# MODELLING OF FEMALE PUPAL BODY WEIGHT AND FECUNDITY OF THE MULBERRY SILKWORM (*BOMBYX MORI* L) STRAINS

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## ABSTRACT

Promotion of Sericulture depends, besides other factors, on availability of quality silk seed. Present study was conducted to construct a model for predicting fecundity using the female pupal body weight. Among the nine reared silkworm strains, the mean heaviest pupa was 1.52±0.01 g of hybrid PFI 14, while the mean lightest pupa was 1.24±0.03 g of hybrid 206MKD*C-102. The mean highest fecundity was 458.1±16.9 eggs/female laid by hybrid PFI 14, while the mean lowest fecundity was 387.6±9.74 eggs/female laid by inbred 206MKD. A positive significant ($p<0.05$) to highly significant ($p<0.01$) correlation was found between the female pupal body weight and fecundity. The correlation coefficient ($r^2$) ranged from 0.728 to 0.957. A positive linear model was established between the female pupal body weight and fecundity. The coefficient of regression varies between 0.53 and 0.92, thus indicated a moderate-good fit of fecundity prediction model. Based on these findings it is concluded that the nine silkworm strains, both inbred strains and hybrids, have promising fecundity potential. Moreover, the female pupal body weight is a reliable indicator for fecundity estimation and may be used for estimation of silk seed production. The findings will also be helpful in increasing silk seed production by selecting females based on pupal body weight.

**Keywords:** Fecundity, Pupa, body weight, Seed cocoons, Silk Seed, *Bombyx mori*,

## INTRODUCTION

Availability of quality silk seed is foremost important for promotion of Sericulture as a cottage industry. Quality silk seed increases production of commercial cocoons and consequently raw silk. Production of silk seed can be increased either by rearing large number of egg layings or enhancing fecundity of silkworm strains. Large scale rearing of silkworm is a costly investiture, however, changing rearing conditions and subsequently improving health of the larva, as well as, the pupa can improve fecundity (Bajwa and Ali, 2005; Hussain *et al*., 2011).

Fecundity, egg fertility and egg hatchability are complex physiological processes which depend upon several intrinsic and extrinsic factors, including silkworm strains, neural, hormonal, environmental, behavioral factors, etc. The fecundity and egg hatchability of silkworm also vary with silkworm rearing season

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and silkworm strains (Radhakrishnan *et al*., 2001), mulberry leaf quality and quantity, environmental conditions and oviposition conditions (Hussain *et al*., 2011), copulation duration (Rahman and Khan, 2005).

*Bombyx mori* is a “Capital-breeding” Lepidopterous species in which reproduction entirely depends on metabolic resources assembled by larval stage. Maternal body size plays an important role in fecundity especially in capital-breeders. This relationship between maternal size and fecundity also indicates similar influences of environmental factors on these two biological traits. Generally a linear fecundity-maternal body size relation was reported (Miller, 2005). In *B. mori*, a positive correlation has been reported between female pupal body weight and fecundity (Singh *et al*., 2011). Fecundity has been found increasing with pupal body weight. Thus, selection of breeding stock based female pupal body weight can lead to increased fecundity. Keeping in view importance of fecundity in sericulture promotion, present study was conducted with the objectives to assess (i) reproductive potential of different strains of the Mulberry Silkworm Moth, and (ii) establish a correlation between the female pupal body weight and fecundity.

## MATERIALS AND METHODS

Nine strains of the Mulberry Silkworm Moth (*Bombyx mori* L., Lepidoptera: Bombycidae) including: three inbred lines and six hybrids were reared in Autumn Silkworm Rearing Season for assessing correlation between pupal body weight and fecundity (number of eggs laid by a female moth). General disinfection of silkworm rearing shed, rearing stands, incubation room, coupling room and appliances was conducted using formaldehyde containing 37% formalin and slack lime. Two percent formalin solution was augmented with 0.5% slacked lime solution and mixture was spayed @ 800 ml/10 $m^2$ using pneumatic knapsack sprayer. Walls, Ceiling, floor and rearing stands, rearing trays, cleaning nets, montages, mulberry leaf cutting knives & scissors, etc. were sprayed thoroughly. The rearing rooms and sheds were kept air tight for 48 h after the spray. The disinfection was conducted at 25±2°C.

The eggs were examined and fertile eggs were sorted for incubation. The eggs were incubated at 26±1°C, 80±5% relative humidity and 16:8 h photoperiod. The eggs at blue eye stage (day 10 after start of incubation) were black boxed for 48 hours. The black boxed eggs, after 48 hours, were exposed to light at 0600 hour. The hatching of 6-hours was selected and brushed for rearing. The egg cards were covered with nets sprinkled with chopped mulberry leaves. The larvae moved on the mulberry leaves through meshes and shifted into wooden rearing trays. The larvae were reared at 25±2°C and 75±5% relative humidity by feeding mulberry leaves five times daily.

