.67^{f}	600.00^{e}	660.00^{e}	536.00	1000
B4×B1	213.33^{defg}(14.54)	260.00^{bc}	346.67^{bcd}	400.00^{ab}	466.67^{abc}	337.33	1000
B4×B6	126.67^{bcdef}(10.34)	273.33^{bc}	353.33^{cd}	426.67^{abc}	500.00^{bc}	336.00	1000
B4×B8	166.67^{cdefg}(12.91)	253.33^{bc}	340.00^{bcd}	413.33^{ab}	480.00^{abc}	330.67	1000
B6×B1	0.00^{a}(0.71)	253.33^{bc}	266.67^{abc}	360.00^{ab}	440.00^{abc}	330.25	1000
B6×B4	0.00^{a}(0.71)	173.33^{ab}	253.33^{abc}	346.67^{ab}	433.33^{ab}	301.67	1000
B6×B8	66.67^{abcd}(6.89)	160.00^{ab}	260.00^{abc}	326.67^{a}	440.00^{abc}	250.67	1000
B8×B1	33.33^{ab}(4.95)	133.33^{a}	220.00^{a}	360.00^{ab}	453.33^{abc}	239.99	1000
B8×B4	86.67^{bcde}(9.32)	186.67^{ab}	266.67^{abc}	326.67^{a}	393.33^{a}	252.00	1000
B8×B6	33.33^{ab}(4.95)	160.00^{ab}	273.33^{abc}	366.67^{ab}	440.00^{abc}	254.67	1000
F-test	*	*	*	*	*	-	NS
SEm±	1.48	22.05	21.02	20.68	17.72	-	-
CD at (5%)	4.25	63.51	60.54	59.58	51.04	-	-
CV (%)	25.99	14.95	11.03	8.80	6.31	-	-

	Cocoon yield by weight per 1000 worms						
Parents/ hybrids	**stock**	**10^{-2}**	**10^{-4}**	**10^{-6}**	**10^{-8}**	**Mean**	**control**
B1	188.67^{efg}(13.75)	308.61^{f}	498.92^{ef}	539.47^{fg}	867.00^{f}	480.53	1787.28^{h}
B4	139.43^{cdef}(11.74)	228.51^{def}	354.93^{bcd}	459.67^{cdef}	629.87^{cde}	362.48	1754.21^{ef}
B6	0.00^{a}(0.71)	159.89^{abcde}	218.13^{a}	338.67^{ab}	504.73^{ab}	305.35	1610.69^{a}
B8	306.41^{fg}(17.51)	412.27^{g}	439.20^{de}	649.93^{gh}	719.60^{e}	505.48	1742.25^{e}
B1×B4	302.00^{fg}(17.39)	438.66^{g}	637.67^{g}	686.07^{h}	852.40^{f}	583.36	1807.58^{h}
B1×B6	32.61^{abc}(5.56)	151.67^{abcde}	235.60^{ag}	345.47^{abc}	521.47^{abc}	257.36	1700.18^{d}
B1×B8	392.73^{g}(19.81)	480.07^{g}	574.20^{fg}	767.87^{h}	960.47^{f}	635.07	1743.33^{e}
B4×B1	165.15^{ef}(12.77)	216.80^{bcdef}	359.92^{cd}	457.07^{bcdef}	608.27^{bcde}	361.44	1769.75^{fg}
B4×B6	97.25^{bcde}(9.09)	242.20^{ef}	371.74^{cd}	504.33ef	666.33^{de}	376.37	1686.67^{cd}
B4×B8	142.32^{def}(11.93)	222.73^{cdef}	354.50^{bcd}	485.87^{def}	649.33^{de}	370.95	1702.43^{d}
B6×B1	0.00^{a}(0.71)	197.33^{abcde}	251.63^{abc}	380.66^{abcd}	557.33^{abcd}	346.73	1696.66^{cd}
B6×B4	0.00^{a}(0.71)	141.68^{abcd}	233.75^{ab}	353.35^{abc}	515.67^{abc}	311.11	1685.16^{cd}
B6×B8	43.84^{abcd}(5.64)	127.73^{abc}	230.10^{a}	336.13^{a}	516.07^{abc}	250.77	1646.01^{b}
B8×B1	20.27^{ab}(3.93)	98.40^{a}	200.47^{a}	386.53^{abcde}	593.40^{abcd}	259.81	1681.48^{cd}
B8×B4	58.65^{bcde}(7.68)	153.99^{abcde}	261.81^{abc}	341.47^{abc}	481.13^{a}	259.43	1700.86^{d}
B8×B6	19.88^{ab}(3.88)	119.67^{ab}	255.20^{abc}	403.95^{abcde}	525.33^{abc}	264.80	1673.33^{c}
F-test	*	*	*	*	*	-	*
SEm±	1.22	18.98	23.21	22.64	22.65	-	4.90
CD at (5%)	14.11	54.66	66.86	65.22	65.23	-	3.50
CV (%)	23.57	14.21	11.74	8.44	6.17	-	23.57

