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Lighting in Dark Periods Reduced the Fecundity of *Spodoptera frugiperda* and Limited Its Population Growth

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Abstract: Light is a crucial environmental factor implicated in the temporal regulation of important biological events of insects, and some insects are usually sexually active in dark periods. However, the effects of light during dark periods on the growth, development, and fecundity of *Spodoptera frugiperda*, an important agricultural pest, remain unknown. In this study, we evaluated the effects of lighting in dark periods on the biological parameters of *S. frugiperda* in laboratory conditions. Our results showed that lighting in dark periods significantly prolonged the pre-adult stage and reduced the pupal survival and emergence rate. Moreover, the results indicated that the adult stage is the photoperiod-sensitive stage of *S. frugiperda*, and the fecundity and longevity of adults significantly reduced under lighting in dark periods, and the number of eggs per female moth decreased by 99% compared with the control. The mean generation time (T) of *S. frugiperda* population was the longest, and the intrinsic rate of natural increase (r) and finite rate of increase (λ) were the smallest under lighting in dark periods, and the population growth of *S. frugiperda* was significantly limited. Our findings may provide valuable insights to develop effective integrated pest management strategies to control *S. frugiperda*.

Keywords: *Spodoptera frugiperda*; light; dark periods; fecundity; population dynamics

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1. Introduction

Crop pathogens and pests cause severe crop yield reduction in agricultural systems and result in substantial economic losses worldwide [1]. Crop pests are responsible for up to 40% yield losses annually around the world, with an estimated value of $70 billion in lost production [2]. Currently, invasive species have gained considerable attention, especially invasive pests, seriously threatening crop productivity and global food security [3]. Invasive pests reduce the yield and quality of agricultural production by undermining the stability of local food systems [1]. At the same time, international trade activities and worldwide travel mean that crop pests could travel farther and faster [4]. Therefore, effective control and management of invasive pests is one of the important challenges to safeguard global food security.

Spodoptera frugiperda (Lepidoptera, Noctuidae), known as the fall armyworm, one of the most destructive insect pests in the world [5], can feed on 353 different kinds of plants belonging to 76 plant families, including major food crops such as wheat, rice, corn, and sorghum [4,6]. *S. frugiperda* is a small moth native to tropical and subtropical regions of the

Americas, which has been widely spread around the world due to its ability to migrate over long distances [7]. Maize is the preferred host for the invasion of *S. frugiperda* [8]. Since *S. frugiperda* successfully invaded China through long-distance migration from Myanmar in 2018, it has caused a serious reduction in maize production, posing a serious threat to maize production and food security of China [9]. Recently, the Food and Agriculture Organization (FAO) of the United Nations released The Global Action for Fall Armyworm Control to ensure coordinated cooperation at national, regional, and global levels to take strong measures for effective management and control of the pest [4]. Common control options for *S. frugiperda* include chemical [10,11], biological [12,13], physicochemical traps [14,15] and agronomic options [16,17]. However, due to large-scale use of insecticides, *S. frugiperda* has developed resistance to most insecticides [18,19]. Biological control and physicochemical traps are effective ways to achieve green and sustainable control [20]. Among them, the physicochemical traps mainly used the chemotaxis and phototaxis of *S. frugiperda* to trap-and-kill larvae and adults [21]. Light traps are one of the important means to predict and control Lepidoptera, and have been widely used in *Helicoverpa armigera* populations monitoring [22,23].

