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Research Article

Adaptability and Comparative analysis of Economic and Biological Traits of various Silkworm Races (*Bombyx mori* L.)

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Authors' Contributions
MFB presented the concept and conceived the study and designed the experiments. HMT supervised the study. AA and FM performed formal analysis and investigation. RK, AA and FM critically revised its important intellectual content. HAK and MFB wrote the manuscript. RFA, FI and HMT wrote revised and edited the manuscript. AM and RK presented methodology

Keywords
Sericulture, Silkworm races, Rearing practices, Climatic conditions, Mulberry plants, Cottage industry

Abstract | Sericulture is a labor intensive cottage industry that has great potential for poverty alleviation. In Pakistan, the farming community so far has not identified the specific race suitable for the specific climatic zones of Pakistan in terms of yield, performance and adaptability. The current study was conducted to find out the optimum hatching and rearing conditions of three silkworm races (Chinese, Bulgarian and Pakistani) and to compare their biological and economic traits at optimum conditions. The silkworm eggs were hatched at a range of temperatures (21-30°C) and humidity levels of 75-80-% and 80-85% respectively. The silkworms hatched at optimal conditions were provided variable meals and the leaves consumption rate was calculated. In a separate experiment, the 5th instar silkworm larvae were assessed for biological and economic traits. The results of this study exhibited that Chinese silkworm eggs showed better hatchability at high temperatures. The larvae of the Chinese race also showed an increased leaf consumption rate with an increase in the number of meals (6) per day. Moreover, a significant increase in biological traits including average larval weight (0.979±0.038) and ratio silk gland to body weight (27.386 % ±0.843) was also observed in this group as compared to other groups. The economic traits including cocoon length and width as well as fibroin content of larvae of the Chinese race were significantly higher as compared to Pakistani and Bulgarian races. It is concluded that the Chinese silkworm showed better adaptation and produced a high yield in the local climatic conditions of Pakistan.

Novelty Statement | Sericulture is a declining cottage industry. One of the major limitation faced by the farmers is the availability of most appropriate silk seed that suits the local environmental conditions. This research study suggests that the silkworms of Chinese race are better adapted and produce more yield in local climatic conditions of Punjab, Pakistan.

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Introduction

Sericulture is a cottage industry related to the rearing of silkworms for the production of luxuriant natural silk (queen of textile) (He *et al*., 2021). Silkworm (*Bombyx mori* L.) is a domesticated monophagous insect that undergoes metamorphosis. The 5th instar larvae of silkworms produce silk in the form of silk cocoons (Soumya *et al*., 2017). The Silk gland is the chief organ responsible for the production of silk proteins (Fibroin and Sericin) in the form of cocoon (Dong *et al*., 2016; Hou *et al*., 2010). Although silk is produced by different arthropods but silk produced by silkworms has superior qualities such as softness, elegancy, durability, luster and tensile strength (Rahmathulla, 2012). Silk produced by silkworms consists of two different proteins including fibroin (fibrous protein) and sericin (gummy substance). Silk fibroin forms the filament of silkworms and gives them distinct chemical and physical properties. Sericin or silk gum has sol-gel properties, as it gets dissolved easily at 50-60^{0}C in water and on cooling returns to gel form (Leem *et al*., 2020).

Silkworm rearing has been practiced for 5000 years. Silkworm rearing practices were started in China from 2600-2700 BC. China is the world's largest producer of silk with annual production of around 80% (170,000 metric tons) which is worth more than 1 billion USD (Tabunoki *et al*., 2016; Sun *et al*., 2012). Silk production started in European and Asian countries due to its smoothness and commercial importance (Begum *et al*., 2008). Pakistan has a high potential for the development of sericulture due to favorable agro-climate and socio-economic conditions. Pakistan has around 210 hectares of mulberry plantations, sufficient to feed 2500 packets of silkworm eggs thus having the potential to produce about 400 tons of silk cocoon per annum. Silkworm played an important role in supporting Japan's modernization. Japan has led the world as a warehouse of silkworm bio-resources (Banno *et al*., 2010).

Silkworm feeds on mulberry leaves that provide all the essential nutrients required for silk protein production such as vitamins, minerals, protein amino acid and sugar (Murugesh *et al*., 2022). The quality and quantity of mulberry leaves as well as seasonal differences are important for the growth and development of silkworms, affecting their biological and economic traits (Kanwal *et al*., 2018). Pakistan being an agricultural country has a variety of seasons or variable climatic zones and has a great potential for sericulture. Cottage industries have an important position both in urban as well as rural set up of Pakistan (Mubin, 2013). Till the 1990s, sericulture was marked as an important cottage industry and remained a flourishing and profitable entrepreneurship in Pakistan. After 1990 the Forest Department opted to adopt the cultivation of eucalyptus in irrigated plantations and thus removed local varieties of *Morus* spp. On account of the replacement of mulberry trees with eucalyptus trees from all major plantations of the Forest Department, the decline of the sericulture industry started (Akram, 2016).