Table 2: Cocoon economic traits in response to *B. bassiana* infection in thermotolerant bivoltine silkworms

Single cocoon weight (g)							
Parents /hybrids	**Stock**	**10^{-2}**	**10^{-4}**	**10^{-6}**	**10^{-8}**	**Mean**	**Control**
B1	0.92^{b}(1.19)	1.01^{f}	1.10^{de}	1.19^{ef}	1.37^{de}	1.12	1.81^{h}
B4	0.80^{b}(1.14)	0.92^{e}	1.04^{cd}	1.15^{de}	1.31^{de}	1.04	1.76^{efgh}
B6	0.00^{a}(0.71)	0.83^{bcd}	0.91^{a}	1.02^{a}	1.17^{a}	0.79	1.60^{a}
B8	0.86^{b}(1.17)	1.01^{f}	1.12^{ef}	1.23^{fg}	1.37^{e}	1.12	1.74^{defg}
B1×B4	0.93^{b}(1.19)	1.06^{f}	1.18^{fg}	1.28^{g}	1.37^{e}	1.16	1.82^{h}
B1×B6	0.71^{b}(1.10)	0.78^{abc}	0.91^{a}	1.04^{ab}	1.20^{ab}	0.93	1.68^{bcd}
B1×B8	0.94^{b}(1.20)	1.02^{f}	1.21^{g}	1.28^{g}	1.46^{f}	1.18	1.77^{fgh}
B4×B1	0.77^{b}(1.13)	0.83^{cd}	1.04^{cd}	1.14^{cde}	1.26^{bc}	1.01	1.79^{gh}
B4×B6	0.78^{b}(1.13)	0.88^{de}	1.05^{cde}	1.18^{ef}	1.33^{cde}	1.04	1.66^{abc}
B4×B8	0.85^{b}(1.16)	0.88^{de}	1.04^{cd}	1.17^{def}	1.35^{cde}	1.06	1.71^{cdef}
B6×B1	0.00^{a}(0.71)	0.78^{abc}	0.94^{ab}	1.06^{ab}	1.27^{bc}	1.01	1.68^{bcd}
B6×B4	0.00^{a}(0.71)	0.82^{abcd}	0.92^{ab}	1.02^{a}	1.15^{a}	0.98	1.64^{ab}
B6×B8	0.66^{ab}(0.95)	0.79^{abc}	0.88^{a}	1.03^{ab}	1.17^{a}	0.91	1.63^{ab}

