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Effects of photoperiod on the development of hide beetle, *Dermestes maculatus* DeGeer (Coleoptera: Dermestidae)

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Abstract
Three different photoperiodic regimes, 24h light (LL), 24h dark (DD) and 12h light: 12h dark (LD) were used to assess the development of hide beetle, *Dermestes maculates* in dried kachki fish. The pre-oviposition period, incubation period, total larval period and pupal period lasted for 5.6, 3.5, 19.7 and 5.2 days, respectively at LL regime which were significantly longer compared with the period of 3.7, 2.5, 14.0 and 4.2 days for DD and 4.0, 2.3, 14.1 and 4.1 days respectively for LD photo phase. While oviposition period was shorter (35.0 days) in LL than in DD (41.8) and LD (42.4 days). Total developmental period (egg to adult emergence) was 28.4 days at LL regime and reduced to 20.5 days and 20.7 at LD and DD regime respectively. The fecundity was highest (503.83) in LD, intermediated (430.50) in DD and lowest (215.17) was recorded in LL photophase. Hatchability was found significantly highest in LD (69.2%) and DD (68.4%) compared with LL (54.8%). Survival rate of eggs, larvae and pupae were also highest in LD and DD regime than in LL regime. Adults were long lived at LD photophase (male-171.0 days and female-74.3 days) and DD (male-141.3 days and female-72.9 days) than LL photophase (male-102.6 days and female-47.5 days). These results revealed that continuous photophase (LL) is not suitable for the development and reproduction of *D. maculatus.* It may suggest that continuous light condition (LL) is better than DD and LD photoperiodic regime to suppress *D. maculates* infestation in stored dried fish.

Keywords: Photoperiod, development, *Dermestes maculatus,* fecundity, longevity

1. Introduction

Dry fish is often a good alternative to fresh fish which in many places is scarcely available and it is a very rich source of good quality protein which can be produced fairly and inexpensively [1]. Out of 1.2 million tones of annual production of fish in Bangladesh, 15% of fish is either dried for off-season consumption as low cost dietary protein of mass people or export from Bangladesh [2]. During storage, transportation and marketing, dried fish is readily attacked by several species of insects viz. *Dermestes maculatus*, *D. frischii*, *D. ater* and *Necrobia rufipes* [3]. *Dermestes* spp. and *N. rufipes* were major pests of smoked fish [4]. About 50% losses occur during the storage of smoked fish products due to deterioration by insects [5, 6]. In Bangladesh, *D. maculatus* and *N. rufipes* are generally associated with dried fish deterioration especially during its storage, transportation and marketing stages. They eat away the muscles leaving the skeletons when dry fish are stored for long periods leading to reduction in the amount of nutrients and both quantitative and qualitative losses resulting to declining consumer acceptability and market prices. Farmers usually using insecticide to suppress/control dry fish pests in storage which may have serious health risks. Therefore, it is desirable that such practices used to replace by alternative control method, which ensure effective management of *D. maculates* in stored dried fish. In this regard photoperiod could be a better alternative to the management of *D. maculates* in stored dried fish because photoperiod influences insect biology and behavior. Insects react in several ways to photoperiod and have an absolute requirement for light (periodism, intensity, quality) in order to sustain proper development and reproduction. The scope of the biological activities controlled by photoperiod has been reviewed [7, 8]. Photoperiod and light intensity, in conjunction with temperature changes are known to influence a number of features in the life cycle of stored insects [9].

In addition, other workers have demonstrated that the photoperiod can exert effects on other fundamental aspects of insect's biology and physiology [10]. There is little information regarding the effects of photoperiod on the post embryonic growth and development of *D. maculatus* DeGeer (Coleoptera: Dermestidae) in Bangladesh. This study was conducted to evaluate the effect of photoperiod in the life cycle of *D. maculatus* in dried fish in the laboratory under three photoperiodic conditions at constant temperature with the aim of understanding the biology of the pest for effective and efficient management measures against losses caused by this pest in stored dried fish.