Light is an important ecological factor, which is of great significance to the growth and development, tropism behavior and population reproduction of insects [24,25]. For example, Hori et al. [26] reported that the eggs, larvae, pupae, and adults of *Drosophila melanogaster* died under the radiation of short-wavelengths visible light, with the highest lethality under the blue light. Artificial light at night affected the endocrine, reproductive, and neural development of *Aquatica ficta* firefly larvae, and the mortality rate of *A. ficta* larvae increased after two weeks of artificial light at night. [27]. The circadian clock system is closely related to the day-night alternation and is commonly observed in insects [28]. The light requirement of insects usually depends on their life stages and biological characteristics [29]. A day is commonly divided into two phases in studies of the effects of photoperiod on insects, namely the photophase (light periods) and scotophase (dark periods) [30]. The scotophase is the active phases of reproductive behavior of Noctuidae [31], and the reproductive behaviors such as female calling, male courtship and mating of *S. frugiperda* are also active in scotophase [32]. For some species of insects, illumination in the scotophase prolongs the pre-oviposition period and reduces the number of mating and egg production [33]. *S. frugiperda* adults could rapidly enter a light-adapted state after light stimuli in a dark environment [34]. Meng et al. [35] reported that under the photoperiods of 16L:8D, the shortest larval duration and pre-oviposition duration of *S. frugiperda* were observed, and the intrinsic rate of natural increase and finite rate of increase both were higher. Chen et al. [36] also found that compared with the other four photoperiods, egg hatching rate of *S. frugiperda* was the highest under photoperiods of 16L:8D, and the longer the timing of light exposure, the higher the pupal eclosion rate. These studies mainly focused on the effects of different photoperiods, especially the light-dark ratio on *S. frugiperda*, and not enough attention was paid to the light in the scotophase. Lighting in dark periods interferes with the reproductive behavior of some insects [37], and we hypothesized that lighting in the dark periods would reduce the fecundity of *S. frugiperda* and thus limit its population development. A recent report analyzed the phototactic responses of *S. frugiperda* from the molecular level, and explicitly point out that light traps could be used for the control of *S. frugiperda* [38]. However, to our knowledge, control and management of *S. frugiperda* by using light in scotophase has not been reported to date. Therefore, it is necessary to clarify the impacts of light in scotophase on the growth, development, and reproduction of *S. frugiperda*, to provide insights for the control and management strategies of *S. frugiperda*.

In this study, we assessed the effects of lighting in dark periods on the biological parameters of *S. frugiperda* in laboratory conditions. The objectives of this study were (1) to clarify the effects of light in dark periods on the growth, development, and fecundity of *S. frugiperda*, (2) to determine the changes in the life-table parameters of *S. frugiperda* populations and predict population dynamics. Our results may provide valuable insights to develop effective integrated pest management strategies to control *S. frugiperda*.

2. Materials and Methods

2.1. Insect's Source and Rearing

The larvae of *S. frugiperda* was collected from maize plants in Yangjiang City, Guangdong Province, China, and raised for multiple generations in an incubator (RDZ-300D-4W, Ningbo Jiangnan Instrument Factory, Ningbo, China) for experiments. Larvae of *S. frugiperda* were fed on an artificial diet that changed daily until pupation, and the component and preparation of the artificial diet referred to Su et al. [39]. After emergence, adults were fed 15% honey water through a daily refreshed cotton ball. *S. frugiperda* was maintained at 27 ± 1 °C and 85 ± 10% relative humidity (RH) under a 14L:10D photoperiod, and the light intensity was 3000 lx.

2.2. Experimental Design

In this study, the experiment consisted of two sections. The first experiment was conducted to investigate the effects of different light regimes on the development and survival of the larvae of *S. frugiperda*, and included three treatments, LL, DD and CK. The second experiment was conducted to explore the influence of different light regimes on adult fecundity and longevity, and consisted of five treatments (LL, CK-L, CK, CK-D and DD). In the second experiment, the lifecycles of *S. frugiperda* were divided into egg-pupal stage and adult stage, and different photoperiods were set for the two stages. The treatment with a photoperiod of 14L:10D in both the egg-pupal stage and adult stage was set as a control (CK), and a total of five treatments were set up. The details of each treatment are presented in Table 1. All the climatic incubators used in this study were the same as mentioned above.

Table 1. Different light regimes and their symbols.

Treatment	Photoperiod (L:D)		
	The First Experiment	The Second Experiment	
	Egg-Pupal Stage	From Egg-Pupal Stage	To Adult Stage
LL	24:0	24:0	24:0
CK-L	—	14:10	24:0
CK	14:10	14:10	14:10
CK-D	—	14:10	0:24
DD	0:24	0:24	0:24

LL, CK, and DD indicated that *Spodoptera frugiperda* completes its life history under photoperiods of 24:0, 14:10, and 0:24 L:D, respectively. CK-L and CK-D indicated that the egg-pupal stage of *Spodoptera frugiperda* is under 14:10 L:D photoperiod, while the adult stage is under 24:0 and 0:24 L:D photoperiods, respectively.

2.2.1. Development and Survival

There were three replicates in the LL, CK and DD treatments, with 100 larvae for each replicate, and the development duration and survival rate of *S. frugiperda* under the three treatments were recorded. The feeding technology and culture conditions for the larvae were the same as described above for each treatment, except for the difference in photoperiods.

