Research Article

Effect of Feeding Mix Mulberry Varieties on Growth and Development of C-21 Strain of Silkworm (*Bombyx mori* L.) and on their Cocoon Characters

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Abstract | The present study was carried out to observe and study the growth and developmental stages of mulberry silkworm (*Bombyx mori* L.) C-21 strain by feeding different mulberry varieties and its effect on their cocoon characters during spring and autumn silkworm rearing seasons 2022. The study comprised of thirty number of larvae and cocoons of Chinese C-21 strain. The parameters that were studied in the present experiment and recorded were weight of full-grown larvae (1.4-3.6 gm), length of larvae (49-67 mm), cocoon weight with floss (0.34-2.3 gm), cocoon weight without floss (0.32-1.76 gm), cocoon shell weight (0.16-0.83 gm), cocoon diameter (14-22 mm), cocoon length (27-34 mm), cocoon weight (0.512-1.184 gm), cocoon filament length (757-1123 m), filament wet weight (0.125-0.806 gm) and filament dry weight (0.191-0.288 gm). Four randomly selected cocoons were selected for the reeling process. The mean boiling temperature was recorded at 87°C. Temperature varies between 85°C and 90°C during the rearing season. The study shows that carefully controlling the temperature and humidity levels and managing the feeding of silkworms ensure the optimal growth and development resulting in healthy and productive silkworms.

Received | Ferburary 12, 2022; **Accepted** | June 12, 2022; **Published** | June 27, 2022
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Citation | Salman, M., N. Ahmed, M.M.U. Din, F. Amin and A. Ali. 2022. Effect of feeding mix mulberry varieties on growth and development of C-21 strain of silkworm (*Bombyx mori* L.) and on their cocoon characters. *Pakistan Journal of Forestry*, 72(1): 49-54.
DOI | https://dx.doi.org/10.17582/journal.PJF/2022/72.1.49.54
Keywords | *Bombyx mori* L., Chinese C-21 strain, Mulberry leaves, Silk and cocoon quality, Reeling

Introduction

The science of rearing silkworm for the commercial production of raw silk is termed as sericulture and it includes the operations which are required for the production of silk fiber (Krishnaswami *et al*., 1973). *Bombyx mori* L. (Lepidoptera, Bombycidae) is the common silkworm. *B. mori* undergoes complete metamorphosis i.e., its life cycle passes through four stages including egg, larva, pupa and adult. Besides silk used in manufacturing of cloth, it is also used in making of surgical sutures, artificial blood vessel, tire lining, parachute, electric insulating material, oil, protein and artificial vitamins; even its waste material (excreta) is used as artificial diet for animals and as green manure for crops (Ishfaq and Akram, 1999).

Sericulture is practiced in all the four provinces of Pakistan and also in Azad and Jammu Kashmir; however, the main activity of natural silk production is practiced around the irrigated forest plantation of Changa Manga, Kamalia, Chichawatni and Multan in Punjab province (Anonymous, 1990). The production of raw silk is inadequate to meet requirements of the textile industry. If the textile industry is provided with adequate raw silk, Pakistan can not only save its precious foreign exchange (i.e., reduce imports) but can also improve its economy by exporting the surplus commodity. Since the majority of population lives in rural areas and the villagers including men, women and children can increase their income through rearing of *B. mori* in their spare time (Ishfaq and Akram, 1999).

The *Bombyx mori* is essentially monophagous and survives solely on mulberry leaves (*Morus* sp.) which play an important role in the nutrition of the silkworms, and in turn cocoon and silk production (Nagaraju, 2002). *B. mori* adults are creamy white in colour with several faint brownish lines. They do not feed, rarely fly and usually live only for a few days. Each female lays 300 to 500 eggs and the eggs hatch in about 12 days. When used for a commercial purpose, the pupae are killed before the adults emerge, otherwise the emergence of the moths break the fibers into pieces. Each cocoon is composed of single thread of about 914 meters long. About 3000 cocoons are required to make a pound of silk (Borrer *et al*., 1981). The *B. mori* is host specific insect and feeds only upon leaves of mulberry (*Morus* species) to make cocoon as its protective layer (Anonymous, 1976).

