Int. J. Indust. Entomol. Vol. 12, No. 2, 2006, pp. 81~86

International Journal of *Industrial Entomology*

Impact of Mating Duration on the Fecundity of the Newly Evolved Races

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(Received 13 February 2006; Accepted 1 June 2006)

Of all factors that govern productivity in sericulture, the role of silkworm egg is of prime importance. The production of silkworm seed involves a long chain of interdependent and highly specialized conditions. Female moths of *Bombyx mori* L. commence egg deposition immediately when the moths were decoupled. More than 60% of eggs are deposited within 4 hrs after decoupling *i.e.* 62.33% in CSR-3, 61.67% in CSR-6, 62.50% in CSR-16 and 63.28% in CSR-17. Almost 90% of eggs were laid in the first 12 hrs (93.13% in CSR-3, 90.81% in CSR-6, 89.71% in CSR-16 and 93.17% eggs in CSR-17) after decoupling. Almost 8 to 10% of more eggs were laid when oviposition period was prolonged upto 48 hrs instead of 24 hrs. The present investigation showed that a significant increase of 45 (8.34%), 50 (9.98%), 41 (8.26%) and 45 (8.30%) ($P < 0.01$) numbers of more eggs were found between 24 to 48 hrs (T6 to T9) in CSR-3, CSR-6, CSR-16 and CSR-17 races respectively. The findings of present investigation is very important for sericulture industry while producing layings to keep for different hibernation schedule especially for autumn/late autumn crop, female may be allowed for prolonged oviposition to get 8 – 10% more eggs and farmer may fetch 8 – 10 kg. more cocoon yield/100 dfls with more income.

Key words: *Bombyx mori*, Time duration, Silkworm eggs, Fecundity

Introduction

Silkworm egg is sheet anchor of sericulture industry. Timely supply of adequate quality and quantity of disease free silkworm eggs to the sericulturists is crucial for successful harvest of cocoon crops. Various processes such as procuring the quality cocoons, emergence of moths, mating, egg laying, preservation and hatching of eggs are important from the point of maximizing viable egg production. (Omura, 1938 a,b; Kovalev, 1960; Yokyoma, 1962; Tazima, 1972; Ullal and Narasimhanna, 1981; Jolly, 1983). In *Bombyx mori* an extremely brief period of premating interval exists from the time of emergence to mating. The temporal aspects of mating in terms of duration may also have impact on the number of eggs laid, pattern of egg laying and their viability. Kovalev (1960) reported that in *B. mori* majority of eggs are laid between 12 noon and 3 pm during the daytime and 9 pm to 3 am during night time. Krishnaswami *et al.* (1973) and Singh *et al.* (1994) observed that the moths usually laid eggs from the afternoon onwards and reach the peak of oviposition by 6 pm to 10 pm. By next morning majority of the eggs have been laid. Mathur *et al.* (1995) stated that maximum fecundity and minimum egg retention were recorded when the females were exposed to fluorescent light (80 lux) during day and darkness at night. There is limited information on record concerning the periodicity of egg laying in case of *B. mori* from other parts of the country and abroad. Therefore, present study was undertaken to study the rate of oviposition (fecundity) with time duration and its impact on hatchability of four elite bivoltine pure races *viz.*, CSR3, CSR6, CSR16, CSR17.

Material and Methods

The present study was carried out at the Central Sericultural Research and Training Institute, Mysore, India. The detail methodology adopted during the course of investigation is given below:

Experimental races

The CSR series is evolved in 1992-1993 under Japan

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International Cooperation Agency (JICA) project of Central Sericultural Research and Training Institute, Mysore, India, which is found to be good for good yield and higher grade of silk. Four pure races of elite CSR series i.e., CSR3, CSR6, CSR16 and CSR17 were used for the present study & layings of above races were received from the silkworm breeding laboratory of CSR & TI, Mysore.

Rearing procedure

To assess the oviposition rate of egg layings , the rearing of CSR3, CSR6, CSR16 and CSR17 races were conducted as per the procedure laid by Krishnaswami *et al.,* in 1973. The rearing of above races were conducted in three different seasons *i.e.* May - June (Summer), November (Autumn), and January - February (Winter).