Larvae were reared individually in a transparent Petri dish (1 cm in height, 5 cm in diameter) until pupal emergence. The time of pupation, emergence and death were observed and recorded daily, the duration of larvae, pupae and adults was noted, and the pupation, emergence, and daily survival rates were calculated. At the peak of pupation, 50 pupae were randomly selected from each treatment, and the weight and length of the pupae were measured on the day of pupation.

2.2.2. Adult Fecundity and Longevity

Once a larvae pupated, each pupa was independently loaded into a Petri dish. During the peak eclosion date of each treatment, the adults that emerged on the same day were paired in paper tubes, with a diameter of 8 cm and a height of 20 cm, and the internal volumes of the paper tube was 0.001 m^3. There were five treatments with three replicates, and 20 pairs for each replicate. Moths were randomly selected with an equal sex ratio of 20 males and 20 females for each replicate, and paired into paper tubes, survival and oviposition of adults were observed and documented daily until the female adults died. The white paper that the same material as the tube was used for oviposition substrates, and adults rearing, and culture conditions were same as mentioned above. If the male died in the paper tube but female still survived, another male from the same replicate was supplied to meet the need for female fecundity, but if the female died, it was considered to have finished breeding. When the female moth laid eggs in the paper tube, the eggs were carefully removed, and the number of egg masses and eggs were counted.

2.2.3. Life Table Parameters and Population Dynamics

According to the methods of Chi and Liu [40] and Chi [41], life table parameters of the experimental population were calculated, including the net reproductive rate (R_0), generation time (T), intrinsic natural growth rate (r) and finite growth rate (λ). TimingMSChart was used to predict the population dynamics of *S. frugiperda* population in the next 60 days. The calculation equations for the life table parameters are as follows:

$$l_x = \sum_{j=1}^{m} S_{xj} \tag{1}$$

$$m_x = \frac{\sum_{j=1}^{m} S_{xj} f_{xj}}{\sum_{j=1}^{m} S_{xj}} \tag{2}$$

$$\sum_{x=0}^{\infty} l_x m_x e^{-r(x+1)} = 1 \tag{3}$$

$$R_0 = \sum_{x=0}^{\infty} l_x m_x \tag{4}$$

$$T = \frac{lnR_0}{r} \tag{5}$$

$$\lambda = e^r \tag{6}$$

where x and m are the time interval in days (d) and the number of stages, respectively; S_{xj} is the survival rate of *S. frugiperda* from egg development to x days old and developmental stage j, l_x is the survival rate of *S. frugiperda* from egg to x days old, f_x is the age-specific fecundity at age x, m_x is the mean population fecundity from egg to x days old, and $l_x m_x$ is the product of l_x and m_x.

2.3. Statistical Analysis

All data were statistically analyzed by Microsoft Excel 2016 (Microsoft Corporation, Redmond, WA, USA) and SPSS software (SPSS 20.0, IBM, Armonk, NY, USA), and the data were analyzed using a one-way analysis of variance (one-way ANOVA) followed by

Duncans test. The Shapiro–Wilk test was used to test for data normality, and the Levene test was performed to test for homogeneity of variance. Post hoc test was performed by Dunnett test. The life table parameters were calculated by TWOSEX-MSChart, and the population dynamics were predicted by Timing-MSChart software (Version 2022.02.27) [42].

3. Results

3.1. Development and Survival

Constant light (LL, 24L:0D) greatly affected the growth and development of *S. frugiperda* (Table 2). For development duration, the egg-larval stage was significantly prolonged by 2.19 d (F = 468, df = 69.001, $p < 0.01$) under constant light compared with CK (14L:10D), and the pupal stage was remarkably shortened by 0.63 d, with longer and larger pupae which were observed in the LL treatment. Although there were significant differences in development duration under different light regimes, larval survival and pupation rate were not significantly different compared with CK. However, the emergence rate was affected by the constant light, which was reduced by 57.48% compared with CK, while constant darkness (DD, 0L:24D) was more conducive to pupation and emergence of *S. frugiperda* and had the highest pupation and emergence rates.

Table 2. Effects of lighting in dark periods on the growth and development of *Spodoptera frugiperda*.

