



Effect of LED Illumination on the Biological Habits of the Adults of *Ectropis grisescens*

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ABSTRACT

The effects of illumination of four LED wavelengths (440–450 nm, 460–465 nm, 600–605 nm and 490–495 nm) on egg quantity, oviposition rate and adult longevity of *Ectropis grisescens* Warren were investigated in laboratory. The results showed that the total egg quantity, oviposition rate and adult longevity were all affected. The egg number every female adult of *E. grisescens* Warren was reduced 37.36%, 26.17%, 41.88% and 35.11% contrast to the control. The average oviposition rate reduced 16.61%, 11.44%, 11.81% and 8.86% respectively with the supply of four wave lengths at night. Meanwhile, the pre-oviposition period and oviposition period were affected by the four illumination deals of wave lengths. The longevity of male and female adult was decreased, and the male adult was longer than that of female adult under each treatment of *E. grisescens* Warren. The eclosion rate of four deals were affected respectively. The purpose was screen out the best spectrum possible by study the effect of spectral treatment on biological habit of *E. grisescens* Warren. The results provide a scientific basis for the use of phototaxis to the integrated management of *E. grisescens* Warren.

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Authors' Contribution

SG designed the study. LQ wrote the paper and analyzed the data. SG and QZ collected the data. FZ provided guidance and ideas. JC provided the material support.

Key words

Spectrum, *Ectropis grisescens* Warren, Egg quantity, Oviposition rate, Adult longevity.

INTRODUCTION

Ectropis grisescens Warren is one of the most serious pests in tea garden, belongs to the Lepidoptera, Geometridae, which seriously affects the quality and yield of tea leaves (Qiao *et al.*, 2020; Zhang *et al.*, 2019; Wang *et al.*, 2018; Ma *et al.*, 2016). The frequent and large amount use of pesticides in production not only causes drug resistance, but also causes pesticide residues, which affects the quality of tea (Zhang *et al.*, 2019; Luo *et al.*, 2018), therefore, it is of great significance to find safe and effective control methods for tea production.

Light trapping is an environmental and effective prevention for control measures. Lighting can disturb the normal growth rhythm of insects, interfere with their mating, oviposition, normal growth and development, or use insect's response to a certain light source, drive them out of the tea garden, reduce the amount of eggs laid in the field, reduce the cost of prevention, thus providing a new idea for pest control (Wang *et al.*, 2020; Liu *et al.*, 2019; Sang *et al.*, 2018). It is reported that insects have strong tendency towards short-wave light or long-wave light (Duan *et al.*, 2009, 2010; Jiang *et al.*, 2008). The test results showed that 505, 540 and 589 nm of illumination

could prolong the oviposition period of the *Spodoptera exigua* (Hubner), and 505 and 590 nm illumination could also prolong the early oviposition period of the *Plutella xylostella* (Linnaeus) and shorten their oviposition period, and 505 and 590 nm illumination could also prolong the oviposition period of the *Helicoverpa armigera* Hubner (Chen *et al.*, 2016; Lin *et al.*, 2007). When the wavelength was 560 nm, the phototaxis of *Drosophila melanogaster* was strong. The light wavelength of 520–523 nm and 465–467 nm could affect the growth, development and reproduction of insects (Tu *et al.*, 2014). Yang and Yang have found that red light had the most obvious effect on larval growth, and blue light had the most obvious effect on pupal and eclosion stage (Yang and Yang, 2014). The LED dual-spectrum solar insecticidal lamp composed of violet light and blue light has the most trapping capacity to the *Ectropis grisescens* in the 380–400 nm band (Tu *et al.*, 2019). Some studies have also shown that the spectrum range of 350, 348 and 452 nm is the best for the trapping and killing *Ectropis grisescens* (Wang *et al.*, 2018). In recent years, there have been many reports about the biological habit and the regularity of outbreak of *Ectropis grisescens*, and some reports are about the phototaxis and sexual attractants, but there are no reports about the influence of LED spectrum on the growth of adult *Ectropis grisescens*.

In this study, lights of different wavelength were used to test the biological characteristics of *Ectropis grisescens*

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under treatment of blue light at 440~450 nm, 460~465 nm, orange light at 600~605 nm, and ice indigo light at 490~495 nm, a total of 4 different wavelengths, the adult *Ectropis grisescens* mortality, egg hatching rate, single female oviposition amount and adult *Ectropis grisescens* life, *etc.*, providing reference for the effective utilization of spectrum in pest control of *Ectropis grisescens*.

