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Comparative effect of feeding frequency on economic traits of bivoltine silkworm, *Bombyx mori* L.

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Abstract
The quality and quantity of food can play an important role in the growth and development of silkworm, particularly during larval stage which in turn influences the expression of cocoon productivity traits. In the present investigation, an attempt has been made to quantify the superiority of different feeding frequency (i.e. one time, two times, three times and four times per day) on the growth and development of bivoltine silkworm hybrid CSR26 × CSR27 for economic character expression. Observations were made for economically important traits of each stage viz., larval, cocoon and post cocoon filament length and denier) which indicated that feeding frequency of four times had significantly lesser larval duration (IV- 4:05, V-6:05) higher cocoon yield/10,000 larvae (by weight) (14.14), single cocoon weight (1.58), single shell weight (0.35), shell ratio percentage (21.99) and total filament length (788.67) closely followed by three times feeding frequency for larval duration (IV- 4:08, V-6:09), cocoon yield/10,000 larvae (by weight) (13.35), single cocoon weight (1.49), single shell weight (0.31), shell ratio percentage (21.24) and total filament length (724.33). Thus, based on per se performance values and significant difference values for important commercial traits these feeding frequencies can be easily utilized for commercial rearing without affecting the qualitative and quantitative economic characters.

Keywords: Silkworm, Bivoltine, feeding frequency, quantity, growth, economic characters

Introduction
Mulberry silkworm, *Bombyx mori* L. is a monophagous insect, feeding exclusively on the mulberry leaves (*Morus* spp.) for its nutrition and produces the natural proteinous silk. Silkworm grows around 4-5 g in weight in its total larval life depending upon the mulberry leaf, environment and silkworm race/hybrid. It consumes about 15-20 g of leaf throughout its larval instars with 80-85 per cent of consumption in the last two instars. The rate of consumption of food increases with each larval instars but the rate of conversion of food into body weight decreases (Bongale *et al.,* 1997) [5]. The leaf requirement also differs depending upon the age of the silkworms. Intensive and cautious domestication over centuries has apparently privileged this commercial insect the opportunity to increase in nutrition efficiency. Nutritional intake has a direct impact on the overall genetic architecture of larvae and cocoon characters, pupation, amount of silk production, and reproductive traits (Rathod *et al.,* 2015) [23]. Timely provision of nutritionally rich mulberry leaves in optimum quantity to meet the nutritional requirements of silkworms needs to be considered as the most important component as it largely influences cocoon productivity (Gangarathanamma *et al.,* 2005) [10].
Feeding frequency perhaps is the most important factor in silkworm rearing as it has a direct effect on the growth and development of worms on one hand and with the cost of silkworm rearing on the other (Sannappa *et al.,* 2004) [24]. Silkworm is a voracious feeder during the last two instars and requires to be fed many times for better and uniform larval growth and development. The number of feeds given varies from place to place depending upon many factors (Das *et al.,* 1994) [8]. Further, mulberry leaf quality, time of harvesting, method and duration of storage of mulberry, feeding method, way of chopping, appetite of silkworms, silkworm breeds / hybrids, larval instar and temperature and relative humidity existing in the rearing room are known to decide the feeding frequency in silkworm rearing so as to harvest better cocoon crops. Thus, an experiment was conducted to study the effect of different feeding frequency on the growth and development of bivoltine silkworm hybrid for economic character expression.

Materials and Methods

The present investigation was conducted during spring 2018 at the Department of Sericulture, Government Degree College, Udhampur with an intention to identify and evaluate the effect of different feeding frequency on economic traits of silkworm hybrid for commercial exploitation. The experimental research material for the proposed study comprised of four feeding frequency fed to the worms i.e. one time per day (8 am), two times per day (8 am and 8 pm), three times per day (8am, 2 pm and 8 pm) and four times per day (8 am, 12 noon, 4 pm and 8 pm). Bivoltine silkworm hybrid, CSR26 × CSR27 was taken for the study. The experiment was laid out in Completely Randomized Block Design (CRBD) with three replications each. Standard rearing techniques as suggested by Dandin *et al*. (2003) [7] were followed. After brushing, the silkworms were reared for different treatments separately. Each replication had a population size of 200 larvae. Ripe worms were picked for seriposition and spinning was conducted on collapsible plastic mountages. The cocoons were harvested on sixth day after mounting. Data was recorded replication-wise for all economic traits viz., larval duration (IV & V instar), larval weight, larval survival percentage, cocoon yield per 10,000 larvae (by weight and by number), single cocoon weight, single shell weight, shell ratio percentage, total filament length, non-breakable filament length and denier. To estimate significant differences among different feeding frequency the mean data of each character were subjected to Analysis of Variance Techniques. The results were tested for the treatments mean by applying F- test of significance (ANOVA) on the basis of null hypothesis as mentioned by Panse and Sukhatme (1967) [20].

