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Comparative Performance of Three Silkworm Races Fed on Local Mulberry against Biological and Commercial Parameters

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SZ conducted research work. MH conceived idea, supervised the research work, wrote the manuscript and performed data analysis. KA helped in the write up. MFM helped in improving the manuscript and data analysis. RK provided silk seed and technical support. SL and MK helped in silkworm rearing and data collection.

Key words
Sericulture, Cocoon, Commercial parameters, Silkworm rearing, Local mulberry

ABSTRACT

We evaluated the performance of biological and commercial parameters of three bivoltine silkworm races fed on local mulberry. The disease-free eggs of Chinese, Korean and Bulgarian races were obtained from Sericulture Research Laboratory, Lahore. The silkworm eggs were incubated at standard conditions. Larval rearing was maintained at standard rearing conditions of temperature (25 ± 1°C), Relative Humidity (75 ± 5 %), and photoperiod (12 light: 12 dark). The experiment was laid out in the Completely Randomized Design (CRD) with five replications. Bulgarian race showed significantly greater variations were observed in the mean larval weight (g) and mean larval length (cm) during all instars i.e. maximum larval weight i.e. 0.076g, 054g, 3.14g, 4.29g, and 6.23g in 1^{st}, 2^{nd}, 3^{rd}, $4^{th,}$ and 5^{th} instars, respectively. A similar trend in the mean larval length ($P < 0.05$) was also observed. Significantly greater fecundity (437 no.), fertility (85.20%), and hatchability (84.40%) were recorded in the Bulgarian races which were significantly higher as compared to Chinese and Korean races. Similarly, cocoon weight (1.32 g), cocoon shell weight (0.28g), cocoon shell percentage (18.74 %) were recorded found in the Bulgarian race which was significantly greater ($P < 0.05$) than other two races. We documented that the Bulgarian race is promising and has great potential to perform on local mulberry under prevailing environmental conditions. We also suggest that popularizing sericulture as the allied sector of the agricultural economy needs to exploit the potential of the Bulgarian race for the production of hybrid silk seed.

INTRODUCTION

Silkworm as monophagous insects, feeding exclusively on fresh mulberry leaves (Moraceae, genus *Morus*), making silkworm rearing and cultivation of mulberry a single enterprise (Resh and Cardé, 2009). Thus, the quality of mulberry leaves plays a significant role in the successful rearing of the mulberry silkworm and cocoon production (Bajwa and Khan, 2015). Both the quantity and quality of mulberry leaves affect the biological characters of silkworm and economic cocoon characters (Rafique and Bajwa, 2003).

Pakistan being an agricultural country with a variety of seasons and variability in climate in different agricultural zones is considered to have great potential for sericulture as a cottage industry (Hanjra *et al*., 1995; Ashfaq *et al*., 2001; Hussain *et al*., 2010; Mubin *et al*., 2013). Though demand for natural silk is ever-increasing globally, sericulture has not flourished in many countries including Pakistan as an allied sector of the agricultural economy (Hussain *et al*., 2010, 2011a; Rahim and Hyder, 2017).

Many constraints have contributed to the limited growth of sericulture in Pakistan. Lack of disease-free silk seed, poor silkworm rearing technology, unavailability of mulberry plantations, lower leaf yield of local varieties, lack of awareness, lack of training, lack of support from government and non-governmental institutions, lack availability of market, and environmental fluctuations (Siddiqui, 1988; Hussain *et al*., 2011b; Rahmathulla, 2012; Kanwal *et al*., 2018). In Pakistan, the sericulture industry has limited growth mainly due to the poor quality of mulberry leaves and silk seeds. Thus, the cultivation of mulberry is one of the most important factors in the production of silkworm eggs, rearing of silkworm cocoons, and on the whole in the entire operation of sericulture (Ashfaq *et al*., 2001; Hussain *et al*., 2011c; Mubin *et al*., 2013). Mulberry is an excellent source of nutrients and phytochemicals and is highly palatable (Srivastava *et al*., 2006; Akram *et al*., 2017; Thaipitakwong *et al*., 2018). The morphological characters of mulberry accessions found in Azad Jammu and Kashmir and Pakistan suggested that the

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Morus germplasm is quite diverse (Ammara *et al*., 2018). Different varieties of mulberry may have compositional differences in the nutrient content and palatability that ultimately affect the growth of *B. mori* and silk productions (Mahmood *et al*., 1987; Shah *et al*., 2007a).