MATERIALS AND METHODS

Insect source

The source of *Ectropis grisescens* was captured from the tea garden (N32°, W114°) in Baimiao Village, Shihegang Township. Then were fed with fresh tea leaves in artificial climate room, feeding environment was at temperature of 22~26°C, relative humidity was 60~70%, photoperiod was 12L: 12D.

Main equipment

The main equipment used in this study are listed below: RTOP-310Y artificial climate box (Zhejiang Topu Yunnong Science and Technology Co., Ltd.). PM6612 digital photometer (Shenzhen Huayi Science and Technology Co., Ltd.). Insect cage (50 cm×50 cm×60 cm). Insect cage cover (acrylic transparent round tube with 50 mesh white gauze at the top and a petri dish with a diameter of 9 cm at the bottom, height of 20 cm). Light treatment device (40 cm × 30 cm × 40 cm by length, width and height; light intensity: 50~100 lx).

Light sources

The color and wavelength of the light source are blue light at 440~450 nm, 460~465 nm, orange light at 600~605 nm and ice indigo light at 490~495 nm, respectively.

Test methods

After mating the female and male adults of the newly-emerged *Ectropis grisescens*, placed them in the insect cover, one pair per cover. The treatment group was given 12 h (7: 00~19: 00) ordinary fluorescent light (150~200 lx)

during the day, and 440~450 nm, 460~465 nm, 600~605 nm of orange light or 490~495 nm of ice indigo light at night for 12 h (19: 00~7: 00 the following day) in the treatment unit. The light conditions of control group were as follows: 12 h of normal fluorescent light during the day, and 12 h of darkness at night. Each treatment for 10 pairs of adult *Ectropis grisescens*, repeat 3 times. Add 10% honey water to supplement insect nutrition at regular intervals. Observe the number of eggs laid by the female and the life span of the adult until all the adults die. At the same time, during the 3rd day to the 5th day, select 50 eggs randomly on each day, repeated 3 times, calculate the hatchability of eggs. In addition, collect 20 female and 20 male pupae (start to collect from pre-pupal period, then treat them by male and female, respectively), which were treated under light source for 12 h every night, and under ordinary fluorescent light source for 12 h during day. Record the number of pupae, repeated 3 times.

Data analysis

The data was processed using Excel 2010 software and SPSS 16.0 (SPSS Inc., Chicago, IL). F test was performed for the significant difference between treatments, and Tukey's test for multiple analysis.

RESULTS

Effect of LED lights on egg-laying

Under the treatment of 4 lights of different wavelengths, the single female oviposition amount of the adult *Ectropis grisescens* was significantly lower than that of natural light feeding (Table I). Compared with the control group, the total amount of oviposition decreased by 37.62% (2568) and maximum decrease of single female oviposition was 41.88%. The difference was significant, and other treatment group were significantly different from the control group. The following treatments were 460~465 nm, with significant differences from other treatments; 440~450 nm and 600~605 nm were significantly different from other treatments; the total oviposition and single

Table I.- Effects of different wavelength spectra of LED light on oviposition of *E. grisescens* adult.

Treatment	Total spawned/ granule	Single female spawning/granule	Highest egg production/granule	Spawning rate (%)	Preoviposition period (d)	Spawning time (d)
440~450 nm	4590.00 ± 155.88 ^c	306.00 ± 10.39 ^c	589	73.73	2.93 ± 0.18 ^a	3.63 ± 0.24 ^{bc}
460~465 nm	5410.00 ± 177.97 ^b	360.66 ± 11.86 ^b	699	86.67	2.16 ± 0.23 ^b	4.03 ± 0.13 ^b
490~495 nm	4259.00 ± 120.67 ^d	283.93 ± 8.05 ^d	390	93.00	2.76 ± 0.09 ^a	3.43 ± 0.09 ^c
600~605 nm	4754.67 ± 144.64 ^c	316.98 ± 9.64 ^c	403	95.00	1.83 ± 0.23 ^{bc}	4.56 ± 0.15 ^b
CK	6827.33 ± 163.54 ^a	488.49 ± 10.90 ^a	780	100.00	1.59 ± 0.36 ^c	6.48 ± 0.74 ^a