Results and Discussion

Optimal feeding frequency is of vital importance for proper growth and development of insects (Sehnal, 1985) [27]. It has been clarified unequivocally that *Bombyx mori* grows very fast and needs adequate feed during the last two larval instars because of real feeding stage consuming about 80-85 per cent of the total feed (Krishnaswami *et al.*, 1988) [15]. This leads to the increase in body size and dry weight of cellular mass which are dependent on the rate of environmental conditions in each instars in the rearing bed (Ahmed *et al.*, 2015a) [2]. Feeding frequency and overcrowding in rearing bed affects the economics of cocoon crop significantly as over feeding leads to leaf wastage and higher leaf cocoon ratios (Ahmed *et al.*, 2015b) [1], while overcrowding of silkworm in rearing bed leads to insufficient consumption of feeds, poor growth and higher incidence of disease, resulting in low cocoon yield of inferior cocoon quality (Krishnaswami *et al.*, 1977) [16]. Superior quality of silkworm feeds should be fed to young and late age larvae and quantitative differences in feed influence both the larval growth and cocoon character of mulberry silkworms. Therefore, it is crucial to determine quantity of feed required per day for each instars of silkworms and feeding frequencies according to environmental conditions.

Commercial Character Expression of Silkworm for Different Feeding Frequency

Larval Stage

Larval duration being important, influences rearing duration, labour input and leaf consumption that are directly related to the cost of production and silk productivity. In the present study, IV and V age larval duration exhibited significant differences among the feeding frequencies. Significant decrease in larval duration with four (4:05, 6:05) and three times (4:08, 6:09) feeding frequency was observed (Table 1). The reduced larval duration may be attributed to the better nutritional value given to the hybrid. Similar observations were made by Basu *et al.* (1994) [4]. Silkworms are voracious eaters of mulberry during its larval stages and around 80 percent leaf is consumed in the last two instars (Fukuda, 1960) [9]. Highlighting the importance of food intake Horie *et al.* (1978) [11] reported that for the production of 1 g larval dry weight, requirement of ingestion and digestion of food is 4.2 mg and 1.8 mg respectively. The intake of food during total larval life is also reflected by the weight of 10 mature larvae. In present study, feeding frequency marked significant difference for weight of 10 mature larvae. Feeding frequency of four times (43.67) followed by feeding frequency of three times (39.67) and two times (37.33) which recorded significantly higher values than feeding frequency over one time feeding frequency for the said character (Table 1). This may be due to the fact that the higher frequency of feed leads to robust growth and development and the competition for the food is also less. Das *et al.* (1994) [4] and Kedir *et al.* (2015) [13] reported that, three to four times feeding per day resulted in higher larval weight, lower larval mortality and shorter larval durations than two or one time feeding per day. Similar observations were made by Chandrashekar, (1996) [6]. Commercially larval survival constitutes an important character from rearer`s point of view. In the present study, significant difference was recorded for larval survival for feeding frequency. Feeding frequency of four times (96.33) recorded highest survival percentage closely followed by three (94.33) and two times (92.67) with no marked difference between them (Table 2). The significant variation for larval survival can be attributed to more incidences of silkworm diseases and weakness due to starvation. Similar observations were made by Sannappa *et al.*, 2004 [24] reported that feeding at regular intervals throughout larval period was very important for optimum growth and development of the worms.

Cocoon Stage

Minagava and Otsuka (1975) [19] have reported inter relationship between multiple characters in silkworm. Cocoon yield (by weight and by number) was significantly affected by feeding frequency. Larval feeding frequency of four (14.14, 9133) and three times (13.35, 8700) did not vary much significantly followed by two times (11.18, 7700). However, feeding frequency of one time (6.68, 5933) recorded least value (Table 2). This may be due to the fact that larval survival percentage was higher in high feeding frequency of larvae when compared to less feeding frequency of larvae. The observations are in accordance with the findings of Chandrashekar, (1996) [6]. Malik *et al.* (2006) [18] suggested that cocoon yield / 10,000 larvae by weight and number, good cocoon percentage, pupation percentage, single cocoon weight, shell weight and shell ratio percentage are important parameters for a quality cocoon crop. The cocoon weight, shell weight and shell ratio are important commercial parameters of the cocoon stage for quality reeling performance. The cocoon weight has a negative correlation with the shell ratio but positive correlation with shell weight where as shell ratio has positive correlation with shell weight. There was significant effect of feeding frequency on single cocoon weight. Feeding frequency of four times (1.58) recorded highest value followed by three times (1.49), whereas, feeding frequency of one time (1.24) recorded lowest value (Table 2). However, feeding frequency of four times and three times did not exhibit any significant