	Pupal weight (g)						
Parents /hybrids	**Stock**	**10^{-2}**	**10^{-4}**	**10^{-6}**	**10^{-8}**	**Mean**	**control**
B1	0.71^{b}(1.10)	0.83^{de}	0.90^{fg}	0.96^{cdef}	1.13^{efgh}	0.91	1.43^{f}
B4	0.66^{b}(1.08)	0.76^{cd}	0.87^{ef}	0.97^{cdef}	1.08^{cdefg}	0.87	1.41^{ab}
B6	0.00^{a}(0.71)	0.69^{abc}	0.76^{ab}	0.86^{ab}	1.01^{abc}	0.83	1.33^{ab}
B8	0.75^{b}(1.12)	0.83^{de}	0.90^{fgh}	1.00^{ef}	1.15^{fgh}	0.93	1.41^{abcdef}
B1×B4	0.75^{b}(1.12)	0.88^{e}	0.97^{gh}	1.04^{f}	1.17^{gh}	0.96	1.46^{abc}
B1×B6	0.60^{b}(1.05)	0.65^{ab}	0.75^{ab}	0.85^{ab}	1.00^{ab}	0.77	1.36^{ef}
B1×B8	0.76^{b}(1.12)	0.82^{de}	0.98^{h}	1.03^{f}	1.18^{h}	0.95	1.44^{def}
B4×B1	0.63^{b}(1.06)	0.68^{ab}	0.84^{cdef}	0.93^{bcde}	1.07^{bcdef}	0.83	1.44^{bcdef}
B4×B6	0.64^{b}(1.07)	0.72^{bc}	0.86^{def}	0.97^{cdef}	1.10^{defgh}	0.86	1.36^{abcde}
B4×B8	0.71^{b}(1.10)	0.73^{bc}	0.86^{def}	0.98^{def}	1.12^{efgh}	0.88	1.38^{abcde}
B6×B1	0.00^{a}(0.71)	0.63^{a}	0.78^{abcd}	0.88^{ab}	1.06^{abcde}	0.84	1.38^{ab}
B6×B4	0.00^{a}(0.71)	0.68^{abc}	0.77^{abc}	0.85^{a}	1.02^{abcd}	0.83	1.34^{a}
B6×B8	0.55^{ab}(0.92)	0.67^{ab}	0.73^{a}	0.87^{ab}	0.98^{a}	0.76	1.35^{abcd}

B8×B1	0.62^{ab}(0.94)	0.74^{a}	0.91^{ab}	1.07^{abc}	1.28^{bcd}	0.92	1.67^{abc}	0.53^{ab}(0.91)	0.62^{a}	0.77^{abc}	0.90^{abc}	1.12^{efgh}	0.79	1.37^{abc}
B8×B4	0.68^{b}(1.08)	0.83^{bcd}	0.98^{bc}	1.05^{ab}	1.22^{ab}	0.95	1.69^{bcde}	0.57^{b}(1.04)	0.69^{abc}	0.82^{dbcde}	0.87^{ab}	1.03^{abcd}	0.79	1.37^{abcde}
B8×B6	0.59^{ab}(0.93)	0.75^{ab}	0.93^{ab}	1.10^{bcd}	1.15^{a}	0.90	1.66^{abc}	0.50^{ab}(0.90)	0.63^{a}	0.76^{ab}	0.91^{abcd}	1.00^{ab}	0.76	1.38^{abcde}
F-test	*	*	*	*	*	-	*	*	*	*	*	*	-	*
SEm±	0.05	0.02	0.01	0.01	0.02	-	0.01	0.05	0.02	0.01	0.01	0.02	-	0.01
CD at (5%)	0.15	0.04	0.04	0.04	0.04	-	0.04	0.13	0.04	0.04	0.04	0.05	-	0.04
CV (%)	8.66	3.03	2.38	2.11	2.01	-	1.31	7.92	3.60	2.96	2.58	2.64	-	1.73

*- Significant at 5%, NS- Non significant; NA- Not analysed; figures with same superscript are statistically on par; Stock – 3.17 × 10^5 spores/ml

Table 3: Cocoon shell traits as affected by *B. bassiana* infection in thermotolerant bivoltine silkworms