Different small letters following the data in a column indicate significant differences among 0.05 treatments, the same letter indicates no significant difference among treatments (the values in the table are mean ± standard error, the same below).

female oviposition at 490~495 nm were the lowest. The highest oviposition of single female was the control group, and that of other treatments were all decreased, and their oviposition rate were all lower than that of control, with a maximum decrease value of 26.27%, light treatment led to some adults not oviposit. Spectral treatment prolongs the early oviposition period. Except at 600~605 nm treatment, there were significant difference between the four kinds of spectral treatment groups and the control group. The oviposition period under four kinds of spectral treatments were shortened obviously, and the longest shortening time was 3.05 days, and the difference was significant.

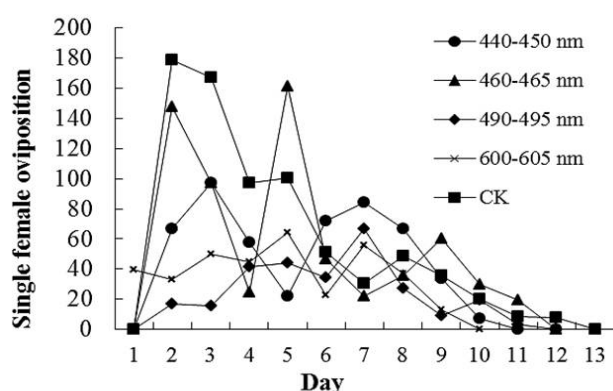


Fig. 1. Effects of LED light of different wavelengths on oviposition of *E. grisescens* adult.

Four kinds of LED spectra all have a certain influence on the spawning dynamics of the adult *Ectropis grisescens* (Fig. 1). First, the total amount of each treatment was significantly lower than that of control group. Secondly, the peak time of oviposition was the same as that of control group (460~465 nm) or delayed (440~450 nm and 465~465 nm), appeared on the 3rd and 5th day, respectively. The peak time of treatment at 490~495 nm d 600~605 nm, was not obvious, appeared on the 7th and the 5th day, respectively. The average maximum oviposition of single female was 179 (CK), followed by 161 (460~650 nm), and 98 (440~450 nm). The overall trend showed that the oviposition peak period was during the 2nd day to 7th day, then decreased gradually. The oviposition period of female adults treated at 460~465 nm and 490~495 nm was 11 days, only less than control group (12 days). The oviposition period of female adults treated at 600~605 nm was the shortest.

Effect of LED lights on egg incubation rate

Figure 2 showed the illumination with LED lights of different wavelength treatments have great influence on hatching rate of *Ectropis grisescens* eggs. The hatching rate

of control group was the highest, and significantly different from other treatment groups. The difference between treatments at 460~465 nm, 490~495 nm and 600~605 nm was the same. The difference between treatments at 440~450 nm and 600~605 nm was significant, and the others have no difference. Compared with the control group, the hatching rate of eggs decreased by 16.61%, 11.44%, 11.81% and 8.86%, respectively.

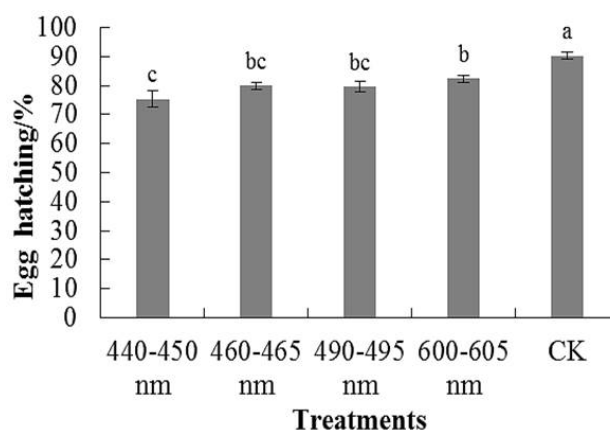


Fig. 2. Effects of LED light of different wavelengths on egg hatching rate of *E. grisescens*.

Table II.- Effects of LED light of different wavelengths on adult longevity of *E. grisescens* adult.