The full grown larvae were mounted on cocoonage for single cell pupation. On day 6 of pupation, cocoons were cut and body weight of female pupae was recorded. The pupae were reared at standard temperature and relative humidity (25±1°C and 75±5% rH) for adult emergence. Fifteen female moths per strain were allowed for copulation for four hours and decoupled. The inseminated females were placed singly under cellule and allowed for egg laying for 24 hours. The data were compiled and analyzed using Statistical software Minitab version 17. Relationship between pupal body weight and fecundity was assessed applying Pearson Correlation. The mathematical models between the pupal body weight and fecundity were established using Regression Analysis.

## RESULTS AND DISCUSSION

The female pupal body weight and fecundity of nine silkworm strains are presented in table 1. The results showed that female pupal body weight was a reliable indicator for assessing silkworm fecundity. The mean heaviest pupa was found in PFI 14, while the mean lightest pupa was found in 206MKD*C-102. The heaviest individual pupa was 1.62 g in 206PO*J-101, while the lightest individual pupa was 1.06 g also in 206PO*J-101 (Table 1). The highest and the lowest mean fecundity was 458.1±16.9 eggs/female and 387.6±9.74 eggs/female found in PFI 14 and 206MKD, respectively. The highest individual female fecundity was 560.0 eggs/female recorded in PFI 15, while the lowest individual female fecundity was 310.0 eggs/female recorded 205PO. The hybrid PFI 14 and PFI 15 performed better compared to other inbred and hybrid strains. The fecundity of the silkworm depends on several genetic and physical factors. Present findings of fecundity were comparable broadly with Bajwa and Ali (2005) and Bajwa *et al*. (2017). A significant ($p<0.01$) positive correlation was found between female pupal body weight and fecundity. The association between the female pupal body weight and fecundity was positive irrespective of weight. The correlation coefficient ranged between 0.728 and 0.957. The strongest correlation between female pupal body weight and fecundity was found in 205PO, while the weakest correlation between female pupal body weight and fecundity was found in 206PO*J-101. Previously, a highly significant positive correlation between the female pupal body weight and fecundity was reported by Singh (1994).

Table 1. Female pupal body weight and fecundity of inbred and hybrid silkworm strains

| Strains | Pupal body weight (g) | | Fecundity (Eggs/female) | | Correlation coefficient $r^2$(p) |
|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | |
| C-102 | 1.42±0.05 | 1.30-1.56 | 427.0±14.74 | 380.0-470.0 | 0.913 (<0.01) |
| 205PO | 1.26±0.04 | 1.09-1.45 | 391.4±20.46 | 310.0-490.0 | 0.957 (<0.01) |
| 206MKD | 1.30±0.05 | 1.19-1.47 | 387.6±9.74 | 353.0-413.0 | 0.866 (<0.05) |
| 206PO*J-101 | 1.50±0.07 | 1.06-1.62 | 434.8±13.93 | 382.0-501.0 | 0.728 (<0.05) |
| J-101*205PO | 1.27±0.01 | 1.21-1.34 | 429.4±12.3 | 391.0-495.0 | 0.885 (<0.01) |
| 205MKD*205PO | 1.30±0.04 | 1.22-1.56 | 417.8±15.2 | 350.0-490.0 | 0.873 (<0.01) |
| 206MKD*C-102 | 1.24±0.03 | 1.11-1.30 | 424.0±14.7 | 370.0-485.0 | 0.902 (<0.01) |
| PFI 14 | 1.52±0.01 | 1.45-1.56 | 458.1±16.9 | 386.0-552.0 | 0.900 (<0.01) |
| PFI 15 | 1.34±0.04 | 1.20- 1.51 | 433.8±23.8 | 350.0-560.0 | 0.928 (<0.01) |

The overall results showed that the hybrids performed better in terms of better pupal body weight (mean: 1.36 g per pupa) compared to the inbred strains (mean: 1.33 g per pupa). Similarly, the mean number of eggs laid by hybrid females were greater (mean: 432.9 eggs) compared to the inbred lines (mean: 402 eggs). These finding are in corroboration with Bukhari *et al*. (2008). Bukhari and his colleagues reported superior growth and fecundity performance of hybrid silkworm strains compared to inbred silkworm strains.