One of the key constraints of the decline of sericulture is the lack of interest due to low cost-benefit ratio, high investment cost in terms of silkworm rearing, land uses, and lack of proper knowledge on different races of mulberry silkworm, *Bombyx mori*. Therefore, the present study aimed at investigating the comparative performance of three silkworm races for biological and commercial parameters while feeding larvae on local mulberry.

MATERIALS AND METHODS

Incubation and larval rearing

This study was conducted in the spring season to evaluate biological and commercial parameters of silkworm races i.e. Chinese, Korean and Bulgarian. The disease-free eggs of these three races were obtained from the Sericulture Research Laboratory, Lahore, Punjab, Pakistan. Eggs were maintained under standard conditions of temperature and humidity for incubation and hatching in the Laboratory of Entomology and Pest Management, Department of Zoology, at the University of Gujrat, (Hussain *et al*., 2011a; Akram *et al*., 2017).

The eggs were incubated at 24 -26 °C with 75 ± 5 % relative humidity, and photoperiod (12 light: 12 dark). For better embryonic development and uniform hatching, eggs were spread as a single layer on the sheet and black-boxed (Krishnaswami *et al*., 1973; Hussain *et al*., 2011a; Rahmathulla, 2012). We reared the first three larval instars at 26 ± 2 °C and 80-90 % RH while the 4th and 5th larval instars were 24-26 °C and 70-80 % RH.

Data were recorded for the following parameters: (i) larval weight (g) which was calculated at the end of each larval stage by weighing five larvae selected randomly by using an electronic balance. (ii) larval length (cm) which was measured by selecting five larvae randomly at the end of each larval instar by using the measuring tape. (iii) cocoon weight (g) was determined by taking ten cocoons (5 female + 5 male cocoons) randomly from each replication on the 7th day of spinning.

Cocoon weight (g) = (weight of 5 female cocoons + weight of 5 male cocoons)/10

(iv) Shell weight (g) which was determined as:

Shell Weight (g) = Cocoon weight with pupa (g) - Cocoon weight without pupa (g)

(v) Shell percentage was calculated by the following formula:

Shell percentage=shell weight (g)/(cocoon weight (g)×100

(vi) Fecundity (no.) which was determined by counting eggs laid by five females in each replication for each silkworm race. (vii) fertility (%) which was evaluated by counting the average fertilized eggs by five females in each replication. (viii) hatchability (%) the number of eggs hatched from a single laying was calculated by the following formula:

Hatchability (%) = (Eggs hatched per laying) / (Fertilized eggs per laying) ×100

Statistical analysis

The experiment was laid out in completely randomized design (CRD) with five replications each containing 300 larvae. Each value was expressed as the Mean ± Standard Deviation (SD) of five observations. Data on various parameters commercial and biological parameters were analyzed by applying ANOVA (P< 0.05) and means were compared by applying the Tukey test (Steel and Torrie, 1980). Data were analyzed by using Statistix Software.

RESULTS

Larval body weight (g)

Maximum larval body weight was observed in the Bulgarian race in all instars. The data showed significant differences in 1st instar larval weight ($F_{2,14}$ = 35.8, p = .0000), 2nd instar larval weight ($F_{2,14}$ = 51.3, p = .0000), 3rd instar larval weight ($F_{2,14}$ = 558, p = .0000). We also observed that the 4th instar larval weight ($F_{2,14}$ = 262, p = .0000), and the 5th instar larval weight ($F_{2,14}$ = 838, p = .0000) of the Bulgarian race were significantly different from the Korean and Chinese race (Table I).