Treatment	Male (d)	Female (d)
440~450 nm	6.83±0.18 ^c	6.67±0.29 ^b
460~465 nm	7.47±0.27 ^{bc}	7.27±0.18 ^a
490~495 nm	7.86±0.52 ^b	6.73±0.56 ^b
600~605 nm	7.30±0.10 ^{bc}	6.59±0.25 ^b
CK	9.16±0.33 ^a	7.73±0.18 ^a

Influence of LED lights on the life of adult

As can be seen from Table II, the life span of male and female adult *Ectropis grisescens* decreased under 4 kinds of spectral treatments, and the difference of male adults between in treatment group and that in control group was significant. Except for treatment of female adults at 460~465 nm with no difference from control group, and the other treatment trends were at the same level. The life span of male adults under each treatment was higher than that of female adults. The life span of female and male adults was reduced by 1.06 days and 2.33 days, respectively under 440~450 nm treatments, and reduced by 0.46 days and 1.69 days under 460~465 nm treatments, reduced by 1 days and 1.3 days under 490~495 nm treatments, respectively. Female and male adults reduced

by 1.14 days and 1.86 days under 600~605 nm treatments compared with control group. Thus, the life span of female and male adults was decreased in certain degree under 4 kinds of spectral treatments.

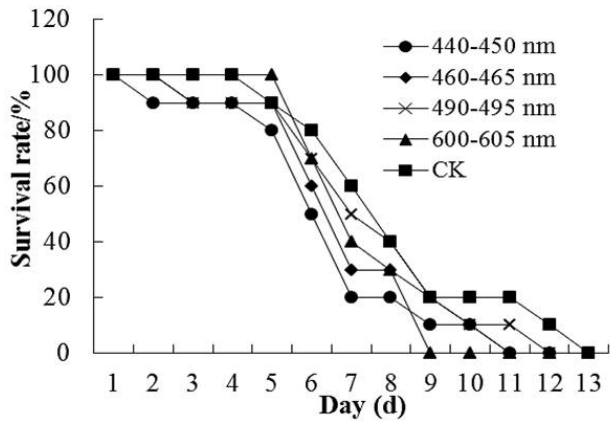


Fig. 3. Effects of LED light of different wavelengths on female adult survival rate of *E. grisescens* adult.

From Figure 3, we can see that spectral treatment has certain effect on the survival rate of female adult, and the survival rate of 6th day decreased obviously. The life span of the female adult was the longest in control group, followed by 490~495 nm, and the maximum life span of the adult was 11 days, but the maximum life span of the adult was 8 days under 600~605 nm treatment and more affected by spectrum. The maximum life span under 440~45 nm and 460~465 nm treatment were both 10 days. The survival rates of all treatments were decreased with time. The survival rate of the adult under four kind spectrums treatments was basically the same as those in control group (Fig. 4). The survival rate of adults under 440~450 nm and 600~605 nm treatment was 13 d, and the life of other treatments was 12 d as control group. The survival rates of adults in different stages under 4 kinds of spectra were interacted with each other.

Effect of LED lights on eclosion rate of adult

It can be seen from Figure 5 that all the 4 kinds of spectrum treatment have influence on the eclosion rate of adults, and the control group is the highest, which is significantly different from other treatments. The eclosion rate under 490~495 nm treatment is the lowest, except the difference is the same as that under 440~450 nm treatment is significantly different from other treatment groups. The difference of eclosion rate under the other 3 kinds of spectrum treatment was at the same level.

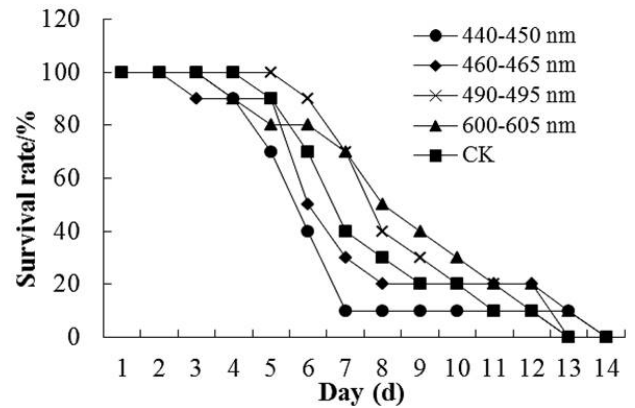


Fig. 4. Effects of LED light of different wavelengths on male adult survival rate of *E. grisescens* adult.