2. Materials and Methods

2.1 Collection and mass culture of *D. maculates*

Adult *D. maculatus* were obtained from the laboratory colonies maintained in Radiation Entomology and Acarology Division, Institute of Food and Radiation Biology, AERE, Savar, Dhaka. Before starting the experiment newly emerged adults were maintained inside the incubators under three different controlled sets of photoperiodic regimes: 24 hours light (LL), 24 hours dark (DD) and 12 hours light-12 hours dark (LD) separately. Lights were put on at 6 AM local time in three different incubators (Sanyo) set at constant 28±2^{0}C temperature and 65±5% relative humidity. Photo phase was obtained by installing a 20W white tube light source in the incubator connected with an external timer. Temperature and humidity were monitored by a fisher brand traceable relative humidity meter with temperature readout. The intensity of illumination for the photo phase was measured as 150-200 lux using a digital lux meter (L×101). The experimental insects those were maintained under continuous dark were handled under red light. F_1 adults emerged from each photoperiodic condition were used for further experiments. Throughout the experiment the insects were maintained on a diet of dried Kachki fish (*Corica soborna* Hamilton). Food and oviposition substrates were substituted every second day to avoid fungal growth.

2.2 Effects of photoperiod on the developmental stages of *D. maculatus*

To determine whether photoperiod affected the reproductive parameters of *D. maculatus*, the beetles were separated into males and females from each photoperiodic condition within 24 hours of emergence. Newly emerged males and females were then paired and copulated in Petri dish (110mm X 15mm). Each pair was provided with 0.5041 g of dried kachki fish as food and a drinking wick was also added. They were kept at three different photoperiodic regimes. Folded black cotton cloths were provided in each Petri dish for egg laying and were monitored once daily for the presence of eggs using hand lens and any egg seen was counted and removed. The duration of different developmental stages of the beetle were carefully recorded under three photoperiod's viz. LL, DD and LD at constant temperature and humidity mentioned above.

Mortality of both larvae and pupae in each photoperiodic condition were also recorded. The entire experiment was replicated 10 times for each photoperiodic regime.

2.3 Data analysis

All data were subjected to analysis of variance (ANOVA) followed by the Tukey HSD test to determine statistical differences. The differences were considered significant when $P<0.05$. All data represented as mean ± SD and n represents the number of replications.

3. Results

3.1 Fecundity and hatchibility of *D. maculatus*

The highest 503.83±80.06 eggs laid per female were recorded within 30 days oviposition period and their hatchibility was 69.2% in LD regime, followed by 430.50± 28.13 eggs laid and hatchibility was 68.4% by DD regime. The mean total number of eggs laid per female was 215.17± 33.87 and hatchibility was 54.8% at LL photoperiodic regime which was significantly lower than LD and DD regime ($P>0.05$, df =2, 15; F=48.53) (Table 1).

Table 1: Effects of photoperiod on fecundity and fertility of *D. maculatus* at different photoperiodic regime

Photoperiodic regimes	Fecundity (mean ±SD)	Hatchability (%)
LD (12h light :12h dark)	503.83±80.06a (n=6)	69.2%
DD (24 h dark)	430.50± 28.13a (n=6)	68.4%
LL (24 h light)	215.17± 33.87b (n=6)	54.8%

Vertical means followed by the same letter are not significantly different at the 5% level ($P>0.05$).

3.2 Developmental period of *D. maculates* at three different photoperiodic regimes

3.2.1 Pre-Oviposition period

The time between the date of adult emergence and the first egg deposition was considered as pre-oviposition period. The pre-oviposition period was shorter in DD (3.7±0.48 days) and LD (4.0±0.47 days) regime but it was longer in LL (5.6±0.84 days) regime (Table 2). The differences in pre-oviposition period among the photoperiodic regimes were found to be significant ($P<0.05$, df=2, 27; F=26.82).

3.2.2 Oviposition Period

The oviposition period of *D. maculates* was 42.4±4.22 days at LD, 41.8±3.33 at DD and 35.0±5.50 days at LL photoperiodic condition. Statistical analysis of mean oviposition period was significantly not different ($P<0.05$, df=2, 27; F=8.57) between LD and DD regime but the oviposition period of both (LD and DD) regime was significantly different from LL regime. (Table 2).

3.2.3 Incubation Period

The mean incubation period was 3.50±0.85 days in LL regime on the other hand 2.50±0.53 days and 2.30±0.48 days was in DD and LD regime, respectively. The incubation period was more or less similar in LD and DD photophase and that was less than LL photophase. Results also found the incubation period by LL regime was significantly different from other (LL and DD) photoperiodic regimes ($p<0.05$, df=2, 27; F=10.05).