Treatment	LL	CK	DD
Egg-larval stage (d)	18.99 ± 0.19 a	16.80 ± 0.08 b	17.31 ± 0.10 b
Pupal stage (d)	8.02 ± 0.14 c	8.65 ± 0.08 b	9.06 ± 0.07 a
Pre-adult stage (d)	23.44 ± 0.09 a	22.59 ± 0.09 b	23.42 ± 0.06 a
Pupal weight (g)			
Female	0.30 ± 0.01 a	0.25 ± 0.00 b	0.21 ± 0.00 c
Male	0.29 ± 0.00 a	0.23 ± 0.01 b	0.23 ± 0.01 b
Pupal length (mm)			
Female	18.31 ± 0.12 a	17.14 ± 0.14 b	16.36 ± 0.14 c
Male	18.47 ± 0.12 a	17.44 ± 0.19 b	17.22 ± 0.1 b
Pupation rate (%)	93.82 ± 0.68 b	96.40 ± 0.55 ab	97.07 ± 1.67 a
Pupal emergence rate (%)	31.31 ± 7.13 b	88.79 ± 2.85 a	94.53 ± 3.02 a

LL, CK, and DD indicated that *Spodoptera frugiperda* completes its life history under photoperiods of 24:0, 14:10, and 0:24 L:D, respectively. Data are mean ± standard errors (SE), and different lowercase letters in the same row indicate significant difference at $p < 0.05$ level by Duncan's new multiple range test.

3.2. Adult Fecundity and Longevity

Continuous light significantly decreased the fecundity and longevity of adult *S. frugiperda* (Table 3). Under the LL treatment and the treatment of lighting in the scotophase at the adult stage (CK-L), the number of eggs per female moth, oviposition days and oviposition probability were significantly lower than those of the other three treatments. The number of eggs per female moth under the LL and CK-L treatments decreased by 99% on average compared with CK (Table 3). There were significant differences in the number of eggs per female and oviposition days between CK-L and CK treatments, whereas no differences between LL and CK-L treatments were observed. Similar results were found among DD, CK-D and CK treatments, which indicated that the adult stage is the photoperiod-sensitive stage of *S. frugiperda*. Both the constant light and dark environments significantly reduced the number of eggs per female moth and oviposition days, but continuous light conditions (LL and CK-L) had a greater impact on adult fecundity. In addition, adult longevity significantly decreased under the lighting in scotophase, which reduced by 50% and 25% in LL and CK-L treatments compared with CK, respectively, while the dark environments (DD and CK-L) had no significant effects on adult longevity.

3.3. Life Table Parameters

Constant light greatly affected the life table parameters of *S. frugiperda* (Table 4). Compared with CK, the mean generation time was prolonged, and the net reproduction rate, intrinsic rate of increase, and finite rate of increase remarkably decreased under continuous light environments (LL and CK-L). Compared with CK, the mean generation time in the LL treatment increased by 4.44 days, and the net reproductive rate significantly decreased, which indicated that the population growth of *S. frugiperda* was reduced by 99% in the LL treatment. Life table parameters of *S. frugiperda* were also affected in continuous dark environments (DD and CK-D), but the influences were far less than that of continuous light environments (LL and CK-L).

Table 3. The fecundity and longevity of *Spodoptera frugiperda* in different light regimes.

Treatment	LL	CK-L	CK	CK-D	DD
Adult pre-oviposition period (d)	6.50 ± 0.29 ab	8.00 ± 1.00 a	3.27 ± 0.59 b	6.07 ± 0.69 ab	4.94 ± 0.57 ab
Total pre-oviposition period (d)	30.00 ± 0.00 a	30.00 ± 0.00 a	25.93 ± 0.59 a	28.64 ± 0.70 a	28.34 ± 0.58 a
Number of eggs per female moth	3.57 ± 1.80 c	5.90 ± 4.92 c	662.65 ± 70.02 a	310.43 ± 45.06 b	327.97 ± 59.73 b
Oviposition days (d)	0.07 ± 0.03 c	0.03 ± 0.02 c	2.72 ± 0.27 a	1.63 ± 0.20 b	1.45 ± 0.22 b
Oviposition probability (%)	6.67 ± 3.33 b	3.33 ± 3.33 b	83.33 ± 3.33 a	70.00 ± 10 a	63.33 ± 9.28 a
Female longevity (d)	6.67 ± 0.52 c	9.53 ± 0.32 b	12.79 ± 0.76 a	12.41 ± 0.46 a	11.51 ± 0.39 a
Male longevity (d)	6.22 ± 0.36 c	9.31 ± 0.25 b	11.77 ± 0.51 a	10.66 ± 2.79 a	10.64 ± 0.32 a