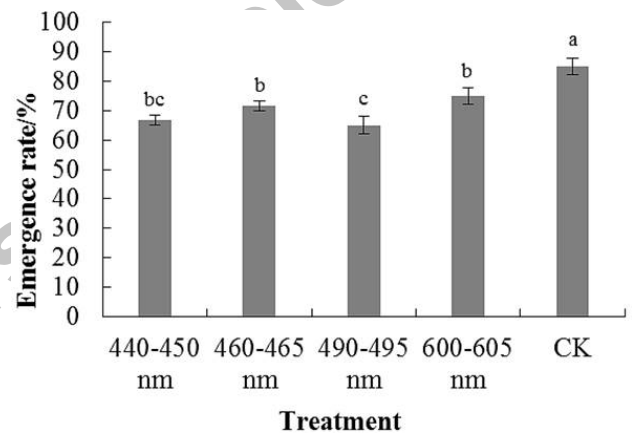


Fig. 5. Effects of LED light of different wavelengths on emergence rate of *E. grisescens* adult.

DISCUSSION

Light is an important influencing factor in insect's life and activity. Lights of different colors can cause some changes in insect's taxis behavior and affect the growth and reproduction ability of some insects (Zhang *et al.*, 2018). Under the environment of promoting ecological agriculture and organic planting, using light source to prevent and control pests is the trend of development (Wang *et al.*, 2018).

In this study, under the treatment of 4 spectra at 440~450 nm, 460~465 nm, 490~495 nm and 600~605 nm, the oviposition amount of the *Ectropis grisescens* decreased by 32.77%, 20.76%, 37.62% and 30.36%, respectively. The oviposition rate decreased obviously, the oviposition period was shortened, and the difference was significant from that of control group. In addition, all the four kinds of spectra had an effect on the oviposition

dynamics of the adults, and the peak time of oviposition was from 2nd - 7th day, and the spawning period was obviously shortened compared with control group. Previous studies on the effect of yellow light on the reproduction of *Plutella xylostella* showed that the oviposition amount decreased and the oviposition period was shortened (Duan *et al.*, 2007). In this paper, compared with the control group, the hatching rate decreased, which is consistent with the previous studies. In the four spectral treatments, the lifespan of both male and female *Ectropis griseescens* was reduced. Under the treatment at 440~450 nm, the lifespan of both male and female *Ectropis griseescens* reduced by 1.06 days and 2.33 days, respectively, reduced by 0.46 days and 1.69 days under the treatment at 460~465 nm, reduced by 1.0 days and 1.3 days under the treatment at 490~495 nm, reduced by 1.14 days and 1.86 days under the treatment at 600~605 nm, respectively. Thus it can be seen the survival rate of the female was decreasing with time, and the male's survival rate appeared alternately at different stages. At the same time, the spectral treatment had a certain effect on eclosion rate of adult, and eclosion rate was the lowest under treatment at 490~495 nm, except the same difference as treatment at 440~450 nm, was significantly different from that of other treatments. The results showed that treatment at 490~495 nm had a great influence on the eclosion rate of the adults.

In this study, we used insect phototaxis to interfere with their fertility rhythm so as to control their population, and finally reduce the incidence of the next generation of larvae to below the amount which causing economic losses, and improve the yield, quality and ecological environment of tea garden. At present, most of the trapping lamps used in production are mixed continuous light sources, which can achieve better results in pest monitoring and trapping, but also cause some harm to non-target insects such as natural enemies (Tu *et al.*, 2014). Therefore, it is of great practical significance to design and develop special lamps according to the specific sensitive spectrum of pest occurrence.

CONCLUSION

In conclusion, this study showed that light at 440~450 nm, 460~465 nm, 600~605 nm and 490~495 nm had different effects on the parameters of *Ectropis griseescens* including oviposition prophase, average oviposition period, single female oviposition rate, hatching rate and life span. Providing light in the tea garden from 7: 00 p.m. to 7: 00 a.m. in the next morning before the eclosion of *Ectropis griseescens* adults could effectively interfere the population development and provide reference for green prevention and control technology of tea garden.

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Ethical compliance

There are no researches conducted on animals or humans.

Statement of conflict of interest

The authors have declared no conflict of interests.

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