difference among them. Similar were the observations recorded by Bali *et al.* (2004) [3]. Saratchandra *et al.* (1992) [25] has reported superior mulberry variety particularly triploids responsible for higher cocooning characters. Shell weight has a positive co-relation with cocoon shell ratio. The current findings indicate significant variability in the expression of single shell weight among different feeding frequency. Highest significant value was recorded by feeding frequency of four times (0.35) closely followed by three times (0.35) for the said trait (Table 2). Similar were the finding of Mahmoud and Yehia (2008) [17]. Higher shell ratio percentage is important for silk filament and different feeding frequencies behaved differently in respect of shell ratio. The differences among themselves were significant. Maximum shell ratio with respect to per se performance was observed for feeding frequency of four times (21.99) closely followed by three times (21.24), whereas, feeding frequency of one time (18.27) recorded the minimum value (Table 2). High fecundity may be the reason for low value of shell ratio as fecundity and shell ratio are negatively correlated as reported by Ram *et al.*, (2003) [22]. These results are similar to those reported by Bali *et al.* (2004) [3] who studied the effect of starvation on cocoon weight. They found a decrease in the cocoon shell weight due to deprivation during the feeding period. The results are in accordance with the findings of Subramaniyan (2013) [28].

Post-Cocoon Stage

Post cocoon characters have greater significance not only from reeler's point of view but also from industrial point of view. Three post-cocoon parameter viz. total filament length, non-breakable filament length and filament size mainly contribute for silk, the end product. Increase or decrease in filament length is dependent on the increase or decrease in the thickness of silk filament and cocoon shell weight of breeds and hybrids. In this study, total filament length and non-breakable filament length was significantly affected by feeding frequencies. Four times (788.67) feeding frequency significantly increased the total filament length and non-breakable filament length, whereas, one time (436,432.67) feeding frequency significantly decreased the said trait (Table 3). This may be due to higher mature larval weight (Satenahalli *et al.*, 1999) [26]. It is generally said that high fecundity results in lower filament length because these two characters are negatively correlated (Ram *et al.*, 2003) [22]. Rajalakshmi *et al.* (2000) [21] opines that the quality of a good hybrid is to have minimum or no breaks during reeling. The results corroborates with the findings of Ibrahim *et al.*, (2017) [12]. Filament size was significantly affected by feeding frequencies. The one time (2.31) feeding frequency recorded reduced filament size and feeding frequency of three times (3.12) recorded highest filament size. This may be due to the fact that the shorter filament length generally results into comparatably thin denier. The results are in close agreement with the findings of Gangarathanamma *et al.*, (2005) [10].

In silkworm (*Bombyx mori* L.), selection for various quantitative characters results in change in their mean to a varying degree and the selection for one character is found to produce correlated change in other quantitative characters of economic importance (Kobori & Fujimoto, 1966) [14]. In the present investigation, the eleven commercial quantitative and qualitative traits revealed broad variability between different feeding frequencies under study. This may be attributed to the adaptability of silkworm larvae to different feeding frequencies for the rearing of silkworms. The cumulative results based on the mean values for the economic traits from the present investigation clearly indicates that rearing of silkworm for feeding frequency of four times expressed better results followed closely by feeding frequency of three times (Fig. 1). Therefore, among four feeding frequencies studied for eleven commercial traits of bivoltine hybrid $CSR_2 \times CSR_4$ feeding frequency of four times and three times is best suitable for commercial rearing and hence can be recommended for field utility.