LL, CK, and DD indicated that *Spodoptera frugiperda* completes its life history under photoperiods of 24:0, 14:10, and 0:24 L:D, respectively. CK-L and CK-D indicated that the egg-pupal stage of *Spodoptera frugiperda* is under 14:10 L:D photoperiod, while the adult stage is under 24:0 and 0:24 L:D photoperiods, respectively. Data are mean ± standard errors (SE), and different lowercase letters in the same row indicate significant differences at $p < 0.05$ level by Duncan's new multiple range test.

Table 4. Population life table parameters for *Spodoptera frugiperda* in different light regimes.

Treatment	R_0	T (d)	r (d^{-1})	λ (d^{-1})
LL	2.33 ± 1.14 c	31.00± 0.00 a	0.0272 ± 0.0181 c	1.0276 ± 0.0184 c
CK-L	3.77 ± 2.97 c	30.35 ± 0.81 a	0.0437 ± 0.0277 c	1.0447 ± 0.0286 c
CK	268.68 ± 49.45 a	26.56 ± 0.34 c	0.2106 ± 0.0079 a	1.2344 ± 0.0097 a
CK-L	137.87 ± 29.88 b	28.51 ± 0.61 b	0.1728 ± 0.0100 b	1.1886 ± 0.0118 b
DD	189.74 ± 40.15 ab	27.92 ± 0.26 b	0.1879 ± 0.0088 ab	1.2067 ± 0.0105 ab

LL, CK, and DD indicated that *Spodoptera frugiperda* completes its life history under photoperiods of 24:0, 14:10, and 0:24 L:D, respectively. CK-L and CK-D indicated that the egg-pupal stage of *Spodoptera frugiperda* is under 14:10 L:D photoperiod, while the adult stage is under 24:0 and 0:24 L:D photoperiods, respectively. R_0, T, r and λ indicate net reproduction rate, mean generation time, intrinsic rate of increase and finite rate of increase, respectively. Data are mean ± standard errors (SE), and different lowercase letters in the same column indicate significant differences at $p < 0.05$ level by Duncan's new multiple range test.

3.4. Population Dynamics

With 10 eggs as the initial value, the Timing-MSChart software was used to predict the population dynamics of *S. frugiperda* in the next 60 days under different light regimes, based on our life table parameters (Figure 1). The results indicated that the population growth of *S. frugiperda* was not obvious, and the population was only 10 after 60 days in continuous light conditions (LL and CK-L). However, the populations in the CK and continuous dark environments (DD and CK-D) increased rapidly, and the number of individuals in the populations increased from 10 to more than 100 thousand after 60 days. These results demonstrated that the lighting in scotophase had a significant inhibition effect on the population growth of *S. frugiperda*.