Larval body length (cm)

Maximum larval body length was observed in the Bulgarian race in all instars. The data showed significant differences in 1st instar larval length ($F_{2,14}$ = 31.5, p = .0000), 2nd instar larval length ($F_{2,14}$ = 46.2, p = .0000), 3rd instar larval length ($F_{2,14}$ = 86.2, p = .0000). Similarly, late stage instars i.e. 4th instar larval length ($F_{2,14}$ = 23.1, p = .0000), and 5th instar larval length ($F_{2,14}$ = 55.9, p = .0000) which were significantly different from Korean and Chinese race (Table I).

Fecundity (no.)

The fecundity recorded for the three races indicated significant differences ($F_{2,14}$ = 43.1, p = .0000). Maximum fecundity was observed in the Bulgarian race (437) while minimum in the Korean race (410) (Table II).

Fertility (%)

The fertility recorded for the three races indicated significant differences ($F_{2,14}$ = 31.3, p = .0000). Maximum

Table I. Larval body weight (Mean ± SD) of different races reared on local mulberry under controlled conditions.

Silkworm race	Instars				
	1st	2nd	3rd	4th	5th
Larval weight (g)					
Bulgarian	0.076ᵃ ± 0.01	0.54ᵃ ± 0.03	3.14ᵃ ± 0.05	4.29ᵃ ± 0.02	6.23ᵃ ± 0.05
Chinese	0.072ᵇ ± 0.01	0.47ᵇ ± 0.03	2.96ᵇ ± 0.06	3.94ᵇ ± 0.04	5.74ᵇ ± 0.06
Korean	0.065ᶜ ± 0.01	0.44ᶜ ± 0.02	2.84ᶜ ± 0.04	3.84ᶜ ± 0.02	4.94ᶜ ± 0.04
Larval length (cm)					
Bulgarian	0.75ᵃ ± 0.02	1.48ᵃ ± 0.01	2.69ᵃ ± 0.02	3.84ᵃ ± 0.02	5.72ᵃ ± 0.07
Chinese	0.72ᵇ ± 0.01	0.42ᵇ ± 0.01	2.57ᵇ ± 0.01	3.78ᵇ ± 0.02	5.56ᵇ ± 0.04
Korean	0.69ᶜ ± 0.01	0.39ᶜ ± 0.01	2.49ᶜ ± 0.02	3.74ᵇ ± 0.02	5.47ᶜ ± 0.02

Means not sharing a letter (superscript) are significantly different.

fertility was observed in the Bulgarian race (85.20 %) followed by the Chinese race (79.60) whereas the Korean race showed the lowest fertility (Table II).

Table II. Fecundity, Fertility, and Hatchability (Mean±SD) of silkworm races fed on local mulberry.

Silkworm races	Fecundity (no.)	Fertility (%)	Hatchability (%)
Bulgarian	437.00ᵃ ± 2.07	85.20ᵃ ± 3.12	84.40ᵃ ± 1.31
Chinese	425.40ᵇ ± 3.67	79.60ᵇ ± 2.51	77.00ᵇ ± 3.27
Korean	410.00ᶜ ± 4.58	75.00ᶜ ± 2.43	74.20ᶜ ± 2.62

Means not sharing a letter (superscript) are significantly different.

Hatchability (%)

The hatchability recorded for the three races indicated significant differences ($F_{2,14}$ = 55.5, p = .0000). Maximum hatchability was observed in the Bulgarian race (84.40 %) whereas the lowest hatchability was found in the Korean race (69.00 %) (Table II).

Cocoon weight (g)

The cocoon weight (g) recorded for the three races indicated significant differences ($F_{2,12}$ = 1628, p = .0000). Cocoon weight (g) recorded after spinning of *B. mori* larvae fed on mulberry leaves showed a significantly different ($P < 0.05$). Bulgarian race larvae (1.310 g) recorded maximum cocoon weight whereas Korean and Chinese races showed statistically non-significant differences in cocoon weight between them (Table III).

Cocoon shell weight (g)

The cocoon shell weight (g) recorded for the three races indicated significant differences ($F_{2,12}$= 690, p = .0000). The results showed that significant differences exist. The Bulgarian race yielded maximum shell weight (0.250 g) whereas Korean and Chinese races showed statistically non-significant differences in shell weight (Table III).