Mulberry leaves are rich in protein and amino acids. The nutritional elements of mulberry leaves determine the growth and development of the larvae and cocoon production (Seidavi *et al*., 2005). It is known that there is high correlation between leaf protein level and production efficiency of cocoon shell, which means cocoon shell weight to the total amount of mulberry leaves consumed by the *B. mori* (Mechii and Katagiri, 1991). In recent years, many attempts have been made to improve the quality and quantity of silk (Hiware, 2006) through enhancing the leaves with nutrients, spraying with antibiotics, juvenile hormone, plant products, with JH-mimic principles or using extracts of plants. Therefore, increase in protein level may lead to improvement in productivity of cocoons and silk. Keeping in view the above-mentioned importance of *B. mori* and sericulture, the experiment was conducted with the objective to observe and study the different life stages of silkworm C-21 strain and their cocoon quality and characters.

Materials and Methods

The experiment was conducted to study the performance and developmental stages of mulberry silkworm C-21 strain and their cocoon characters and quality. The present study was carried out in the Sericulture laboratories of Pakistan Forest Institute, Peshawar during spring and autumn silkworm rearing seasons 2022. The study consist of thirty number of larvae and cocoons of Chinese C-21 strain. The following procedures were adopted for conducting the research work.

Silk reeling

It is the process by which several cocoons are boiled together and then reeling singly. This is accomplished by unwinding the filaments. The cocoons are cooked continuously in a hot water bath at 90±5°C and winding the resulting yarn onto a fast-moving reel. The data were collected on the following parameters:

Cocoon weight with floss (g): 30 larvae were randomly collected from experimental unit and their weight have been recorded with floss with the assistance of digital weighing balance.

Cocoon weight without floss (g): Floss was removed from 30 randomly selected cocoons and their weight was determined in grams with the aid of digital weight machine.

Diameter of cocoons (mm): The diameter of all 30 cocoons of Chinese C-21 were taken with the help of Vernier caliper.

Length of cocoons (mm): 30 randomly selected cocoons of Chinese C-21 strain and length was measured with the help of Vernier caliper.

Cocoon filament length (m): Cocoon filament length of randomly selected cocoons were determined by the digital counter attached with silk reeling machine.

Cocoon filament size: The cocoon filament size in terms of denier was assesssed using following formula:

$$\text{Filament size (Denier)} = \frac{\text{Filament weight (g)}}{\text{Filament length (m)}} X\,9000$$

Boiling and processing loss

Boiling and processing loss of 30 cocoocs weight was determined which had been selected from experimental unit.

Results and Discussion

The silkworm rearing under lab condition and their different developmental stages, business filament and cocoon characters of Chinese C-21 strain are studied and the following outcomes of different parameters are tested, evaluated and recorded during conducting the research study. Table 1 shows the different developmental stages of *B. mori* under lab conditions. The eggs of silkworm hatch in 9-10 days and larval stage have 5 instars remain for 20-30 days. They remain in pupal stage for 8-10 days while adults have 5-10 days lifespan.

Table 1: *Developmental stages of B. mori under lab conditions during 2022.*

Egg		**9 – 10 days**				
Larva	20-30 days	1st instar	2nd instar	3rd instar	4th instar	5th instar
		4-5 days	3-4 days	3-4 days	3-4 days	4-5 days
Pupa	8 – 10 days					
Adult	5 – 10 days					

Larvae weight (gm)

The result of the 30 randomly selected larval weight showed in Table 2 indicates that the mean larvae weight was 2.6 gm. The highest larvae weight recorded was 3.6 gm while the lowest larvae weight was 1.4 gm. Qader *et al.* (1992) investigated the nutritive effects of leaves of three mulberry varieties on larval growth and cocoon characters of three *B. mori* races. The result revealed that mature larval weight, single cocoon weight, shell weight, shell percentage and length of filament were greatly influenced by the nutritive value of different mulberry leaves. 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). The growth rate of *B. mori* larvae and subsequent silk production depend mainly on the nutrient contents of mulberry leaves. So, it is cleared from above discussion that if the silkworm consumes large amount of mulberry leaves so there will be a significant differences in their body weight and size as clearly shown in Table 2. Kobayashi (1992) reported that varietal improvement of mulberry through breeding not only gives superior leaf yield for feeding the *B. mori* but also better raw silk and its adaptability to climatic conditions and resistance against diseases. Fukuda (1960) reported that about 70% of the silk protein produced by the *B. mori* is directly derived from the protein contents of mulberry leaves. The nutritive value of mulberry leaves varies due to species and leaf maturity of the plant.