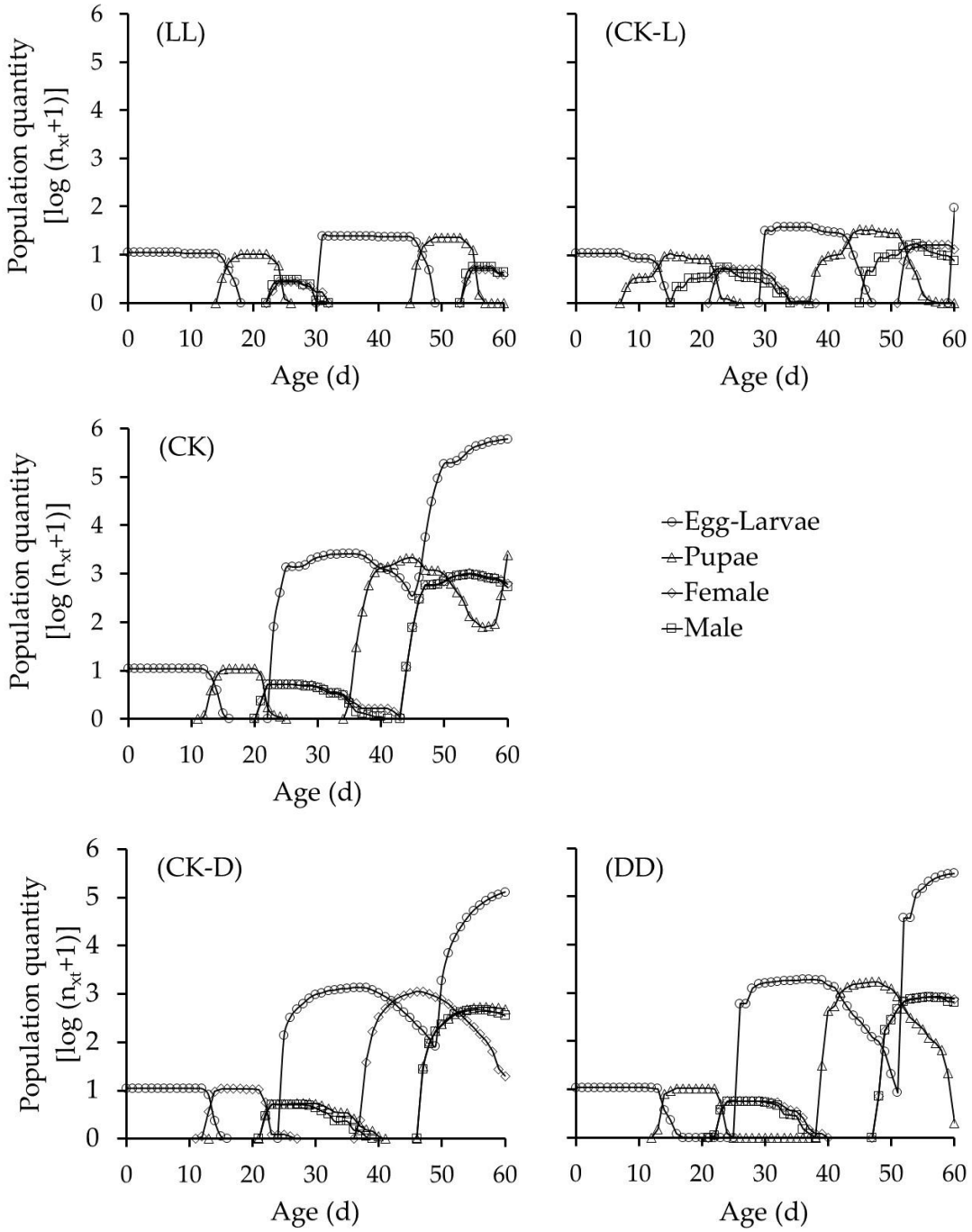


Figure 1. Population dynamics of *Spodoptera frugiperda* under different light regimes. LL, CK, and DD indicated that *Spodoptera frugiperda* completes its life history under photoperiods of 24:0, 14:10, and 0:24 L:D, respectively. CK-L and CK-D indicated that the egg-pupal stage of *Spodoptera frugiperda* is under 14:10 L:D photoperiod, while the adult stage is under 24:0 and 0:24 L:D photoperiods, respectively.

4. Discussion

The reproduction behavior of *S. frugiperda* is commonly active in dark periods, understanding the influences of light on *S. frugiperda* during dark periods is of great significance for using light traps to monitor and manage the pest. In present study, we evaluated the effects of lighting in dark periods on the growth, development, and reproduction of *S. frugiperda*.

Light is a crucial environmental factor that synchronizes endogenous rhythms with the circadian cycle, which is implicated in temporal regulation of important biological events such as egg hatching, adult eclosion and development, diapause, and mating [28,43,44]. Our study demonstrated that photoperiod significantly affected the developmental progression of *S. frugiperda*, which is consistent with previous findings [35,36]. Compared with CK treatment (14L:10D), the egg-larvae and the pre-adult stage were prolonged in both all-light (24L:0D, LL) and all-dark photoperiodic condition (0L:24D, DD), but the pupae in the all-light condition were larger and longer than those in all-dark condition. This may be related to the fact that larvae have more time for feeding and growth in light conditions. The development rate of insects is directly affected by photoperiod, which is mainly attributable to the variation in daily activity duration [45]. Hormonal imbalances caused by different photoperiods may lead to changes in the duration of development in some insects, as indicated by Cymborowski and Giebułtowicz [46]. In nature, insects survive in an impending harsh environment by altering the development rate of their larvae in response to the seasonal shift in photoperiod [47,48]. For example, the larvae of *Aedes albopictus* accelerated their development and reduced body size to adapt the seasonal time constraints in a short photoperiod [49]. However, the influences of photoperiod on the development duration of insect are not always consistent, and the direction mainly depends on the biological characteristics of species. For example, *Telenomus remus* had the fastest development rate with the shortest average generation time under 24L: 0D photoperiod [50], while *Sclerodermus pupariae* developed faster in a short-day condition [51]. Although the significant difference existed in larval development duration of *S. frugiperda* among different light regimes, larval survival and pupation rate had no significant differences. However, the constant light significantly impacted the survival and emergence of the pupae, and the emergence rate was greatly reduced by the constant light treatment, while the highest emergence rate was found in the constant darkness condition, and the result is closely related to the biological characteristics of the larva pupation and emergence in the soil under natural conditions, because they usually spend the pupal period at 2–8 cm in the soil [52].