Experimental design

The cocoons of different races were harvested on the seventh day. By shaking the cocoons gently the number of live and dead pupae of all the cocoons of different races was assessed and the percentage of pupation was calculated. Defective and deformed cocoons from these batches were removed and cocoons, which were uniform in shape, size and confirming to racial traits, were retained for conducting the grainage operation and experiments as explained below.

Grainage operation: The selected cocoons of all the four races were cut to remove pupae from them. Male and female pupae were separated based on genital markings. The separated pupae of different races were preserved separately in mating room where recommended temperature and relative humidity was maintained at 25°C ± 1°C and 80% ± 5%. respectively. On the expected day of moth emergence, light was put on at 5 am to7 am and moths were allowed to emerge in this period. The emerged moths were collected and allowed to copulate. Light was again provided on the next day from 5 am. to 7 am. This process was repeated till the completion of moth emergence.

Duration of coupling: Three hours coupling was given as per the procedure laid by Krishnaswami *et al.* (1973) and Ullal and Narasimhanna (1981). Excess males were collected and preserved at 5°C with 75 – 80% relative humidity.

Treatment details: Decoupled females were kept in egg sheet at 10 am and cellules were kept over it and female were allowed to deposit eggs with time duration as detailed below:

T1 → 4 hrs after decoupling (upto 2 pm)
T2 → 8 hrs after decoupling (upto 6 pm)
T3 → 12 hrs after decoupling (upto 10 pm)
T4 → 16 hrs after decoupling (upto 2 am) (next day)
T5 → 20 hrs after decoupling (upto 6 am)
T6 → 24 hrs after decoupling (upto 10 am) (control)
T7 → 32 hrs after decoupling (upto 6 pm)
T8 → 40 hrs after decoupling (upto 2 am) (next day)
T9 → 48 hrs after decoupling (upto 10 am)

Calculation of fecundity: Twenty replications were maintained of each treatment and females were allowed to deposit the eggs. Periodicity of egg laying with different time duration were recorded. Eggs deposited by the female after 24 hrs of decoupling were considered as control. Eggs laid by each female were recorded replication wise for all the treatments as mentioned above. Data obtained were statistically analyzed for calculating the fecundity at different time duration.

Results

The present study was undertaken to know the rate of oviposition (Fecundity) with time duration of elite bivoltine races viz. CSR-3, CSR-6, CSR-16 and CSR-17. The results obtained in different races of different treatments are given in Tables 1-4.

CSR-3

Data on fecundity at different time duration is given in Table 1. The average fecundity of CSR-3 was recorded 539 after 24 hrs of oviposition (T6), which was considered as control. Total 336 eggs were laid in 4 hrs after oviposition (T1). This formed 62.33% of the total eggs laid upto 24 hrs after oviposition. The average fecundity of T2 was 442, followed by T3 (502), T4 (518) and T5 (528). An increase of 106 (19.67%) numbers of eggs in T2 from T1 and 60 (11.13%) numbers of eggs in T3 from T2 was found respectively. About 82% eggs were laid in eight hrs after the moths were decoupled and placed for egg laying. Around 93.13% of eggs were laid within 12 hrs after oiviposition. In the remaining 12 hrs 37 (6.87%) numbers of eggs were laid. An average of 16 (2.88%), 30 (5.56%) and 45 (8.34%) numbers of more eggs than control were laid in T7 (555), T8 (569) and T9 (584), respectively (Table 1).

CSR-6

Periodicity of egg laying with different time duration is given in Table 2. Twenty four hrs after decoupling was considered as control (T6). The average fecundity of CSR-6 was recorded 501 after 24 hrs of oviposition (T6-control). After 4 hrs of decoupling (T1) 309 eggs were laid. This formed 61.67% of the total eggs laid upto 24 hrs after oviposition. The average fecundity of T2 was 410,

Table 1. Deposition of eggs with time duration in CSR-3 race of *B. mori*

Treatments	Eggs laid upto mean number	Each treatment mean percent (%)	Eggs laid between each treatment	
			Mean number	Mean percent (%)
T1	336	62.33	336	62.33
T2	442	82	106	19.63
T3	502	93.13	60	11.13
T4	518	96.10	16	2.97
T5	528	97.95	10	1.85
T6	539	100	11	2.05
T7	555	2.88% more than control	16	2.88
T8	569	5.56% more than control	14	2.68
T9	584	8.34% more than control	15	2.78