Table 1: Effect of feeding frequency on CSR26 × CSR27 silkworm hybrid for larval traits

Traits → Feeding Frequency↓	Larval duration (D:H)		Weight of 10 mature larvae (g)	Larval survival percentage
	IV instar	V instar		
One time/ day	5:10	8:04	24.67	78
Two times/ day	5:06	7:08	37.33	92.67
Three times/ day	4:08	6:09	39.67	94.33
Four times/ day	4:05	6:05	43.67	96.33
Sem (±)	0.01	0.01	0.78	0.41
LSD (p=0.05)	0.02	0.02	2.59	1.35

Table 2: Effect of feeding frequency on CSR26 × CSR27 silkworm hybrid for cocoon traits

Traits → Feeding Frequency ↓	Cocoon yield/10,000 larvae		Single cocoon weight (g)	Single shell weight (g)	Shell ratio percentage
	By weight (kg)	By number			
One time/ day	6.68	5933	1.24	0.23	18.27
Two times/ day	11.18	7700	1.39	0.28	20.19
Three times/ day	13.35	8700	1.49	0.31	21.24
Four times/ day	14.14	9133	1.58	0.35	21.99
Sem (±)	0.14	102.74	0.01	0.01	0.37
LSD (p=0.05)	0.45	340.25	0.04	0.02	1.24

Table 3: Effect of feeding frequency on CSR26 × CSR27 silkworm hybrid for post-cocoon traits

Traits → Feeding Frequency ↓	Total filament length (m)	Non-breakable filament length (m)	Denier (d)
One time/ day	436	432.67	2.31
Two times/ day	620	620	3.08
Three times/ day	724.33	724.33	3.12
Four times/ day	788.67	788.67	2.72
Sem (±)	7.87	9.29	0.02
LSD (p=0.05)	26.05	30.77	0.07

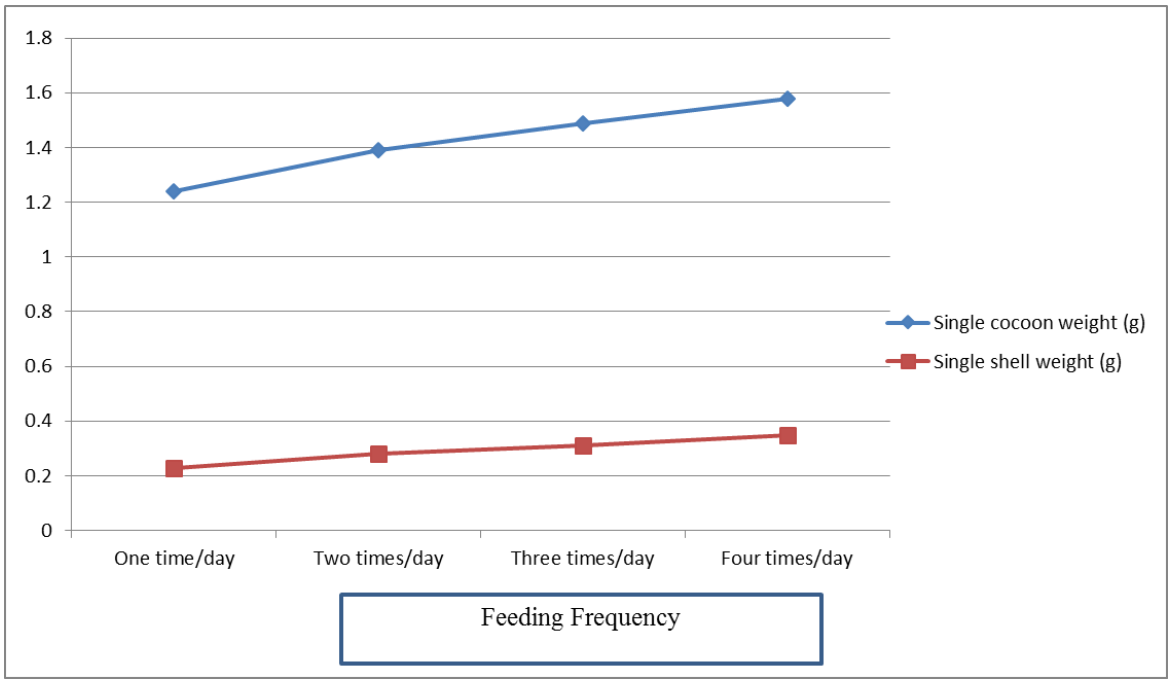

Fig 1: Effect of feeding frequency on CSR26 × CSR27 silkworm hybrid for economic traits

Conclusion

Based on the investigation, it can be safely concluded that hybrid CSR_2 × CSR_4 when fed for feeding frequency of four times and three times is best suitable for commercial rearing and hence can be recommended for field utility under sub-tropics after multi locational trials.

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