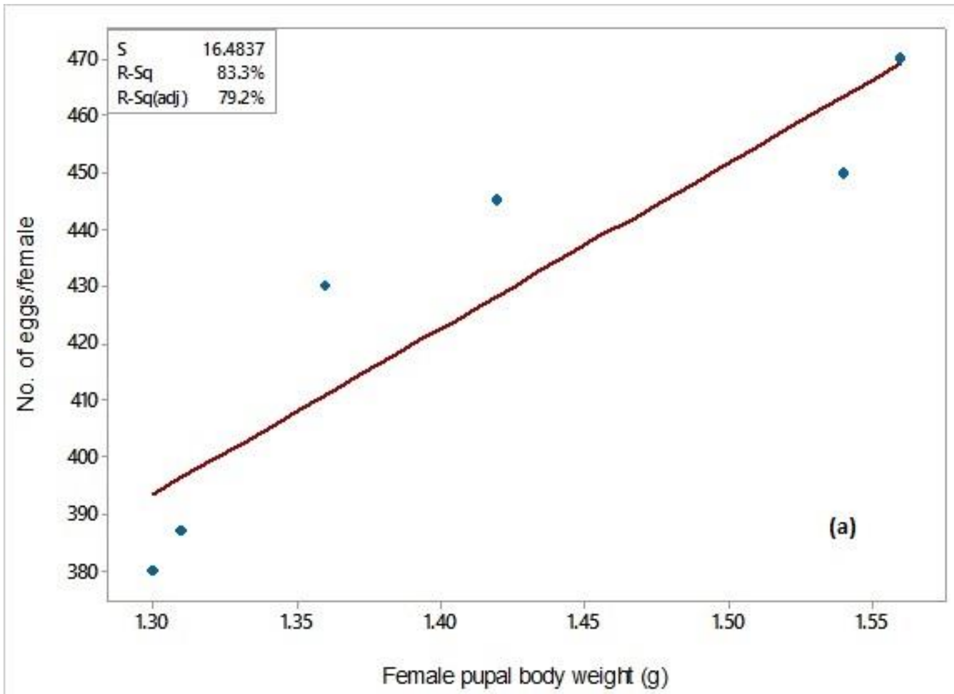
Chinese inbred strain C-102 showed a highly significant ($p<0.01$) positive response function between female pupal body weight and fecundity. The optimum female pupal body weight was between 1.45 g and 1.55 g (Figure 1-a). The regression coefficient $R^2$ of 0.83 indicated a good fit of model for predicting fecundity based on the female pupal body weight of C-102 silkworm strain (Table 2). Similarly, inbred strain 205PO showed a highly significant ($p<0.01$) linear response between female pupal body weight and fecundity (Figure 1-b). The effect of female pupal body weight on fecundity was greater compared to C-102 strain. The regression coefficient $R^2$ of 0.93 showed a good fit of model for predicting fecundity based on the female pupal body weight of 205PO strain (Table 2).

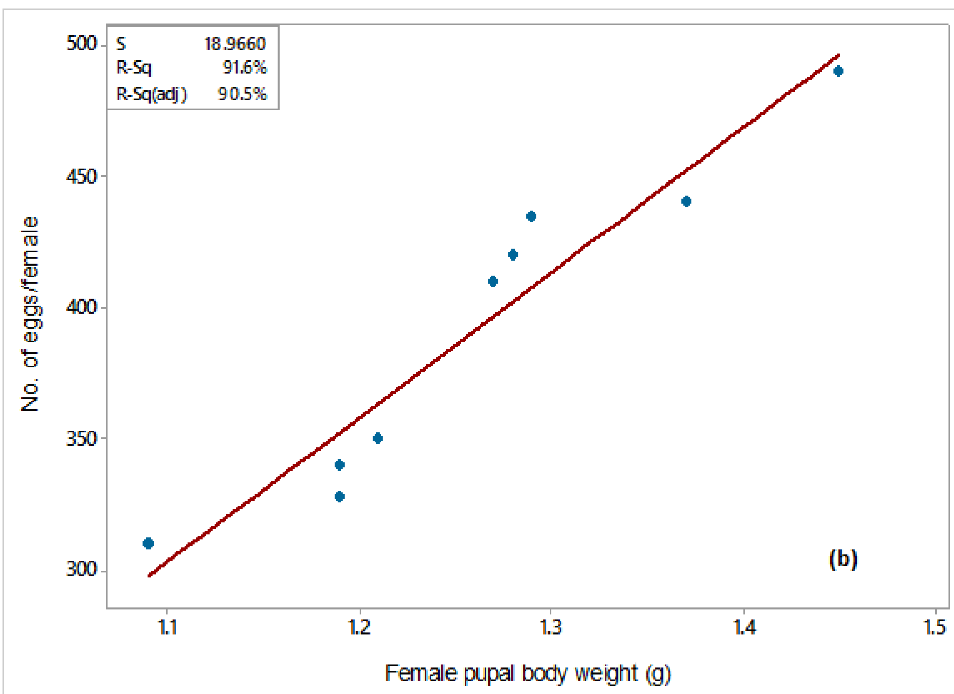
Strain 206MKD showed a significant ($p<0.05$) and positive response function between female pupal body weight and fecundity (Figure 1-c). However, this response function was relatively weaker compared to strains C-102 and 205PO. The optimum female pupal body weight was between 1.30 g and 1.45 g for 206MKD. The regression coefficient $R^2$ was 0.75 that showed a moderate level of prediction model for predicting fecundity based on the female pupal body weight of strain 206MKD (Table 2). Hybrid strain 206PO*J-101 showed a significant ($p<0.05$) response function between female pupal body weight and fecundity (Figure 1-d). However, this response function was the weakest among all the tested inbred and hybrid silkworm strains. Most of the female pupae weighed between 1.5 g and 1.6 g. The females laid <425 eggs/females. This indicated a low return of eggs per unit weight of pupa for the hybrid. The regression coefficient $R^2$ of 0.53 showed a below moderate prediction model for predicting female fecundity based on the female pupal body weight of hybrid 206PO*J-101 (Table 2).