C.D. at 5%: 17.89, C.D. at 1%: 22.89

Table 2. Deposition of eggs with time duration in CSR-6 race of *B. mori*

Treatments	Eggs laid upto mean number	Each treatment mean percent (%)	Eggs laid between each treatment	
			Mean number	Mean percent (%)
T1	309	61.67	309	61.67
T2	410	81.83	101	20.16
T3	455	90.81	45	8.98
T4	487	97.20	32	6.39
T5	498	99.40	11	2.20
T6	501	100	3	0.60
T7	520	3.79% more than control	19	3.79
T8	540	7.78% more than control	20	3.99
T9	551	9.98% more than control	11	2.20

C.D. at 5%: 19.46, C.D. at 1%: 24.32

followed by T3 (455), T4 (487) and T5 (498). An increase of 101 (20.16%) numbers of eggs in T2 from T1 and 45 (8.98%) numbers of eggs in T3 from T2 was found respectively. The results indicated that 81.83, 90.81 and 97.20% eggs were laid within 8, 12, 16 hrs of oviposition. An average of 14 (2.80%) numbers of more eggs were laid in the remaining 8 hrs. An average of 19 (3.795), 39 (7.78%) and 50 (9.98%) numbers of more eggs than control were laid in T7 (520), T8 (540) and T9 (551), respectively (Table 2).

CSR-16

Periodicity of egg laying with different time duration is given in Table 3. The average fecundity of CSR-16 was recorded 496 after 24 hrs of oviposition (T6), which was considered as control. Total 310 eggs were laid in 4 hrs after oviposition (T1). This formed 62.50% of the total eggs laid upto 24 hrs after oviposition. The average fecundity of T2 was 413, followed by T3 (445), T4 (480) and T5 (490). An increase of 103 (20.76%) numbers of more eggs in T2 from T1 and 32 (6.45%) numbers of more eggs in T3 from T2 was found respectively. Result indicated that 83.26% eggs were laid in eight hours after decoupling. Around 89.71% of eggs were laid within 12 hrs after oviposition as compared to control i.e. eggs laid upto 24 hrs. An average of 96.77% eggs were laid within 16 hrs of oviposition. An average of 16 (3.23%) numbers of eggs were laid in the remaining 8 hrs. An average of 8 (1.61%), 23 (4.63%) and 41 (8.26%) numbers of more eggs than control were laid in T7 (504) T8 (519) and T9 (537) respectively (Table 3).

CSR-17

Data on fecundity at different time duration is given in Table 4. The average fecundity of CSR-17 was recorded 542 after 24 hrs of oviposition (T6), which was considered as control. Total 343 eggs were laid in 4 hrs after oviposition (T1). This formed 63.28% of the total eggs laid upto 24 hrs after oviposition. The average fecundity of T2 was 465, followed by T3 (505), T4 (519) and T5 (529).

Table 3. Deposition of eggs with time duration in CSR-16 race of *B. mori*

Treatments	Eggs laid upto mean number	Each treatment mean percent (%)	Eggs laid between each treatment	
			Mean number	Mean percent (%)
T1	310	62.50	310	62.50
T2	413	83.26	103	20.76
T3	445	89.71	32	6.45
T4	480	96.77	35	7.06
T5	490	98.79	10	2.02
T6	496	100	6	1.21
T7	504	1.61% more than control	8	1.61
T8	519	4.63% more than control	15	3.02
T9	537	8.26% more than control	18	3.63

C.D. at 5%: 18.79, C.D. at 1%: 23.44

Table 4. Deposition of eggs with time duration in CSR-17 race of *B. mori*

Treatments	Eggs laid upto mean number	Each treatment mean percent (%)	Eggs laid between each treatment	
			Mean number	Mean percent (%)
T1	343	63.28	343	63.28
T2	465	85.79	122	22.51
T3	505	93.17	40	7.38
T4	519	95.75	14	2.58
T5	529	97.60	10	1.85
T6	542	100	13	2.40
T7	556	2.51% more than control	14	2.51
T8	571	5.35% more than control	15	2.84
T9	587	8.30% more than control	16	2.95