Parents /hybrids	Shell weight (g)							Shell ratio (%)						
	Stock	10^{-2}	10^{-4}	10^{-6}	10^{-8}	Mean	control	Stock	10^{-2}	10^{-4}	10^{-6}	10^{-8}	Mean	control
B1	0.14^{cde}(0.80)	0.18^{g}	0.18^{e}	0.22^{i}	0.26^{efg}	0.19	0.37^{h}	16.96^{b}(4.18)	17.41^{bcdef}(4.23)	17.98^{defgh}(4.30)	18.60^{fgh}(4.37)	18.78^{bcd}(4.39)	17.95	20.53^{g}(4.59)
B4	0.15^{cde}(0.80)	0.17^{fg}	0.20^{g}	0.19^{ef}	0.24^{ef}	0.19	0.34^{g}	17.73^{b}(4.27)	18.12^{cdef}(4.31)	17.00^{bcde}(4.18)	16.27^{abc}(4.09)	17.49^{abcd}(4.24)	17.32	19.60^{efg}(4.48)
B6	0.00^{a}(0.71)	0.14^{cd}	0.14^{b}	0.16^{a}	0.19^{a}	0.16	0.27^{a}	0.00^{a}(0.71)	16.48^{abc}(4.12)	15.93^{ab}(4.05)	15.55^{a}(4.01)	15.94^{a}(4.05)	15.97	16.97^{ab}(4.18)
B8	0.17^{de}(0.82)	0.19^{h}	0.21^{h}	0.24^{jk}	0.26^{fg}	0.21	0.33^{f}	18.47^{b}(4.36)	18.49^{def}(4.36)	19.19^{gh}(4.44)	19.18^{h}(4.44)	19.22^{d}(4.44)	18.22	19.22^{ef}(4.44)
B1×B4	0.17^{de}(0.82)	0.19^{h}	0.21^{h}	0.23^{j}	0.25^{efg}	0.21	0.36^{h}	18.57^{b}(4.37)	17.63^{bcdef}(4.26)	18.02^{defgh}(4.30)	18.43^{efgh}(4.35)	18.44^{bcd}(4.35)	18.22	19.92^{fg}(4.52)
B1×B6	0.11^{bcde}(0.78)	0.14^{d}	0.16^{c}	0.18^{de}	0.21^{abcd}	0.16	0.32^{d}	15.75^{b}(4.03)	17.44^{bcdef}(4.24)	17.40^{bcdef}(4.23)	17.66^{defg}(4.26)	17.25^{abcd}(4.21)	17.10	19.14^{ef}(4.43)
B1×B8	0.18^{e}(0.83)	0.19^{h}	0.23^{i}	0.25^{k}	0.28^{g}	0.23	0.33^{ef}	19.41^{b}(4.46)	18.96^{f}(4.41)	19.41^{h}(4.46)	19.17^{h}(4.43)	19.07^{cd}(4.42)	19.20	18.76^{de}(4.39)
B4×B1	0.14^{cde}(0.80)	0.16^{ef}	0.19^{g}	0.22^{hi}	0.23^{cde}	0.19	0.34^{g}	18.28^{b}(4.33)	18.83^{f}(4.40)	18.74^{fgh}(4.39)	18.98^{gh}(4.41)	18.58^{bcd}(4.37)	18.68	19.27^{ef}(4.45)