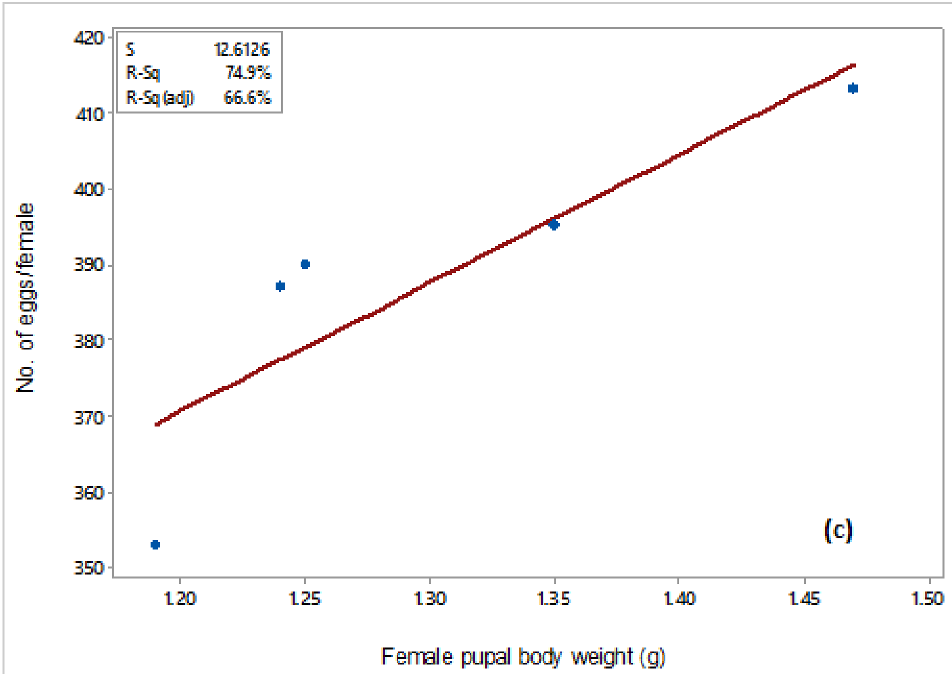
Hybrid J-101*205PO showed a linear function of female pupal body weight with fecundity (Figure 1-e). The optimum female pupal body weight was 1.48 g and 1.50 g, while the fecundity pooled around 400 eggs per female. The regression coefficient $R^2$ of 0.78 showed a good fit of prediction model for predicting fecundity based on the female pupal body weight of hybrid J-101*205PO. This fitness of model is comparable with that of hybrid 205MKD*205PO. The hybrid 205MKD*205PO showed a highly significant ($p<0.01$) function of female pupal body weight with fecundity. The correlation was positive. The optimum female pupal body weight was between 1.2 g and 1.3 g. While most of the females laid eggs above 400 eggs (Figure 1-f). The $R^2$ value of 0.76 indicated fairly good fit of model for prediction of fecundity based on female pupal body weight.

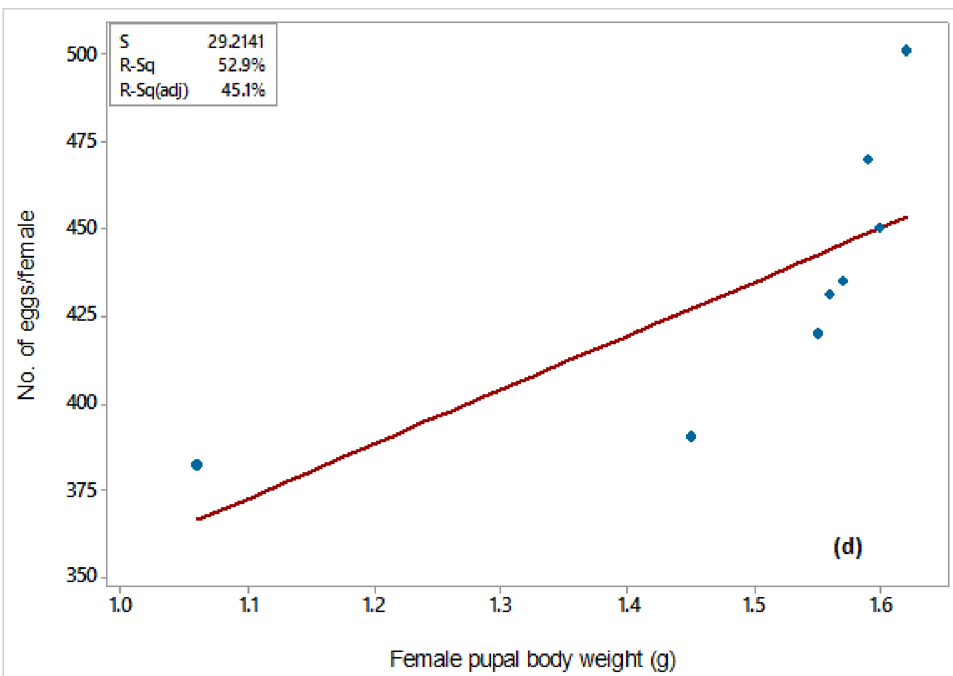
The effect of female pupal body weight on fecundity of 206MKD*C-102 was highly significant ($p<0.01$) and linear (Figure 1-g). The $R^2$ value of 0.81 showed a good fit of model for predicting response function of fecundity with female pupal body weight (Table 2). The hybrid PFI-14 showed a highly significant ($p<0.01$) linear function of female pupal body weight with fecundity. The optimum female pupal body weight was between 1.47 g and 1.55 g, while the majority fecundity response was above 400 eggs per female (Figure 1-h). The $R^2$ value of 0.81 also indicated a good fit of model for female pupal body weight and fecundity (Table 2). The mathematical expression showed a similar level of response for 206MKD*C-102 and PFI 14.