C.D. at 5%: 16.52, C.D. at 1%: 20.77

An increase of 122 (22.51%) numbers of more eggs in T2 from T1 and 40 (7.38%) numbers of more eggs in T3 from T2 was found respectively. The results indicate that 85. 79 and 93.17% eggs were laid in 8 and 12 hrs after decoupling as compared to control i.e. eggs laid upto 24 hrs. Around 95.75% eggs were laid within 16 hrs of oviposition. An average of 23 (4.25%) numbers of more eggs were laid in the remaining 8 hrs and 14 (2.51%), 29 (5.35%) and 45 (8.30%) numbers of more eggs than control were recorded in T7 (556), T8 (571) and T9 (587) respectively (Table 4).

Discussion

Kovalev (1960) reported that in *B. mori* majority of eggs are laid between 12 noon and 3 pm during the day time and 9 pm to 3 am during night time. Krishnaswami *et al.* (1973) observed that the moths usually laid eggs from the afternoon onwards and reach the peak of oviposition by 6 pm to 10 pm. By next morning majority of the eggs will be laid. Jameka e*t al.* (1976) and Yamaoka *et al.* (1976) informed that the first peak of egg laying in *B. mori* female moth was observed before and after every dusk, and the second ones were between every midnight and dawn. While conducting present experiment it was observed that pattern of egg laying of *B. mori* was more or less controlled by circadian rhythm. In case of each races periodicity of egg laying with different time duration were recorded. Egg deposition by female 24 hrs after decoupling was considered as control. The results obtained from different treatments and races are presented in Tables 1-4. Although the average fecundity of CSR-17 and CSR-3 after 24 hrs of oviposition is recorded 542 and 539 and 48 hrs of oviposition 587 and 584, varied significantly with the average fecundity of CSR-6 and CSR-16 after 24 hrs of oviposition 501 and 496 and 48 hrs after oviposition 551 and 537 respectively, but there is no significant differences between the periodicity of egg laying between the races.

Number of eggs laid by CSR-3, CSR-6, CSR-16 and CSR-17 within 4 hrs after oviposition (T1) were 336, 309, 310 and 343 (Tables 1-4). This formed 62.33, 61.67, 62.50 and 63.28% of the total eggs laid upto 24 hrs (control). Our results clearly indicate that the oviposition rate is in peak during the first 4 hrs after decoupling and are similar to the observations of Wang (1988) who reported the rate of oviposition is in peak during the first four hrs at 26-30°C. According to Trag *et al.* (1988) egg deposition commenced immediately when the moths were placed on egg cards and maximum number of eggs were laid in the first 4 hrs after of oviposition and which formed 51.07% of total eggs laid upto 24 hrs. Rajanna *et al* (1996) observed that 58-74% of the eggs were laid in different races during the first 4 hrs. Our results are also in confirmity with the above observations as delivery of eggs was recorded upto 63% within 4 hrs after decoupling in all the races. However, these results are at variance with the observation made by Jameka *et al.* (1976) and Yamaoka *et al.* (1976) who reported a dual peak in ovipositional rhythm.

The present investtigation indicates that 442, 410, 413 and 465 numbers of eggs were laid within 8 hrs after decoupling (T2) in CSR-3, CSR-6, CSR-16 and CSR-17 respectively (Tables 1-4). Which formed 82, 81.83, 83.26 and 85.79% of total eggs laid upto 24 hrs (control). This also indicates a significant increase of 106 (19.63%), 101 (20.16%), 103 (20.76%) and 122 (22.51%) ($P < 0.01$) numbers of more eggs in T2 from T1 in all the races respectively (Tables 1-4). Similar results have also been reported by Krishnaswami *et al.* (1973), Narasimhanna (1988), Trag *et al.* (1988) and Rajanna *et al.* (1996). Krishnaswami *et al.* (1973) and Narasimhanna (1988) further stated that maximum numbers of eggs were laid between 6-8 hr after decoupling. Trag *et al.* (1988) reported that 78.14% of eggs were laid in first 8 hrs after decoupling as compare to total eggs laid upto 24 hrs. Rajanna (1996) observed that more than 80% of eggs were laid within 8 hrs after decoupling. In this present experiment moths were decoupled and kept for oviposition at 10 am and it was found that 8 hrs after oviposition *i.e.* from 10 am to 6 pm most of the eggs (highest 85.79% in CSR-17 and lowest 81.83% in CSR-6) were laid. Manjula (1993) who also reported that in tropical condition first peak was noticed between 10 am to 2 pm (within 4 hrs) and the second peak from 2 p.m. to 6 p.m. (within 8 hrs) and confirms our findings as similar trend was observed in present experiment.