The productivity and efficiency of cocoon yield are very low in Pakistan as compared to other countries like China, India Japan, Bangladesh, Korea and Bulgaria (Mubin, 2013). One of the major issues in the decline of sericulture is a lack of awareness, low cost-benefit ratio, high investment cost in terms of silkworm rearing and lack of proper knowledge about different races of mulberry silkworms. In order to maintain the genetic resources of silkworms, 46 institutes are involved and more than 4000 strains including univoltine, bivoltine and polyvoltine strains are maintained in the germplasm of *B. mori* (Bindroo and Moorthy, 2014). In China, the stock of 600 strains is maintained at Southwest Agriculture University, Chongqing. In Korea more than 400 strains are available at Rural Development Administration, Suwon. In Japan about 500 silkworm races are bred at the National Institute of Agro-biological Sciences and around 820 strains are stored at Kyushu University for use in Research (Banno *et al*., 2010).

The promotion of sericulture in Pakistan will bring multi-dimensional profits like employment opportunities, efficient consumption of resources, eco-system development, meeting the local needs and an increase in exports and rural development (Hungar *et al*., 2016). In Pakistan, there is not a single local strain of silkworm, developed according to the local climate and mulberry varieties. Some of the common silkworm strains that are being used in Pakistan are imported from Korea, Japan, China, Central Asian States and Bulgaria etc. Silk farmers living in various climatic zones, are in most of the cases, unaware of selection of a suitable silkworm stain required to be reared in their areas. The temperature of these climatic zones may vary from 22-30°C, while the average humidity level may vary from 50-65% in the rearing season (September to October). Hence, a strain may perform well in one climatic zone but may give low yield in another climatic zone.

The current study was, therefore designed to evaluate the performance (hatching rate, rearing, feeding, leaf consumption and wastage of leaves, biological and economic traits) of Chinese, Bulgarian and Pakistani silkworm races reared at various temperature and humidity levels to find optimum rearing temperature of each strain. The effect of variation in feeding periods was also assessed.

Materials and Methods

Acquisition of silkworm eggs

The eggs of three races of silkworm Chinese (Haukaned 2), Bulgarian (KK × Hesa 1 × Vesletz 2 × Gergana 2) and Pakistani (Punjab 1) were obtained from the Sericulture Wing of Forestry, Wildlife and Fisheries Department Government of Punjab, Ravi Road Lahore.

Assessment of ideal hatching conditions

Before starting the experiment, the rearing room was disinfected with a 2% formalin solution and kept air tight for 24 h (Gupta and Dubey, 2021). An electrical automated thermostat and humidifier were used to control the temperature and humidity in the rearing room. Five hundred silkworm eggs (n=500) from each race of silkworm (Chinese Race (G1), Bulgarian Race (G2) and Pakistani Race (G3) were randomly taken and divided into twenty experimental groups (each containing 25 eggs) and kept on plain paper in separate cardboard boxes. The eggs of different groups were hatched at temperatures ranging from 21-30°C and humidity levels of 75-80-% and 80-85% respectively. Similarly, silkworm rearing was carried out at temperatures ranging from 16 - 36°C and humidity levels of 55-60% and 70-80%, respectively. Hatchability was determined by the following formula:

$$\text{Hatchability \%} = \frac{\text{Successfully hatched larvae}}{\text{Total number of eggs}} \times 100$$

(Koju, 2015)

Effect of variable meals on leaves consumption rate

After the assessment of ideal rearing conditions, the leaves consumption rate at variable meal provision frequency was calculated. For that purpose, the eggs of given silkworm races were incubated under optimum conditions including humidity (75-80%), temperature (25-26°C) and photoperiod (16:12 h) for better embryonic development and uniform hatching (Chen *et al*., 2022; Zhang *et al*., 2022). The hatched larvae were reared in optimized conditions and 1-4th instar larvae were fed on finely chopped mulberry leaves for four times a day. To prepare the meal fresh mulberry leaves were plucked from desirable mulberry plants (*Morus alba*) and chopped with a knife. Bed cleaning was executed on a daily basis or when it was required to be carried out. The 5th instar larvae (n=375) of three silkworm races were selected and divided into 15 groups (each containing 25 larvae). The larvae of each experimental group were given 516 g of mulberry leaves at the rate of 24, 36, 48, 60, 72, 84, 96 and 96g per day for 8 consecutive days respectively during the 5th instar. However, the feeding pattern was kept between the range of 6-2 meals (6, 5, 4, 3, 2 meals) per day during 5th instar stage. The six, four and three meals were given at 2.5, 4 and 6 h intervals respectively from 8 am to 8 pm. The feeding pattern in the case of 5 meals was 8 am, 11 am, 2 pm, 5 pm and 8 pm. However, 2 meals were given at 9 am and 8 pm. The food consumption rate was calculated by the following formula:

Leaf ingested = Dry weight of leaves offered – Dry weight of un-eaten leaves × 100 (Sabhat *et al*., 2011)

Estimation of biological traits

The study was conducted in the autumn season (September–October) at Central Forest Zone Punjab Pakistan. The silkworm eggs were hatched and reared (in a separate experiment) at optimal conditions assessed in the above-mentioned experiments. The larvae (n=75) of 5th instar were selected and categorized into three groups. The larvae of each group were tagged and the larval weights of all groups were measured daily by vacuum weighing balance (SF-400C). Five silkworm larvae were dissected when they were fully matured at day 6 to estimate the possible increase in weight of the silk gland. The remaining 20 larvae of each group were transferred to the montages separately for the spinning of cocoons. The same experiment was repeated thrice.

Estimation of economical traits

Silkworm larvae started cocoon formation when they matured and transferred to montages and the spinning process was completed in 3-4 days. The cocoons were harvested and dried in bright sunlight (4-5 days) to eliminate moisture content and to kill the moth. The weight, length and width of fifteen cocoons were measured by digital electronic weight balance and Vernier Caliper, respectively.

Fifteen cocoons were selected to measure the remaining parameters. A small cut was made with a knife on each cocoon at its one end and the pupa was removed to calculate the shell weight of each cocoon. The shell ratio of cocoon was calculated by the given formula:

$$\text{Shell Ratio} = \frac{\text{Shell weight (g)}}{\text{Cocoon weight (g)}} \times 100$$

(Soliman, 2021)

The protein (Sericin and Fibroin) contents were estimated by degumming method (Mumtaz *et al*., 2022). After degumming, the fibroin content was equal to dry weight of fibroin while given formula was used to evaluate sericin:

Sericin Content (ml) = Initial weight of shell-Dry weight of filtrate (Mobika *et al*., 2021)

Statistical analysis

To compare the biological (larval weight and % ratio of silk gland weight to body weight) and economic parameters (cocoon weight, cocoon length, cocoon width, % shell ratio and protein content) of silkworms, one-way ANOVA followed by Tukey's test was used. P<0.05 was considered a significant value.

Results and Discussion

Effect of temperature and humidity on incubation and hatching

Chinese and Bulgarian silkworm eggs started to hatch on the 9th and 10th days at 21-22°C and 75-80% humidity while Pakistani silkworm eggs started to hatch on the 10th

and 11th days respectively. Maximum hatching (96%) was observed in Chinese race on 7th and 8th day at 25-26°C whereas the hatching of Bulgarian silkworm eggs was 92% on the 8th and 9th day at 24-25°C and the hatching of Pakistani silkworm eggs was 80% on the 8th-10th days at 24°C. It was also interesting to note that the hatching of Chinese silkworm eggs was better than the other two races under the given set of conditions. Moreover, the hatching percentage increased in the Chinese race in accordance with the rise in temperature whereas declined in the other two races. Chinese race showed an ideal hatching percentage at 25-26°C and RH. 75-80 (Table 1).

Chinese and Bulgarian silkworm eggs started to hatch on 9th and 11th days at 21-22°C and at 80-85% humidity while Pakistani silkworm eggs showed 0% hatching at 21°C and started to hatch on 10th-12th days at 22-23°C, respectively. Maximum hatching (94%) was observed in the Chinese race on 7th and 8th day at 26°C whereas the hatching of Bulgarian silkworm eggs was 92% on 7th and 8th day at 26°C and the hatching of Pakistani silkworm eggs was 72% on the 7th-9th days at 26°C. It was also interesting to note that the hatching of Chinese silkworm eggs was better than other two races eggs under the given set of conditions. Moreover, the hatching percentage increased in the Chinese race in accordance with the rise in temperature whereas declined in the other two races. The Chinese race showed an ideal hatching percentage at 26°C and RH. 80-85 (Table 2).