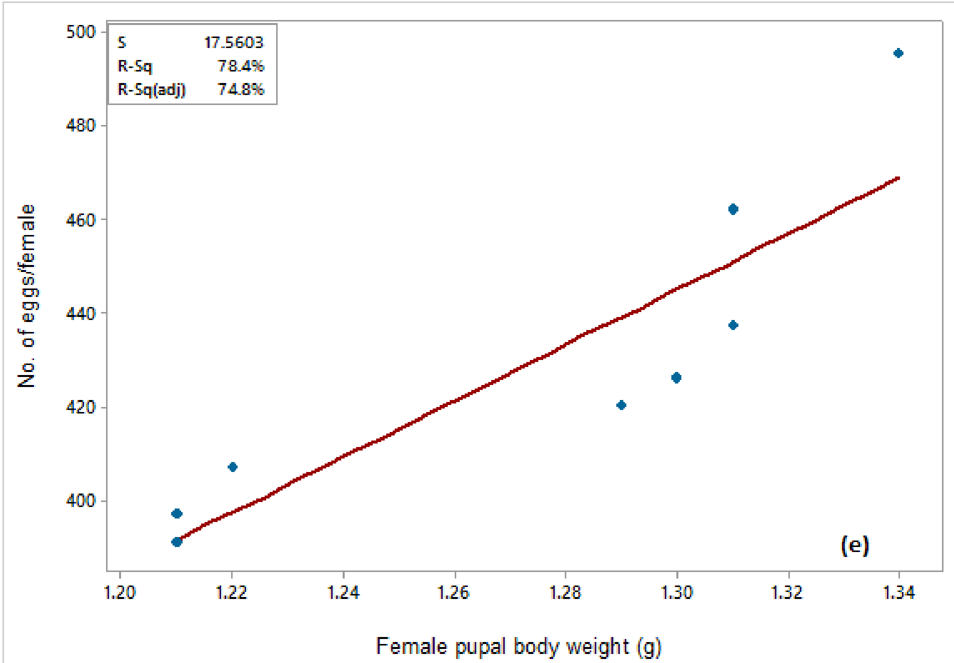
The response function of fecundity with the female pupal body weight was linear, highly significant ($p<0.01$) and positive for PFI 15. The optimum female pupal body weight was between 1.25 g and 1.35 g. (Figure 1-i). The $R^2$ value of 0.86 indicated good fit of model for prediction response function of the female pupal body weight with fecundity. The slope of response was slightly lower compared to inbred strain 205PO which showed the highest slope among the tested silkworm strains (Table 2).