We further explored the response of *S. frugiperda* at different developmental stages to photoperiod, and the results showed that the adult stage is the photoperiod-sensitive stage of *S. frugiperda*. The constant light (LL) or constant light at adult stage (CK-L) had a negative impact on the fecundity and adult longevity of *S. frugiperda*, but the constant light (LL) has a greater impact. Compared with the control, the number of eggs per female adult in the constant light or the constant light at adult stage (CK-L) decreased by 99%, while those in the constant darkness or the constant darkness at adult stage (CK-D) decreased by more than 50%. Similar results have been reported in the study of other insects, Velarde et al. [53] illustrated that the adult stage of *Galerucella calmariensis* L is its photoperiod-sensitive stage, and the larval and pupal exposure to long-day or short-day conditions has no effect on adult ovariole development. However, the individuals which completed their lifecycle in a short photoperiod, had smaller ovaries and few developed eggs, and the photoperiod regulated oogenesis via neuroendocrine system [53,54]. *S. frugiperda* are always sexually active in dark periods, and the mate attraction of *S. frugiperda* is mediated by a species-specific sex pheromone, which is the product of endogenous rhythm regulation and is affected by the length and intensity of light during dark periods [5,29]. When the female of *Ephestia kuehniella* mated with the male raised in the constant light, its fecundity significantly decreased compared with the control [46], and the reason for that is continuous light influence on the eupyrene sperm production [55]. Furthermore, our results indicated that the longevity of adults under constant light was significantly shortened. Generally, the physiology of many insects is mainly prepared for reproduction when they are exposed to a long-day condition [56]. For *Aedes triseriatus*, the signals at the end of the season would cause a shift in terminal investment, which changed from the investment in lifespan and future reproduction to the current reproduction, even at the cost of shortening the adult lifespan [57], and this may explain the shortened longevity of

the adults of *S. frugiperda* under constant light (LL and CK-L). The life table parameters showed that the longest mean generation time and the smallest r and λ for the experimental population were attained under the constant light treatment (LL). Population dynamics were predicted by Timing-MSChart software, and the results suggested that population growth of *S. frugiperda* was effectively inhibited under constant light.

Light is the most important environmental factor for plant growth and development [58]. The application of the technology of supplementary light at night by using light-emitting diodes (LEDs) as light sources in horticultural crop production practices has been increasing in recent years [59,60]. *S. frugiperda* is a polyphagous pest that can feed on more than 353 plant species, including some important horticultural crops such as strawberry, tomato, vine grape and watermelon [6]. Understanding the effects of lighting in dark periods on the growth, development, and reproduction of *S. frugiperda* will help to continuously monitor and manage the invasive pest in controlled cultivation in the future. However, there are large differences in light quality, duration, and intensity in the production practice of supplementing light at night for controlled cultivation. Therefore, these factors should be fully taken into account when future studies on the effect of lighting in dark period on *S. frugiperda* are conducted.

5. Conclusions

We conclude that lighting in dark periods reduced the fecundity of and limited the population growth. Pupal survival and emergence rate were significantly reduced; the adult stage is the photoperiod-sensitive stage of *S. frugiperda*, and the fecundity and longevity of adults significantly reduced under lighting in dark periods. The life table parameters and population dynamics prediction suggested that the mean generation time of *S. frugiperda* population was the longest, and the r and λ were the smallest under lighting in dark periods, and the population growth of *S. frugiperda* was significantly inhibited. Our findings suggested that lighting in dark periods could be used to control *S. frugiperda*., which may provide valuable insights into the control of *S. frugiperda* and the development of integrated pest management strategies.

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