Table III. Cocoon weight, cocoon shell weight, and cocoon shell percentage (Mean±SD) of different races reared on local mulberry.

Silkworm races	Cocoon weight (g)	Shell weight (g)	Cocoon shell %
Bulgarian	1.317ᵃ ± 0.001	0.246ᵃ ± 0.002	18.73ᵃ ± 0.07
Chinese	1.256ᵇ ± 0.002	0.203ᵇ ± 0.003	16.20ᵇ ± 0.06
Korean	1.238ᶜ ± 0.002	0.194ᶜ ± 0.003	15.66ᶜ ± 0.04

Means not sharing a letter (superscript) are significantly different.

Cocoon shell percentage

The cocoon shell percentage calculated for the three races indicated significant differences ($F_{2,12}$ = 481, p = .0000). The Bulgarian race (19.09 %) recorded maximum cocoon shell percentage whereas minimum in the Korean race (15.84 %). Results showed significant differences in mean cocoon shell percentage (Table III).

DISCUSSION

Our study evaluated three silkworm races fed on local mulberry against their biological (fecundity, fertility, and hatchability) and commercial parameters (cocoon weight, shell weight, and shell percentage). Specific silkworm strains and mulberry varieties contribute to the larval growth and silkworm development ultimately enhancing cocoon production under standard conditions of silkworm rearing (Mahmood *et al*., 1987; Hussain *et al*., 2010, 2011b; Bhattacharyya *et al*., 2016; Kanwal *et al*., 2018, 2019).

Our three races exhibited significant variations in the parameters under study (P<0.05). This indicated the variable potential of these races to exploit the mulberry leaves under prevailing rearing conditions. The silkworm races perform differently when fed mulberry leaves of different verities. This may be attributed to the variations in mulberry leaf quantity, quality, and variety affect the production of silk (Zannoon *et al*., 2008). Earlier studies showed that the Chinese race when fed with the leaves of Husang China mulberry variety exhibited the best performance (Shah *et al*., 2007a).

We recorded significant differences in the larval length and larval weight in all instars among three silkworm races. Larval length varies in different races and depends mainly on the mulberry varieties and rearing conditions (Rahmathulla, 2012; Kanwal *et al*., 2018). Larval size showed significant variations (P < 0.05) of three *B. mori* races when reared on mulberry varieties (Hussain *et al*., 2011a; Kanwal *et al*., 2018). Earlier studies reported a significant interaction between mulberry varieties and *B. mori* races for larval length, larval weight, and cocoon shell ratio (Mahmood *et al*., 1987; Shah *et al*., 2007b; Hussain *et al*., 2011c; Kanwal *et al*., 2018; Kaviraj *et al*., 2021; Zhang *et al*., 2022).

The studies have revealed that mature larval weight, single cocoon weight, shell weight, and shell percentage were greatly influenced by the nutritive value of different varieties of mulberry leaves (Mahmood *et al*., 1987; Shah *et al*., 2007a, b; Kanwal *et al*., 2018). However, the silkworm race contributes 4.20 % (Shah *et al*., 2007b) to silkworm productivity. Different species of mulberry may have compositional differences and might lead to varying effects on *B. mori* growth and silk productions (Mahmood *et al*., 1987; Hussain *et al*., 2011c; Kanwal *et al*., 2018). In another study, the results showed the significant variations of silkworms when reared on different mulberry species (Alipanah *et al*., 2020).

Our study showed that the Bulgarian race has the potential to perform well when fed on local mulberry. The seed of this race may be provided to the silkworm rearers having sufficient naturaly growing local mulberry plantations. However, the Bulgarian race showed better results as compared to the other two races for cocoon production and biological parameters. We suggest popularizing sericulture in Pakistan depends on the utilization of local mulberry resources and improving silk seed by conducting trials for developing hybrid silk seed.

Statement of conflict of interest

The authors have declared no conflict of interest.

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