Effect of variable number of meals on leaf consumption rate

It was observed that the number of meals per day inversely affects the consumption rate of silkworm larvae (Table 3). It was observed that 6 times feeding per day to 5th instar enhanced the consumption rate of leaves. Chinese and Bulgarian larvae left 9.69% and 10.37% whereas Pakistani larvae left 10.80% uneaten leaves on the bed when fed 6 times a day. As the number of meals increased, the quantum of uneaten leaves decreased. It was further recorded that a decrease in no. of meals per day significantly reduced the leaf consumption rate of larvae. Chinese and Bulgarian larvae left 20.56% and 21.87% while Pakistani larvae left 22.84% uneaten leaves on the bed when fed 2 times a day.

Table 1: Incubation and hatching at variable temperature and RH 75-80%.

Races	**Days**	**Hatching percentage of larvae at variable temperature**									
		21°C	**22°C**	**23°C**	**24°C**	**25°C**	**26°C**	**27°C**	**28°C**	**29°C**	**30°C**
Chinese	7th	-	-	-	-	-	96	80	72	48	32
	8th	-	-	56	48	80	-	8	8	8	4
	9th	-	16	16	36	16	-	-	-	-	-
	10th	8	20	-	-	-	-	-	-	-	-
	11th	12	12	-	-	-	-	-	-	-	-
	12th	20	16	-	-	-	-	-	-	-	-
	13TH	8	-	-	-	-	-	-	-	-	-
	Total hatching	48	64	72	84	96	96	88	80	56	36
Bulgarian	7th	-	-	-	-	-	68	60	48	36	24
	8th	-	-	60	60	72	20	12	16	12	-
	9th	-	28	20	32	20	-	-	-	-	-
	10th	8	16	-	-	-	-	-	-	-	-
	11th	8	16	-	-	-	-	-	-	-	-
	12th	12	12	-	-	-	-	-	-	-	-
	13th	12	-	-	-	-	-	-	-	-	-
	Total hatching	40	72	80	92	92	88	72	64	48	24
Pakistani	7th	-	-	-	-	-	-	-	-	-	-
	8th	-	-	40	32	32	40	36	24	16	-
	9th	-	-	8	28	28	20	12	16	-	-
	10th	-	16	12	20	12	-	-	-	-	-
	11th	8	12	-	-	-	-	-	-	-	-
	12th	4	8	-	-	-	-	-	-	-	-
	13th	4	8	-	-	-	-	-	-	-	-
	Total hatching	16	44	60	80	72	60	48	40	16	0

Table 2: Incubation and hatching at variable temperature and RH 80-85%.

Races	Days	Hatching percentage of larvae at variable temperature									
		21°C	22°C	23°C	24°C	25°C	26°C	27°C	28°C	29°C	30°C
Chinese	7th	-	-	-	-	-	32	48	56	32	20
	8th	-	-	-	40	64	62	40	12	24	16
	9th	-	-	24	52	28	-	-	-	-	-
	10th	-	12	12	-	-	-	-	-	-	-
	11th	8	16	8	-	-	-	-	-	-	-
	12th	12	8	12	-	-	-	-	-	-	-
	13TH	8	-	8	-	-	-	-	-	-	-
	Total hatching	28	36	64	92	92	94	88	68	56	36
Bulgarian	7th	-	-	-	-	-	24	44	48	40	20
	8th	-	-	-	24	56	68	32	8	8	8
	9th	-	-	20	56	32	-	-	-	-	-
	10th	-	16	12	-	-	-	-	-	-	-
	11th	8	12	8	-	-	-	-	-	-	-
	12th	12	8	8	-	-	-	-	-	-	-
	13th	12	8	8	-	-	-	-	-	-	-
	Total hatching	32	44	56	80	88	92	76	56	48	28
Pakistani	7th	-	-	-	-	-	28	32	44	32	12
	8th	-	-	-	24	36	24	16	4	4	8
	9th	-	-	16	36	32	20	12	-	-	-
	10th	-	12	8	8	-	-	-	-	-	-
	11th	-	8	12	-	-	-	-	-	-	-
	12th	-	4	8	-	-	-	-	-	-	-
	13th	-		-	-	-	-	-	-	-	-
	Total hatching	0	24	44	68	68	72	60	48	36	20

Table 3: Effect of variable meals on leaf consumption rate of 5th instar.