3.2.4 Larval Period

There were 6 larval instars of *D. maculatus* at all photoperiodic regime. The mean duration of the total larval period was recorded highest 19.7±1.16 days in LL and the least duration 14.1±0.74 days and 14.0±0.82 days was recorded when placed in LD and DD photoperiodic regime. The variation of total larval period at LL and other two photoperiodic regime was significant but there was no significant difference in total larval periods in LD and DD ($p<0.05$, df=2, 27; F=124.94) (Table 2).

3.2.5 Pupal Period

Pupal period was shortest at LD (4.1±0.32 days) and DD (4.2±0.42 days) regime but it was longest (5.2±0.42 days) at LL regime. The variation was significant ($p<0.05$, df=2, 27; F=24.36). (Table 2).

3.2.6 Total Developmental Period
The total developmental period was longest (28.4±1.65 days) in LL regime and shortest in LD regime (20.5±.97 days) and DD regime (20.7± 0.82 days). This difference was statistically significant (p<0.05, df=2, 27; F=140.46) (Table 2).

Table 2: Effects of photoperiod on the developmental period of *D. maculatus* at different photoperiodic regimes

Photoperiodic regimes	Mean duration of developmental stage in days (mean±sd)					
	Pre oviposition period	Oviposition period	Incubation period	Larval period	Pupal period	Total developmental period (Egg-adult emergence)
LD	4.0±0.47a	42.4±4.22a	2.30±0.48a	14.1±0.74a	4.1±0.32a	20.5±.97a
DD	3.7±0.48a	41.8±3.33a	2.50±0.53a	14.0±0.82a	4.2±0.42a	20.7± 0.82a
LL	5.6±0.84b	35.0±5.50b	3.50±0.85b	19.7±1.16b	5.2±0.42b	28.4±1.65b

Means represent values from 10 replicates. Vertical means followed by the same letter are not significantly different at the 5% level (P>0.05).

3.2.7 Survival rate of eggs, larvae and pupae
The mean survival rate of the different developmental stages (egg, larvae and pupae) of *D. maculates* was significantly highest at LD and DD photoperiodic regime and significantly lowest survival rate of all developmental stages was recorded in LL regime (Table 3).

Table 3: Mean number of survival of the egg, larval and pupal stage of *D. maculates* at different photoperiodic regimes

Photoperiodic regimes	Number survived at different developmental stages (mean±sd)			
	No. of eggs treated	Number of eggs hatching	Number of larvae developing to pupae	Number of pupa emerging as adult
LD (12L:12D)	50	34.6±1.17a	29.3±0.95a	28.7±0.67a
DD (24D)	50	34.2±0.79a	29.4±0.84a	29.0±0.67a
LL (24L)	50	27.4±1.43b	20.3±1.77b	19.0±1.83b

Means represent values from 10 replicates. Vertical means followed by the same letter are not significantly different at the 5% level (P>0.05).

3.2.8 Adult longevity and pupal weight
Pupal weight was highest in DD regime (0.045±0.01) and it was lowest in LL (0.036±0.01) regime and the variation was significant (p<0.05, df=2, 27; F=7.84) (Table 4). There was no significant difference in pupal weight among LD and DD regime. The longevity of adult beetles was counted from the emergence of the adults to their death. Photoperiod was found to affect longevity of *D. maculatus* females (p<0.05, df=2, 27; F=5.54). The highest female longevity (74.3 days) occurred with LD condition, compared with longevity of 47.5 days with LL condition (Table-4). However, there was no significant difference in longevity among LD and DD photoperiodic regime. Similarly male longevity was highest (171.0 days) in LD regime and lowest (102.6 days) in LL regime and the difference was significant ((p<0.05, df=2, 27; F=9.55).

Table 4: Mean longevity and pupal weight (g) of *D. maculatus* on different photoperiodic regime at 28±2 ^{0}C

Photoperiodic regimes	Longevity (days)		Pupal weight (g)
	Male	Female	
LD	171.0±43.89 a	74.3±23.59 a	0.041±0.00 a
DD	141.3±33.71 a	72.9±19.92 a	0.045±0.01 a
LL	102.6±25.12 b	47.5±16.65 b	0.036±0.01 b

Means represent values from 10 replicates. Vertical means followed by the same letter are not significantly different at the 5% level (P>0.05).