B4×B6	0.14^{cde}(0.80)	0.16^{f}	0.19^{g}	0.21^{h}	0.24^{def}	0.19	0.29^{c}	17.86^{b}(4.28)	18.58^{ef}(4.37)	18.35^{efgh}(4.34)	17.67^{defg}(4.26)	17.68^{abcd}(4.26)	18.03	17.77^{bc}(4.27)
B4×B8	0.15^{cde}(0.80)	0.15^{e}	0.18^{f}	0.20^{g}	0.23^{bcde}	0.18	0.33^{de}	17.14^{b}(4.20)	17.42^{bcdef}(4.23)	17.65^{defg}(4.26)	16.78^{abcd}(4.16)	17.05^{abcd}(4.19)	17.21	19.05^{ef}(4.42)
B6×B1	0.00^{a}(0.71)	0.15^{e}	0.16^{c}	0.18^{cd}	0.21^{abcd}	0.18	0.30^{c}	0.00^{a}(0.71)	19.04^{f}(4.42)	16.79^{bcd}(4.16)	16.72^{abcd}(4.15)	16.66^{ab}(4.14)	17.30	17.74^{bc}(4.27)
B6×B4	0.00^{a}(0.71)	0.14^{cd}	0.15^{b}	0.17^{ab}	0.19^{a}	0.13	0.29^{c}	0.00^{a}(0.71)	16.70^{abcde}(4.15)	16.01^{abc}(4.06)	16.40^{abcd}(4.11)	16.81^{abc}(4.160)	16.48	17.97^{cd}(4.30)
B6×B8	0.11^{bc}(0.76)	0.13^{bc}	0.15^{c}	0.16^{ab}	0.19^{a}	0.15	0.27^{a}	17.14^{ab}(3.04)	15.82^{ab}(4.04)	17.42^{cdef}(4.23)	15.88^{ab}(4.05)	16.51^{ab}(4.12)	16.55	16.74^{a}(4.15)
B8×B1	0.08^{ab}(0.74)	0.11^{a}	0.14^{a}	0.17^{bc}	0.20^{ab}	0.14	0.28^{b}	13.31^{ab}(2.71)	15.52^{a}(4.00)	15.18^{a}(3.96)	15.97^{ab}(4.06)	15.88^{a}(4.05)	15.17	16.95^{ab}(4.18)
B8×B4	0.10^{bcd}(0.78)	0.14^{d}	0.17^{d}	0.18^{cde}	0.21^{abc}	0.16	0.32^{de}	15.08^{b}(3.94)	16.60^{abcd}(4.13)	16.98^{bcde}(4.18)	17.03^{bcde}(4.19)	17.08^{abcd}(4.19)	16.55	19.14ef(4.43)
B8×B6	0.09^{ab}(0.75)	0.12^{ab}	0.17^{e}	0.19^{fg}	0.20^{a}	0.15	0.28^{b}	15.60^{ab}(2.91)	15.84^{ab}(4.04)	18.57^{fgh}(4.37)	17.48^{cdef}(4.24)	17.60^{abcd}(4.25)	17.02	17.08^{abc}(4.19)
F-test	*	*	*	*	*	-	*	*	*	*	*	*	-	*
SEm±	0.01	0.002	0.001	0.002	0.005	-	0.002	0.48	0.04	0.03	0.03	0.05	-	0.02
CD at (5%)	0.03	0.006	0.003	0.005	0.02	-	0.005	1.37	0.12	0.10	0.09	0.15	-	0.06
CV (%)	2.12	2.35	1.14	1.62	4.14	-	0.97	24.78	1.76	1.39	1.29	2.15	-	0.86