Races	No. of meals/ day	Uneaten leaves (g)	Add. drying factor @ 43% of (av.) initial weight	% of uneaten leaves
Chinese	6	35	15.05	9.69
	5	40.5	17.41	11.22
	4	50.54	21.73	14
	3	63.82	27.44	17.68
	2	74.20	31.90	20.56
Bulgarian	6	37.3	16.03	10.37
	5	42.73	18.37	11.84
	4	51.60	22.18	14.3
	3	67.32	28.94	18.65
	2	78.93	33.93	21.87
Pakistani	6	39	16.77	10.80
	5	43.30	18.61	11.99
	4	52.90	22.74	14.66
	3	69.70	29.97	19.31
	2	82.43	35.44	22.84

Estimation of biological traits

From day 1 to day 6 there was a gradual increase in the larval weight of the fifth instar. Significant differences ($p<0.001$) in larval weight were recorded in all races (Chinese, Bulgarian and Pakistani) from 2-6 days and a maximum increase (0.979±0.038) in larvae weight was observed in the Chinese race before spinning (Figure 1). The silk gland and body weight percentage ratio was also significantly different among the three races ($F_{2,12}$ =52.750; $p<0.001$) and the highest percentage ratio was observed in the Chinese race (27.386±0.843) (Figure 2).

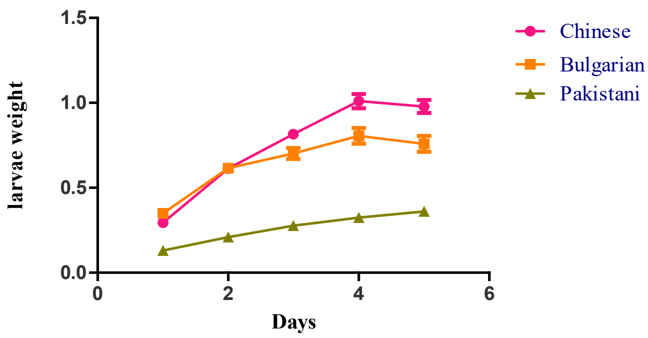

Figure 1: Mean plot of larval weight (g) of 5th instar at different days in different silkworm races.

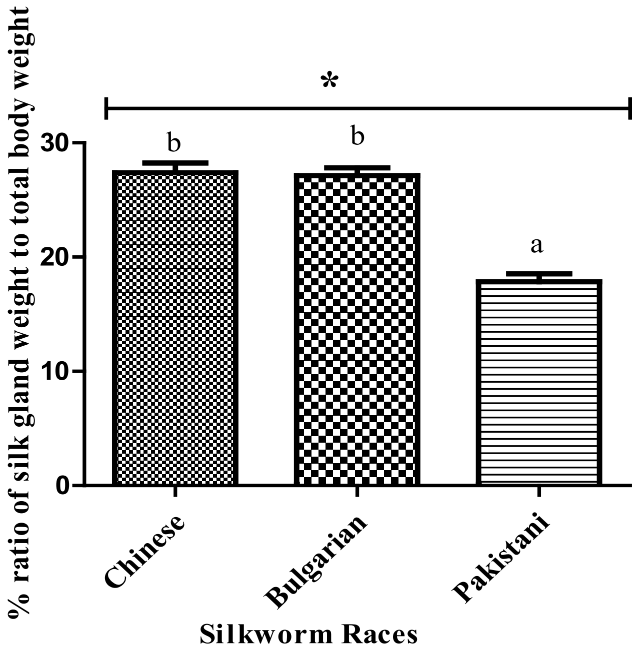

Figure 2: Ratio of silk gland weight to the body weight of larvae in different silkworm races.
Note: The * value represents significant differences.

Estimation of economic traits

A non-significant difference was recorded in cocoon weight ($F_{2,42}$= 0.140; p<0.001) among races while in cocoon length ($F_{2,42}$ =5.150; p<0.001) and cocoon width ($F_{2,42}$= 8.960; p<0.001) a significant difference was observed. The maximum increase in cocoon weight (0.706±0.041) (Figure 3) cocoon length (28.656±0.428) (Figure 4) and cocoon width (16.110±0.291) (Figure 5) was found in the Chinese race.