3.2.9 Egg laying pattern of *D. maculates* at three photoperiodic conditions
Eggs laid at each photoperiodic regime were gradually increased in number during the first week and maximum egg laying was found in second week at all the photoperiodic regimes and subsequently declined with time. In first week, average 95.67±4.96 (18.14%) eggs were laid at LD regime while 116.83±7.20 (26.22%) and only 55.0±1.31 (23.66%) eggs were laid in DD and LL photoperiodic regime respectively. Maximum egg laying periods were recorded at second week; average 146.83±3.91 (27.87%) eggs were laid at LD regime while 130.00±2.63 (29.18%) and 62.83±1.99 (27.02%) eggs were laid at DD and LL respectively by second week. In contrast, minimum egg laying period recorded at all photoperiodic regimes was fifth week that was 37.17±2.87 (7.05%) eggs were laid at LD regime while average 19.83±2.32 (4.45%) and 16.50±0.62 (8.00%) eggs were laid at DD and LL respectively (Fig. 1).

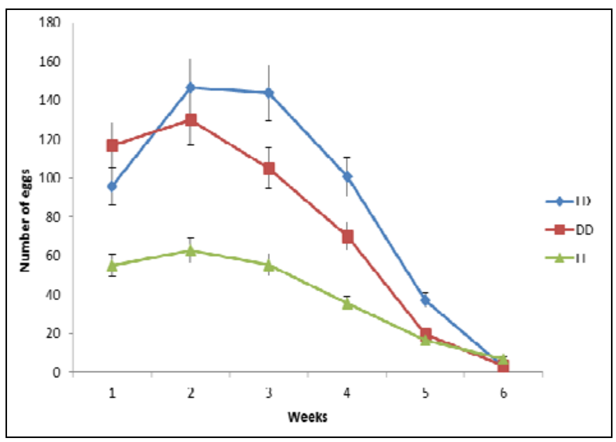

Fig 1: Egg laying pattern of *D. maculates* at three photoperiodic conditions (Values are mean±SD, n=6).

4. Discussion

The present findings revealed that the fecundity within 30 days was highest in LD regime, intermediate in DD and lowest in LL regime. Hatchibility was also significantly lower in LL than LD and DD. Significant decrease in fecundity and hatchibility under continuous light suggested that continuous light disrupts the rhythm of reproductive biology of *D. maculatus* which is regulated by internal biological clock. Fecundity and hatchibility in LD and DD were not significantly different because biological clocks have the ability to entrain by the LD and it free runs in continuous dark. Similar results have shown of lesser meal worm, *Alphitobius diaperinus*, where their fecundity was significantly highest in LD regime and lowest in LL photoperiodic regime [11]. Fecundity of *Oryzaephilus mercator* was highest in the LD regime followed by LL and this difference was not significant [12]. In *Tribolium castaneum* fecundity decreased considerably under continuous light [13]. In Boll Weevil, *Anthonomus grandis grandis* life time fecundity was significantly highest at 12- and 14-h photophase, lowest at 0- and 10-h photophase and intermediate at 24 h of light [14]. Photoperiod has no effect on root-feeding flea beetle *Longitarsus bethae* [15]. But most other reports indicate highest fecundity at long photoperiods [16, 17, 18]. Present study showed the larval period and pupal period of *D. maculates* was significantly shortest in LD and longest in LL condition. Continuous light probably created a restless situation for the insect population that consumed food more slowly, resulting in a significantly longer larval period. This study also showed the longevity of *D. maculatus* male (171.0 days) and female (74.3 days) in LD condition was longer than the LL condition (for male 102.6 days and for female 47.5 days). It is indicating that the biological clock system of *D. maculatus* worked most efficiently with LD photoperiodic regime and continuous light (LL) exerted physiological stress which reduced its longevity. Photoperiod influences longevity of *Drosophila melanogaster* (Meigen) (Diptera: Drosophilidae) [19]. [20] Reported that the photoperiod affects the longevity of *Orius thyestes.* Photoperiod commonly affects insect's development time [21, 22, 23]. The present study revealed that egg to adult development periods were shortest in the LD regime, intermediate in the DD regime and longest in the LL regime agreed with the findings [24]. The peak egg laying period of *D. maculates* was found to be second week at all the photoperiodic regimes but subsequently there was reduction in numbers as the days progress and insect got older. This egg laying pattern agrees with the results of Ezenwaji and Obay [24]. From these results it may be concluded that longer developmental time is probably due to continuous light which created a restless population that consumed food more slowly, resulting a significantly longer developmental period.

The knowledge of photoperiod dependent population growth potential may provide new insight into *Dermestes maculatus* population dynamics to develop better sampling protocols and timing of control measure application. It may therefore be advisable to store products not susceptible to *D. maculatus* infestation in continuous light condition.

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