Larvae length (mm)

Analysis of the data showed that on Husang China variety of mulberry the larvae attained significantly maximum size followed by Japan Early and then Chinese Evergreen variety. Similarly, the size attained by the Chinese and Japanese race of *B. mori* (being non-significant from one another) was significantly more than F1 (Korean) on all the three varieties of mulberry. The result of the larvae length showed in Table 2 shows that the mean larvae length was 57 mm. The longest larvae length recorded was 67 mm and the shortest was 49 mm.

Table 2: *Larvae weight and length of Silkworm.*

S. No.	**Larvae weight (gm)**	**Larvae length (mm)**
Mean	2.6	57
Min	1.4	49
Max	3.6	67

Weight without floss and weight with floss of cocoons in (gm)

The results of the cocoon weight with floss and without floss are reproduced in Table 3. The mean cocoon weight with floss was 1.20 gm. The highest cocoon weight with floss was recorded 2.3 gm while the lowest cocoon weight with floss was 0.34 gm. The results further indicated that the mean cocoon weight without floss was 1.17 gm. The cocoon weight without floss varied between 1.76 gm and 0.32 gm.

Shell weight of cocoons in (gm)

The cocoon weight, shell weight and shell ratio are the important commercial parameters. The cocoon weight has a negative correlation with shell ratio but positive correlation with shell weight, whereas shell weight has a positive correlation with shell ratio (Maqbool *et* *al*., 2008). In present study the results of the cocoon shell weight are reproduced in Table 3. The mean cocoon shell weight was 0.26 gm while the highest cocoon shell weight recorded was 0.83 gm and the shortest was 0.16 gm. Muslim (1977) reported almost similar results that single cocoon weight was 1.85g, cocoon shell weight was 0.37g and cocoon shell ratio percentage was 21.51%. Bheemanna *et al*. (1989) obtained cocoon shell ratio percentage with 24.66 g/10 cocoons of *B. mori* fed with mulberry varieties Mysore local. The reason behind the maximum cocoon shell ratio (%) may probably be due to the optimum leaf moisture, higher protein and sugar content of the mulberry variety and different climatic conditions as well as different *B. mori* races in the present and earlier experiments.

Diameter and length of cocoons in (mm)

The results of the cocoon dimensions showed in Table 3 indicates that the mean cocoon length was 31.1 mm. The longest cocoon length was recorded 34 mm while the shortest cocoon length was 27 mm. Similarly, the mean cocoon diameter was 16.6 mm. The highest cocoon diameter was recorded 22 mm while the lowest cocoon diameter was 14 mm.

Table 3: *Mean Cocoon length and diameter, Cocoon weight with floss, cocoon weight without floss and shell weight of Silkworm under lab conditions during 2022.*

S. No.	CWWF (g)	CWWOF (g)	CSW (g)	CD (mm)	CL (mm)
Mean	1.20	1.17	0.26	16.6	31.1
Min	0.34	0.32	0.16	14	27
Max	2.3	1.76	0.83	22	34

CL= Cocoon length; CD= Cocoon diameter; CWWF=Cocoon weight with floss; CWWOF= Cocoon weight without floss; CSW= Cocoon shell weight.

Cocoon weight

Four randomly selected cocoons were selected for the reeling process. The mean cocoon weight was recorded 0.697 gm. The cocoon weight varies between 0.512 gm and 1.184 gm as shown in Table 4.

Temperature

The mean boiling temperature was recorded 87°C. Temperature varies between 85°C and 90°C as shown in Table 4.

Filament length

The mean cocoon filament length was 936.75 m. The longest cocoon filament length was recorded 1123 m while the smallest cocoon filament length was 757 m as shown in Table 4.