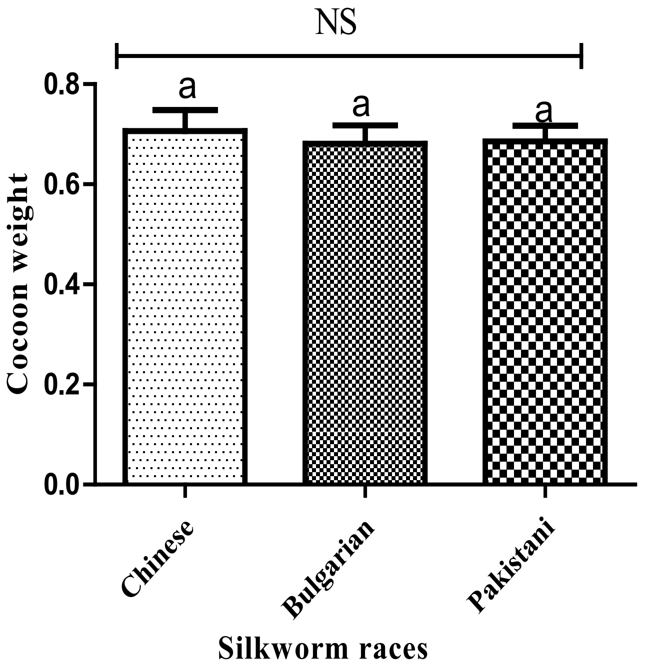

Figure 3: Comparative analysis of cocoon weight (g) in different silkworm races.
Note: The NS represents non-significant differences.

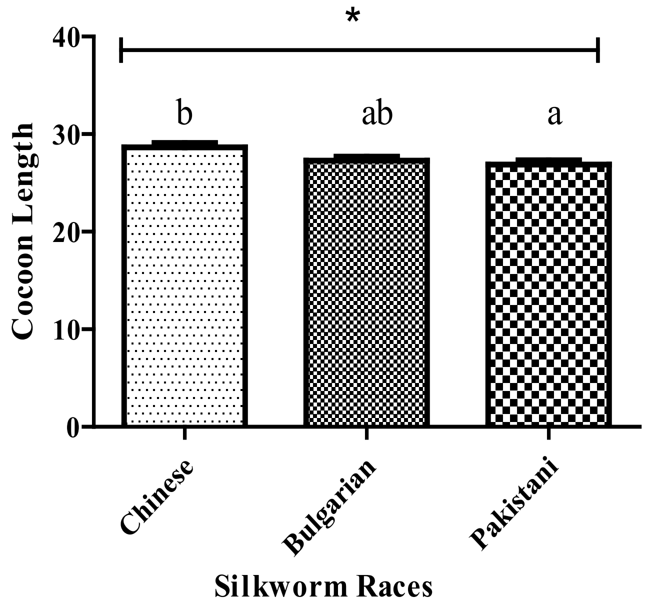

Figure 4: Comparative analysis of cocoon length (mm) in different silkworm races.
Note: The * value represents significant differences.

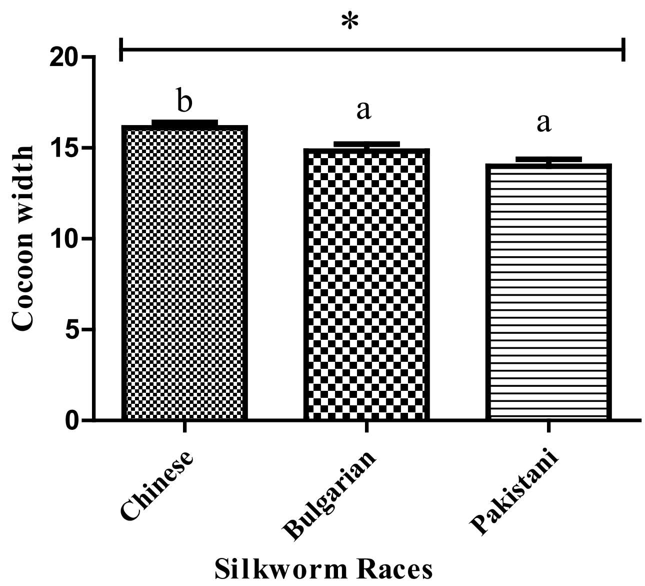

Figure 5: Comparative analysis of cocoon width (mm) in different silkworm races.
Note: The * value represents significant differences.

The cocoon shell ratio was highest in the Chinese race (30.063±1.984) ($F_{2,42}$= 1.052; p<0.001) (Figure 6). The percentage of fibroin content was significantly different ($F_{2,42}$= 3.298; p<0.001) in three experimental groups. The highest fibroin content was observed in the Chinese race (74.900±0.633) (Figure 7). However, the percentage of sericin content was also significantly different among the three groups ($F_{2,42}$ =4.153; p<0.001) and the highest sericin content was observed in the Pakistani race (28.444±1.047) (Figure 8).

The growth and development of silkworms is greatly affected by environmental conditions (humidity and temperature) and feeding patterns as it had a long history of domestication of around 5000 years (Andadari, 2021). Silkworm races showed variable biological and economic responses to climatic conditions of different areas. Thus, the present study was conducted to evaluate the optimized hatching conditions and feeding performance as well as a comparative analysis of biological (larval weight, % ratio of silk gland) and economic parameters (cocoon weight, cocoon length, cocoon diameter and shell ratio) of different silkworm races.