*- Significant at 5%, NS- Non significant; NA- Not analysed; figures with same superscript are statistically on par; Stock – 3.17 × 10^5 spores/ml

Table 4: Cocoon filament traits as affected by *B. bassiana* infection in thermotolerant bivoltine silkworms

	Filament length (m)							Filament weight (g)						
Parents /hybrids	Stock	10^{-2}	10^{-4}	10^{-6}	10^{-8}	Mean	control	Stock	10^{-2}	10^{-4}	10^{-6}	10^{-8}	Mean	control
B1	424.89^{b}(20.62)	459.12^{f}	569.30^{g}	640.08^{c}	728.37^{e}	564.35	992.03^{i}	0.11^{cd}(0.78)	0.14^{ef}	0.16^{abcd}	0.18^{abcd}	0.22^{cde}	0.16	0.28^{de}
B4	378.33^{b}(19.46)	492.71^{g}	512.67^{e}	636.87^{c}	741.68^{f}	552.52	987.38^{hi}	0.12^{cd}(0.79)	0.13^{cdef}	0.14^{a}	0.18^{abc}	0.21^{bcde}	0.16	0.27^{cde}
B6	0.00^{a}(0.71)	404.60^{abc}	454.84^{a}	593.35^{ab}	635.94^{ab}	522.18	897.17^{a}	0.00^{a}(0.71)	0.11^{ab}	0.14^{a}	0.17^{ab}	0.19^{abc}	0.15	0.20^{a}
B8	461.67^{b}(21.50)	512.79^{h}	593.14^{h}	691.64^{f}	745.00^{f}	600.84	955.18^{ef}	0.13^{cd}(0.79)	0.14^{ef}	0.17^{bcd}	0.18^{abcd}	0.21^{bcde}	0.17	0.25^{cde}
B1×B4	459.22^{b}(21.44)	511.86^{h}	597.71^{h}	672.02^{e}	768.94^{g}	601.95	1015.50^{j}	0.12^{cd}(0.79)	0.14^{def}	0.17^{cd}	0.19^{bcd}	0.22^{de}	0.17	0.29^{e}
B1×B6	309.19^{b}(17.60)	417.94^{bcd}	495.85^{d}	587.13^{a}	630.90^{a}	488.20	941.55^{de}	0.09^{bcd}(0.77)	0.12^{abcd}	0.14^{a}	0.17^{a}	0.19^{ab}	0.14	0.24^{abcd}
B1×B8	493.22^{b}(22.22)	512.27^{h}	643.10^{i}	726.54^{g}	816.55^{h}	638.34	972.79^{gh}	0.14^{d}(0.80)	0.15^{f}	0.18^{d}	0.20^{d}	0.24^{e}	0.18	0.26^{cde}
B4×B1	381.74^{b}(19.55)	433.34^{de}	541.82^{f}	658.86^{de}	747.88^{f}	552.73	965.83^{fg}	0.11^{cd}(0.78)	0.12^{abcd}	0.15^{abc}	0.19^{abcd}	0.21^{abcde}	0.16	0.25^{cde}
B4×B6	403.67^{b}(20.10)	435.67^{e}	546.93^{f}	662.60^{e}	753.45^{f}	560.46	931.42^{cd}	0.11^{cd}(0.78)	0.12^{abc}	0.15^{abc}	0.19^{cd}	0.20^{abcd}	0.15	0.22^{abc}
B4×B8	412.29^{b}(20.32)	432.80^{de}	533.54^{f}	643.70^{cd}	725.56^{e}	549.57	944.41^{de}	0.12^{cd}(0.79)	0.12^{abc}	0.16^{abcd}	0.18^{abc}	0.21^{abcd}	0.16	0.24^{abcd}
B6×B1	0.00^{a}(0.71)	420.84^{cde}	477.02^{bc}	604.55^{ab}	651.20^{cd}	538.40	932.86^{cd}	0.00^{a}(0.71)	0.12^{abc}	0.13^{a}	0.17^{abc}	0.18^{ab}	0.15	0.23^{abcd}
B6×B4	0.00^{a}(0.71)	408.60^{abc}	467.22^{ab}	597.01^{ab}	645.86^{bcd}	529.67	917.31^{bc}	0.00^{a}(0.71)	0.11^{abc}	0.13^{a}	0.18^{abc}	0.18^{ab}	0.15	0.23^{abc}
B6×B8	353.00^{ab}(12.63)	399.16^{a}	452.87^{a}	587.54^{a}	642.38^{abc}	486.99	893.21^{a}	0.08^{b}(0.74)	0.11^{abc}	0.13^{a}	0.17^{abc}	0.18^{a}	0.13	0.20^{ab}
B8×B1	307.78^{ab}(11.94)	404.44^{abc}	452.15^{a}	607.73^{c}	657.49^{d}	485.92	917.12^{bc}	0.07^{ab}(0.74)	0.11^{ab}	0.13^{a}	0.17^{a}	0.20^{abcd}	0.14	0.23^{abcd}
B8×B4	277.87^{b}(16.68)	400.35^{ab}	489.84^{cd}	587.17^{a}	641.22^{abc}	479.29	945.15^{de}	0.09^{bc}(0.77)	0.11^{a}	0.14^{ab}	0.17^{a}	0.18^{a}	0.14	0.24^{bcde}
B8×B6	261.32^{ab}(11.02)	412.62^{abc}	495.15^{d}	594.27^{ab}	650.44^{cd}	482.76	903.57^{ab}	0.08^{bc}(0.76)	0.13^{bcde}	0.14^{a}	0.17^{a}	0.19^{ab}	0.14	0.20^{ab}
F-test	*	*	*	*	*	-	*	*	*	*	*	*	-	*
SEm±	2.46	3.37	2.88	3.47	2.27	-	3.11	0.01	0.003	0.006	0.004	0.006	-	0.01
CD at (5%)	7.08	9.71	8.30	9.99	6.52	-	8.96	0.02	0.01	0.02	0.01	0.02	-	0.02
CV (%)	28.70	1.32	0.96	0.95	0.56	-	0.57	1.47	4.82	6.5	3.97	5.00	-	6.04

4. Conclusion

The performance of the thermotolerant bivoltine breeds and their hybrids for cocoon and filament traits under muscardine infection revealed that the breed B8 and the hybrid

B1 × B8 performed better for all the traits studied, while B1 and B1 × B4 for cocoon weight, pupal weight and filament weight. Hence, it may be concluded that, the breeds B8 and B1 and hybrids B1 × B8 and B1 × B4 show relatively better tolerance to muscardine infection apart from being thermotolerant. These breeds and hybrids could be considered for evolving dual stress tolerance i.e., both for high temperature and fungal infections.

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