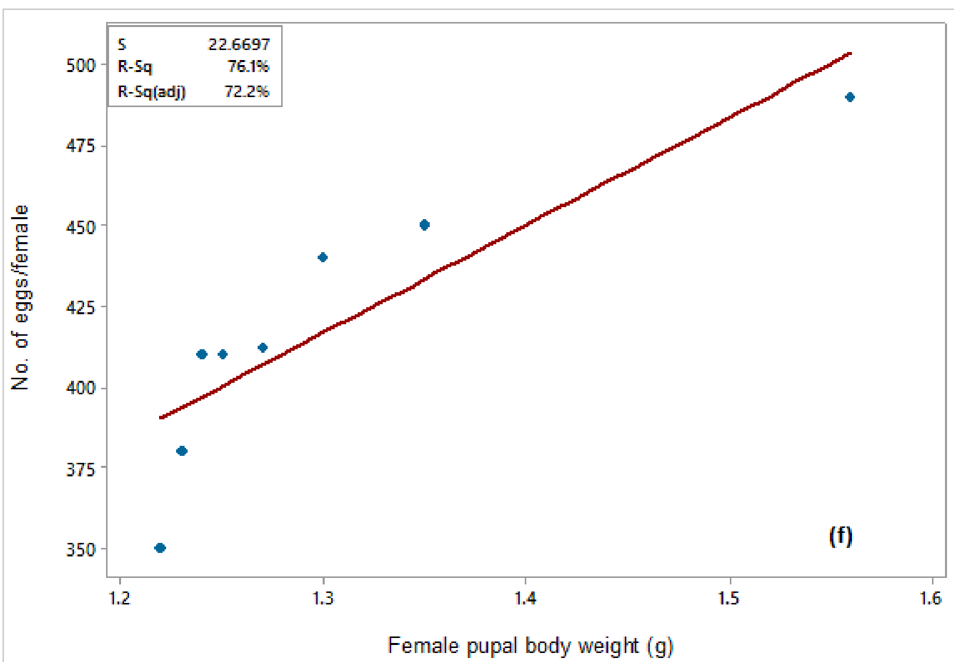

S 16.4837
R-Sq 83.3%
R-Sq(adj) 79.2%
470
460
450
440
430
420
410
400
390
380
No. of eggs/female
(a)
1.30
1.35
1.40
1.45
1.50
1.55
Female pupal body weight (g)

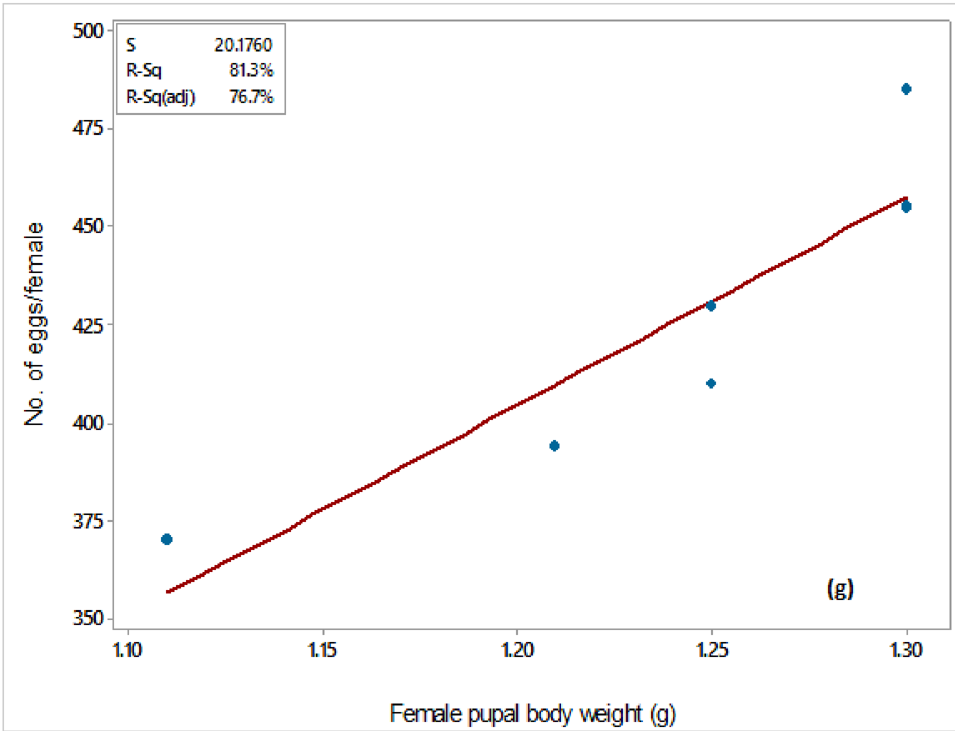

S 18.9660
R-Sq 91.6%
R-Sq(adj) 90.5%
500
450
400
350
300
No. of eggs/female
(b)
1.1
1.2
1.3
1.4
1.5
Female pupal body weight (g)