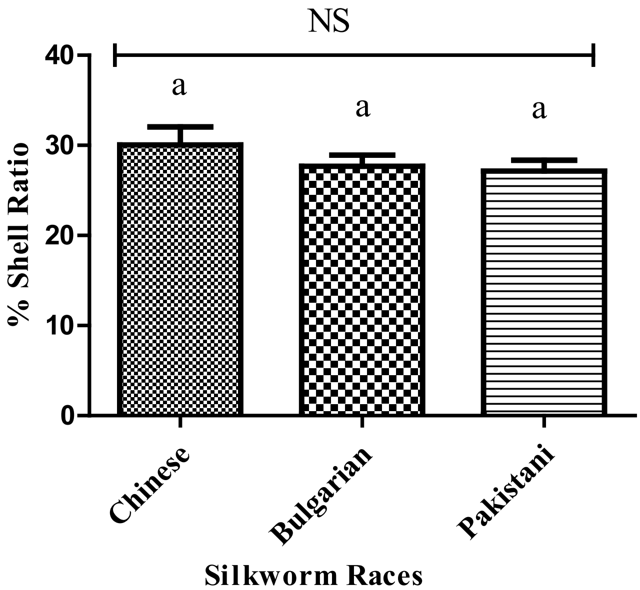

Figure 6: Comparative analysis of % shell ratio in different silkworm races.
Note: The NS represents non-significant differences.

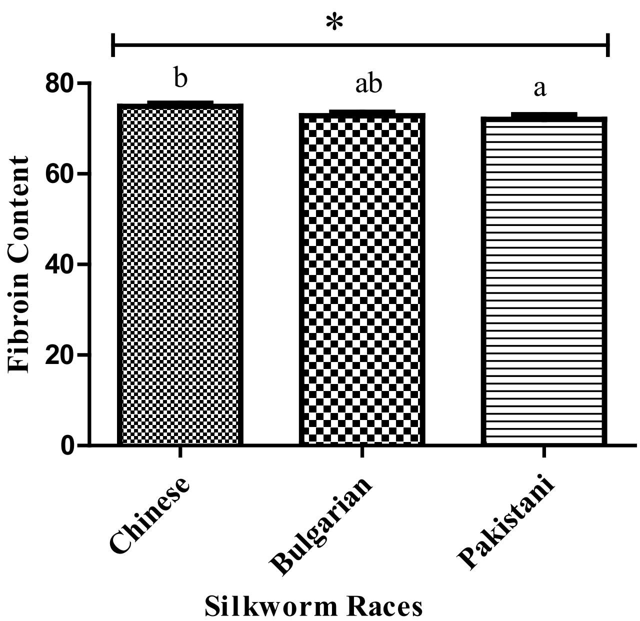

Figure 7: Comparative analysis of % fibroin content in different silkworm races.
Note: The * value represents significant differences.

The Bulgarian bivoltine strain was created in 2001. This strain, characterized by sticky eggs with gray serosa and white chorion had white larvae. The cocoons of this strain were white and elongated. However, the bivoltine Chinese Strain (1990), characterized by sticky eggs with gray or green serosa and white to yellow chorion also showed white larvae as well as white cocoons that were oval-elongated in shape as compared to elongated cocoons of the Bulgarian strain. The third strain that was used during this research study was the Pakistani hybrid strain. Moreover, the characteristics shown by this strain were a mixture of different strains.

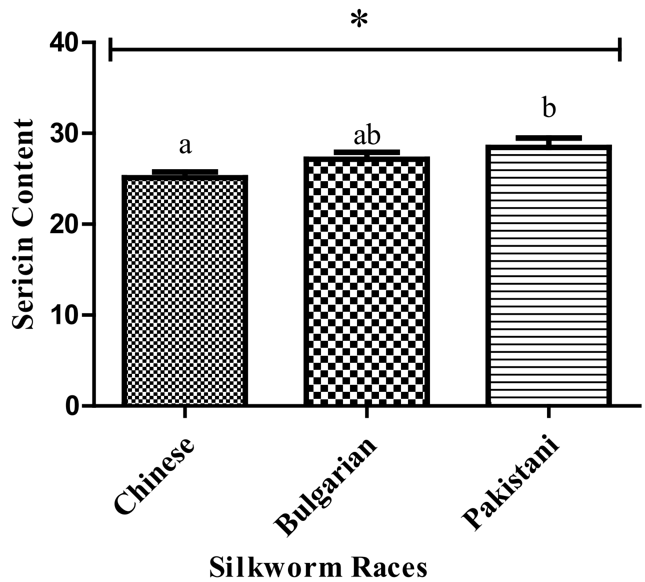

Figure 8: Comparative analysis of % sericin content in different silkworm races.
Note: The * value represents significant differences.