The present investigation has shown that 502, 455, 445 and 505 numbers of eggs were laid within 12 hrs (T3) after decoupling in case of CSR-3, CSR-6, CSR-16 and CSR-17 races, respectively (Tables 1-4). This formed 93.13, 90.81, 89.71 and 93.17% of total eggs laid upto 24 hrs (control). This shows a significant increase of 60 (11.13%), 45 (8.98%), 32 (6.45) and 40 (7.38%) ($P < 0.01$) numbers of more eggs in T3 as compared to T2 in all the races, respectively (Tables 1-4). Almost similar observation was made by Ullal and Narasimhanna (1981) who also observed that most of the eggs in *B. mori* laid 12 hrs after oviposition. Gowda and Jolly (1988) also reported that 84.8, 87.6, 84.9 and 87.2% of eggs were laid within 12 hrs after decoupling in case of multivoltine *i.e.* PM and HM race and bivoltine *i.e.*, NB7 race and NB18 race of *B. mori* respectively. Trag *et al.* (1988) stated that 89.53% of eggs were laid within 12 hrs of oviposition as compare to total egg laid upto 24 hrs. This also supports the findings of present experiment. Rajanna *et al.* (1996) observed that more than 90% of eggs were laid within 12 hrs after decoupling and confirms our findings.

The present experiment indicates that 518, 487,480, 519 numbers of eggs were laid within 16 hrs (T4) after decoupling in case of CSR-3, CSR-6, CSR-16 and CSR-17 races, respectively (Tables 1-4) which formed 96.10, 97.20, 96.77 and 95.75% of total eggs laid upto 24 hrs (control). A significant increase of 32 (6.45%) and 35 (7.06%) ($P < 0.01$) numbers of more eggs were found in T4 from T3 in case of CSR-6 and CSR-16 races respectively but in case of CSR-3 and CSR-17 races only 16 (2.97%) and 14 (2.58%) ($P > 0.05$) numbers of more eggs were found in T4 from T3 (Tables 1-4). Rajanna (1996) who reported that 90 – 95% of eggs were deposited and Trag *et al.* (1988) who reported 98.23% eggs were laid within 16 hrs after decoupling as compare to total egg laid upto 24 hrs are similar to our findings where 95.75 to 97.20% eggs were deposited after 16 hrs of oviposition.

The present study reveals that only 21 (3.90%), 14 (2.80%), 16 (3.23%) and 23 (4.25%) numbers of eggs were laid between 16 to 24 hrs (T4 to T6) (T1 to T4) which is similar to the investigation of Trag *et al.* (1988) who recorded only 1.77% eggs were laid between 16 to 24 hrs. The reason for this can be attributed that due to continuous egg laying, the female moths get exhausted.

The present investigation showed that a significant increase of 45 (8.34%), 50 (9.98%), 41(8.26%) and 45 (8.30%) ($P < 0.01$) numbers of more eggs were found between 24 to 48 hrs (T6 to T9) in CSR-3, CSR-6, CSR-16 and CSR-17 races respectively (Tables 1-4). Similar observation was also made by Kovalev (1960) who observed that 85% of the eggs were laid in first 24 hrs in *B. mori.* Trag *et al.* (1988) also informed that about 9% of eggs were laid between 24 to 48 hrs, which confirms our findings. The findings of present investigation is very important for sericulture industry while producing layings keep for different hibernation schedule especially for autumn/late autumn crop, female may be allowed for prolonged oviposition to get 8 – 10% more fecundity and

farmer may fetch 8 – 10 kg more cocoon yield/100 dfls with more profit margin.

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