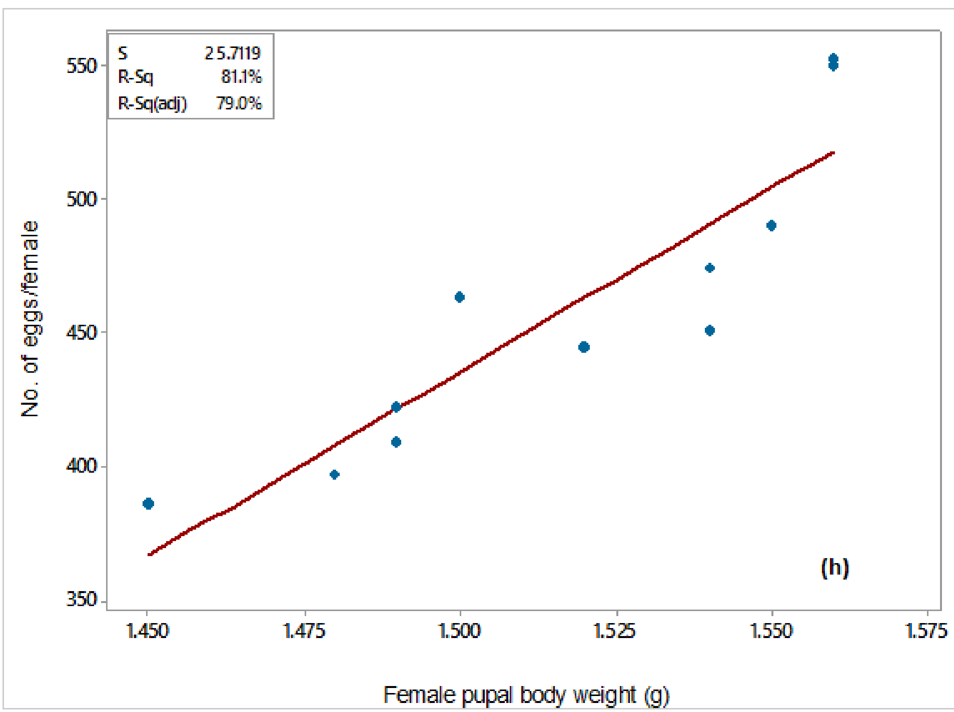

S 12.6126
R-Sq 74.9%
R-Sq (adj) 66.6%
No. of eggs/female
Female pupal body weight (g)
(c)
420
410
400
390
380
370
360
350
1.20
1.25
1.30
1.35
1.40
1.45
1.50


S 29.2141
R-Sq 52.9%
R-Sq(adj) 45.1%
No. of eggs/female
Female pupal body weight (g)
(d)
500
475
450
425
400
375
350
1.0
1.1
1.2
1.3
1.4
1.5
1.6


S 17.5603
R-Sq 78.4%
R-Sq(adj) 74.8%
No. of eggs/female
Female pupal body weight (g)
(e)


S 22.6697
R-Sq 76.1%
R-Sq(adj) 72.2%
No. of eggs/female
Female pupal body weight (g)
(f)


S 20.1760
R-Sq 81.3%
R-Sq(adj) 76.7%
500
475
450
425
400
375
350
No. of eggs/female
1.10
1.15
1.20
1.25
1.30
Female pupal body weight (g)
(g)


S 25.7119
R-Sq 81.1%
R-Sq(adj) 79.0%
550
500
450
400
350
No. of eggs/female
1.450
1.475
1.500
1.525
1.550
1.575
Female pupal body weight (g)
(h)

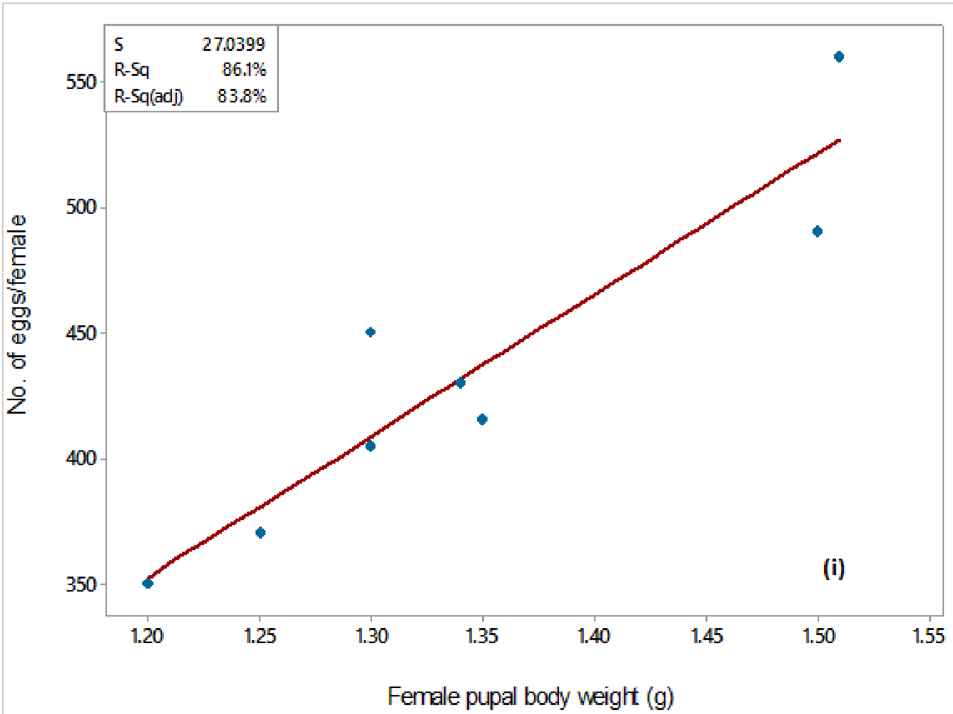



Figure 1: Response function of fecundity to female pupal body weight of: (a) C-102, (b) 205PO, (c) 206MKD, (d) 206PO*J-101, (e) J-101*205PO, (f) 205MKD*205PO, (g) 206MKD*C-102, (h) PFI 14, (i) PFI 15

The overall results showed that inbred lines have relatively better response function of fecundity with the female pupal body weight compared to the hybrids. The overall egg load was 313.1 eggs per female per gram body weight of pupa. The egg load per female was relatively higher in the hybrids (317.6 eggs/gram female pupa) compared to the inbred lines (302.3 eggs/gram female pupa).