Temperature affects the diapauses nature of eggs and embryonic development of silkworms (Rahmathulla, 2012). In our study, among three silkworm races Chinese silkworm race (Haukaned 2 strain) showed better hatchability at high temperatures than the Bulgarian race (KK × Hesa 1 × Vesletz 2 × Gergana 2). Zulfiqar *et al.* (2022) observed that the Bulgarian race showed better tolerance against high temperatures than the Chinese and Korean silkworm races respectively. While they did not mention the silkworm strain they used in experiments. During this research study, it was observed that the feeding performance of silkworm larvae was directly related to the number of meals. The consumption rate was highest in the case of six meals per day. Silkworm larvae of the Chinese race showed a maximum increase in leaf consumption rate rather than Bulgarian and Pakistani races when fed six times per day. Silkworm larvae showed a trend in the reduction of wastage of leaves when the time period between the two meals was reduced. Alipanah *et al.* (2020) reported that mulberry leaves lose their moisture content when increase the time period between two meals and it affects the consumption rate of silkworms.

The weight of silkworm larvae of all the races increased gradually during their life cycle. It was observed that biological traits including larval weight and percentage ratio of silk gland weight to body weight of Chinese race larvae were significantly higher than the larval weight of the other two races when fed with fresh mulberry leaves of *Morus alba* (indigenous variety). Sabhat *et al.* (2011) evaluated that the larval growth rate, weight and survival rate were greatly affected by ecological factors, quality of leaf and rate of food consumption. However, Zulfiqar *et al.* (2022) recorded better growth in the Bulgarian race as compared to Chinese and Korean races reared in the local climatic conditions of Gujrat Pakistan. They performed their study in the spring season on newly sprouting mulberry leaves whereas our study was conducted in the autumn season on comparatively matured and less succulent leaves. Moreover, optimum climatic conditions run antagonistically in both these seasons, therefore, their results might be different from our study. Kaviraj *et al.* (2021) recorded in their study that mulberry varieties and silkworm races had a significant relation with larval length, larval weight and shell ratio.

Cocoon parameters and the quality of silk fiber play an important role in determining the performance of silkworms (Kumar and Umakanth, 2017). Good-quality mulberry leaves are required for successful cocoon production and a high yield of silk (Zannoon *et al*., 2008). The results of our study showed a significant increase in fibroin content as well as the length and width of cocoons in silkworms of the Chinese race as compared to other silkworm races. While a non-significant increase was observed in cocoon weight and shell ratio in the Chinese race. It was observed that mulberry leaves and climatic conditions of Lahore influenced the silkworm rearing and all biological and economic traits. Shah *et al.* (2007) reported that mulberry varieties (Husang China and Chinese Evergreen) produce a significant difference in shell ratio (%) and the Chinese race showed a maximum increase in shell ratio (%) fed with Husang China variety as compared to the Korean race. They found out that the maximum increase in shell ratio (%) may be due to different climatic conditions. Andadari (2021) also recorded that mulberry leaves also had a significant effect on cocoon weight, shell weight and percentage of cocoon shells. They recorded that the formation of silkworm cocoons was affected by the silkworm rearing conditions and environmental conditions during the spinning process.

According, to our results Chinese race has the potential to perform well when fed with the local mulberry variety (*M. alba*) in local climatic conditions of Lahore and shows better performance almost in all biological and economic parameters as compared to the other two races. On the other hand, Zulfiqar *et al.* (2022) reported that in the spring season bivoltine Bulgarian race showed better results as compared to Chinese and Korean races for biological and commercial parameters when fed with local mulberry leaves in local climatic conditions of Gujrat Pakistan, while they did not mention the type of local mulberry.

Conclusions and Recommendations

Here it is concluded that the optimum rearing temperature for silkworms was 25-26°C and the optimum relative humidity for rearing was 75-80%. The number of meals had a significant effect on the leaf consumption rate and the maximum leaves were consumed when silkworms were fed six times a day. The biological and commercial traits were maximum in the case of the Chinese silkworm race at similar environmental conditions.

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Consent for publication

All authors are fine with the current version of the manuscript and give their consent for publication.

Ethical approval

Not applicable.

Conflict of interest

The authors have declared no conflict of interest

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