Filament wet weight

The mean cocoon filament wet weight was 0.354 gm. The highest cocoon filament wet weight was recorded 0.806 gm while the smallest was 0.125 gm as shown in Table 4.

Filament dry weight

The results showed that the mean filament dry weight was 0.231 gm. The highest filament dry weight was recorded 0.288 gm while the smallest was 0.191 gm as shown in Table 4.

Table 4: *Mean cocoon weight, temperature, filament length, filament dry weight and filament wet weight of silkworm under lab conditions during 2022.*

S. No.	CW (g)	Temp °C	FL (m)	FWW (g)	FDW (g)
Mean	0.697	87.5	936.75	0.354	0.231
Min	0.512	85	757	0.125	0.191
Max	1.184	90	1123	0.806	0.288

CW= Cocoon weight, FL = Filament length, FWW = Filament wet weight, FDW = Filament dry weight.

Cocoon weight and shell weight are the major traits evaluated for productivity in sericulture and have been used for more than half a century. Cocoon weight is an important commercial characteristic used to determine approximately the amount of raw silk that can be obtained. Shell weight gives a better measure, but cannot be determined in commercial cultures because it requires damaging the cocoon. The difference between the two measures is the weight of the pupa (Gaviria *et al*., 2006). Yungen and Junliang (1999) confirmed that use of high protein diet effectively increases the quality of cocoon shell. Increases in filament length and non-breakable filament length of silk produced are the most important commercial characters in the improvement of silk quality and yield (Kamimura and Kiuchi, 1998). In their study positive trends were observed in most values of different parameters except for the Cocoon shell ratio percentage in the experimental group, when compared to the control group. A minimal increase of 0.56% was noted in the Shell weight; whereas Filament length and Filament weight recorded a positive increase of 2.93% and 8.87%, respectively. However, a negative trend of 11.62% was recorded for the Cocoon shell ratio percentage an indication that reeling breaks in the experimental group were lower than in the control group. Hiware (2006) results indicated positive results in larval and shell weights, and filament length upon feeding larvae on mulberry leaves treated with *Nux vomica*. Cocoon and pupal weights and average denier had negative results. Their study also infer increased cocoon shell weight is variably converted to the end product, the reelable silk filament.

Conclusions and Recommendations

Silkworm rearing is a profitable cottage industry. The natural silk is the queen of textile. The eggs are chilled at 5°C at least for four months before incubation. The eggs hatch in about 10 days. Usually, a larva passes through four molts during 25±3 day larval lifespan. Larval stage is the only feeding stage. Among larval instars more than 92% feed is taken by 5th instar. The ideal conditions for silkworm rearing are temperature: 26±2°C and 75±5% relative humidity. However, these conditions are adjusted with changing stages of developmental biology. Another important requirement of silkworm rearing is hygienic conditions. It is necessary to disinfect rearing rooms, rearing tools and fixture. A packet of silk seed (eggs) comprising 20,000 eggs with a weight of 12 gm can produce 32-35 kg cocoons. A farmer can earn Rs.35-40,000 approximately in one month by rearing one packet of silk seed. The productivity of silkworm depends on silkworm strains quality and quantity of mulberry leaves. In most of the silkworm rearing countries, hybrids strains are reared instead of pure lines. The hybrid strains are vigorous and resistant against microbial diseases. By carefully controlling the temperature and humidity levels and managing the feeding of silkworms, you can ensure optimal growth and development, resulting in healthy and productive silkworms.

Acknowledgement

The authors express their gratitude to Director NTFP Division, Pakistan Forest Institute, Peshawar for providing resources and support for accomplishing this study.

Novelty Statement

By carefully controlling the temperature and humidity levels and managing the feeding of silkworms, it can ensure optimal growth and development resulting in healthy and productive silkworms.

Author's Contribution

Muhammad Salman: Conceived and designed the experiment, analyzed the data and wrote the paper.
Naveed Ahmed: Designed the experiment.
Mir Manzar Ud Din: Performed the experiment.
Fazli Amin: Data Collection and supervision.
Arsalan Ali: Analyzed the data.

Conflict of interest
The authors have declared no conflict of interest.

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