Table 2. Mathematical expression of effect of female pupal body weight on fecundity of silkworm strains

| Silkworm strains | Mathematical expression | $R^2$ | F-value (p) |
|---|---|---|---|
| C-102 | y=14.56+291.5x | 0.83 | 20.00 (p<0.01) |
| 205PO | y =-303.6+551.7x | 0.92 | 76.82 (p<0.01) |
| 206MKD | y=167.2+169.6x | 0.75 | 8.96 (p<0.05) |
| 206PO*J-101 | y=202.3+155.1x | 0.53 | 6.75 (p<0.05) |
| J-101*205PO | y=-327.2+594.0x | 0.78 | 21.73 (p<0.01) |
| 205MKD*205PO | y=-16.93+333.7x | 0.76 | 19.15 (p<0.01) |
| 206MKD*C-102 | y=-233.4+531.6x | 0.81 | 17.45 (p<0.01) |
| PFI 14 | y=-1628+1376x | 0.81 | 38.53 (p<0.01) |
| PFI 15 | y=-325.4+564.9x | 0.86 | 37.27 (p<0.01) |

The regression analysis showed that the fecundity in all tested silkworm strains increased with increasing female pupal body weight. Similar observations of increasing fecundity from lower female pupal body weight to higher female pupal body weight were also made earlier by Singh *et al*. (2011) Moreover, positive values of correlation coefficient and regression coefficient showed that the female pupal body weight is a good determinant factor for fecundity. These findings are also in conformity with Calvo and Molina (2005). They found that pupal weight was the better size estimator of female egg load in *Streblote panda*. Thus for higher fecundity female individuals should be selected with higher pupal weight. Hence, selection by the female pupal weight will automatically result in increased fecundity.

## CONCLUSION

Based on the present findings it is concluded that the nine silkworm strains, both inbred strains and hybrid strains, have promising fecundity potential. The fecundity has a significant positive correlation with female pupal body weight. However, this correlation varies with silkworm strains. The linear model based on the female pupal body weight as an independent factor is a reliable prediction model for fecundity estimates. Thus these findings will be helpful for estimation of silk seed production, as well as, increasing silk seed production by selecting females based on pupal body weight.

## REFERENCES

Bajwa, G.A. and Ali, M. 2005. Fecundity, egg fertility and hatchability response of silkworm, *Bombyx mori* on different substrata. Pak. J. Forestry 55(2): 107-113.

Bajwa, G. A., Ahmed, N., Shah, S. H. and Adnan, M. 2017. Genetic diversity analysis of mulberry silkworm (*Bombyx mori*) strains using RAPD markers. J. Anim. Plant Sci. 27(2): 575-581.

Bukhari, S.S.B, Bajwa G.A. and Ali, M. 2008. Genetic manifestation of heterosis in hybrid breeds of Mulberry Silkworm, *Bombyx mori*. Pak. J. Forestry 58(2): 66-76.

Calvo, D. and Molina, J.M. 2005. Fecundity–body size relationship and other reproductive aspects of *Streblote panda* (Lepidoptera: Lasiocampidae). Ann. Entomol. Soc. Am. 98(2): 191-196.

Hussain, M., Khan, S. A., Naeem, M. and Nasir, M.F. 2011. Effect of rearing temperature and humidity on fecundity and fertility of silkworm, *Bombyx mori* L. (Lepidoptera: Bombycidae). Pakistan J. Zool. 43(5): 979-985.

Miller, W. E. 2005. Extrinsic effects on fecundity-maternal weight relations in capital-breeding Lepidoptera. J. Lepidopterists' Soc. 59(3): 143-160.

Radhakrishnan, P.G., Sekharappa, B.M. and Gururaj, G.S. 2001. Seasonal response of the new multi-bivoltine hybrids of the silkworm, *B. mori*. Indian Jour. Seric., 40 (2): 174-176.

Rahman, W. and Khan, M. 2005. Effect of mating duration on the fecundity and egg fertility of silkworm, *Bombyx mori*. Pak. Jour. Forest., 55(1): 45-49.

Singh, T. 1994. Correlation between pupal weight and fecundity in *Bombyx mori* (L). Annals of Entomol. 12: 5-7.

Singh, T., Bhat, M. and Khan, M. A. 2011. Critical analysis of correlation and heritability phenomenon in the silkworm, *Bombyx mori* (Lepidoptera: Bombycidae). Advances in Biosci. Biotechnol. 2: 347-353.