Effect of spectrum on biological habit of *Scopula subpunctaria* Herrich-Schaeffer

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**Abstract.** This study aims to screen out the best spectrum possible by study the effect of spectral treatment on biological habit of *Scopula subpunctaria* Herrich-Schaeffer, and provided a reference for the integrated management of *S. subpunctaria*. Total 6 groups (90) of adult *S. subpunctaria*, 9 groups (450) of eggs, 3 groups (300) of pupae, treated with continuous light treatment under room condition from 7:00 pm to 7:00 am every day at 370-375 nm or 420-425 nm, respectively, the control group (45 adult *S. subpunctaria*) without light treatment. The spawning amount and longevity of adults, the hatching rate of eggs and the eclosion rate of pupae in each group were recorded. The results showed that the total egg quantity and oviposition rate had been effected significantly under illumination treatments. The egg number in every female adult reduced 28.9 and 53.5% under 370~375 nm and 420~425 nm illumination, respectively, compared with the control group, and showed a significant difference level; while the average oviposition rate reduced 11.10 and 15.90% respectively. Meanwhile, the pre-oviposition period and oviposition period were affected by the two illumination treatments. There was no significant effect on the adult longevity of *S. subpunctaria* nor adult longevity in group feeding nor paired feeding conditions. The egg quantity in groups feeding was higher than that in pairs, and 420–425 nm was reached a significant level contrast to the control deal. The spectral treatments of 370~375 nm and 420~425 nm have effects on the biological parameters of *S. subpunctaria*, and the latter has significant effects. In conclusion, the light sources can be provided in the tea garden at night (from 7:00 pm to 7:00 am) before the emergence of the adult *S. subpunctaria* to interfere its population development.

1. Introduction

*Scopula subpunctaria* Herrich-Schaeffer, belongs to Lepidoptera, Geometridae. It is one of the main injurious pests in the tea tree [1], whose larve feed on the young leaves and form C-shaped notches. In serious cases, they can eat the whole tea leave, leaving only the main vein [2, 3]. At present, except for a small amount of organic tea gardens, most of pest control in tea gardens uses chemical pesticides, which lead to the increase of insect’s resistance to drugs, pesticide residues also seriously influences tea quality [4, 5]. Therefore, it is of great practical significance to study the new methods of pest control in tea gardens.

It provides a new way for pest control that making use of insect's phototaxis/photophobia to trap, kill and drive the adults by light, or interfere with their development rhythm, to reduce the amount of...
eggs laid in the field and avoid the occurrence of a large quantities of them [6-8]. Insects have a strong tendency towards both short and long wave light [9-12]. Within the range of 340–605 nm spectrum, Frankliniella occidentalis (Pergande) showed phototaxis to 380 nm, 440 nm and 498–524 nm wavelengths [13]. Within the range of 340–605 nm spectrum, the phototaxis of adult Athetis lepigone (Moschler) was higher, and the phototaxis to 360 nm ultraviolet light was the strongest [14]. The LED bispctrum solar insecticidal lamp composed of purple light and blue light has the most trapping effect on the Ectropis grisescens Warren in the 380–400 nm band [15]. Some studies have also shown that the trapping effect of 350 nm, 348 nm and 452 nm in the spectrum is the best [16].

However, there is no relevant study on the influence of spectrum on the biological habits of the adults of Scopula subpunctaria. In this paper, the effects of 370–375 nm or 420–425 nm treatments on the biological habits of the adults of Scopula subpunctaria were studied by means of photoethological method, which provided a theoretical basis for the research and development of the spectrum with high selectivity and high interference efficiency.

2. Materials and methods

2.1. Insect source and breeding

Scopula subpunctaria source come from the tea garden (N32°, W114°) in Baimiao village, Shihekong Township are adult worms after 3 generations fed of fresh leaves in artificial climate room, The breeding environment is that the temperature was 22~26 ℃, the relative humidity was 60~70% and photoperiod was, 12 L: 12 D.

2.2. Equipment and light source

RTOP-310Y type artificial climate box (Zhejiang Topu Yunnong Science and Technology Co., Ltd.); PM6612 digital photometer (Shenzhen Huayi Science and Technology Co., Ltd.); Insect feeding cage (50 cm×50 cm×60 cm), used for Scopula subpunctaria’s eclosion and spawning; Photoreaction device (self-made 2.3). The color and wavelength of the light source are 370–375 nm and 420–425 nm respectively.

2.3. Test methods

Mate the female and male adults of the Scopula subpunctaria which just finished eclosion, then place them in the insect-keeping cover (acrylic transparent round tube, 50 mesh at the top, 9 cm diameter petri dish at the bottom, 8 cm in diameter and 20 cm in height), one pair for each cover. The treatment group was given normal fluorescent light (150–200 lx) for 12 hours (7:00~19:00) during the day and continuous illumination (370–375 nm or 420–425 nm at night) (the volume of photoreaction device is length×width×height=40 cm×30 cm×40 cm; light intensity: 50~100 lx) for 12 hours (19:00~7:00 am). The light conditions of the control group were as follows: 12 hours of normal fluorescent light during the day, 12 hours of darkness at night. Each treatment 15 pairs of Scopula subpunctaria adults, repeat for 3 times. Add 10% honey water to supplement nutrition at regular intervals every day, and record the number of eggs laid by the female and the life span of the adult Scopula subpunctaria until all the adults die. At the same time collected, 50 eggs at random every day during the 3rd to the 5th days, and repeat for 3 times. Observe and record the number of eggs hatched. In addition, collect 50 male and 50 female pupae (collect at the pre-pupa period, then treat the female and male respectively after puation.) and treat them under the light source for 12 hours every night, and under ordinary fluorescent light for 12 hours during the day and record the number of pupae, repeat for 3 times.

2.4. Data processing

Using Excel 2010 software and SPSS 16.0 for data processing. F test was used for the significant difference between processing, and Tukey's test was used for the multiple analysis.
3. Results

3.1. The effect of different wavelength spectra on oviposition conditions of the Scopula subpunctaria

In the spectral treatments of 370–375 nm and 420–425 nm, the single female spawning amount of the adults was significantly lower than that of the natural light feeding (CK), and the amount of the female spawning decreased were 62(28.90%) and 133(53.50%) respectively, which was significantly different from that of the control (Table 1). From the oviposition rate, the oviposition rate of the control was up to 93.33%. Under two different wavelengths, the oviposition rate was obviously decreased, the photo-illumination treatment even made some adults do not lay eggs, which was significantly different from that of the control. The oviposition period of the adults was obviously prolonged for 7.67 days and 4.67 days respectively, which was significantly different from that of the control.

Table 1. Effects of wavelength spectra on oviposition of S. subpunctaria

| Treatment   | Total spawned* | Highest Single female spawning | Spawning rate (%) | Preoviposition period (d) | Spawning Time (d) |
|-------------|----------------|--------------------------------|-------------------|---------------------------|------------------|
| 370~375 nm  | 167.33±11.14 b | 189                            | 86.67             | 6.33±0.33 a               | 24.67±0.88 a     |
| 420~425 nm  | 109.33±5.93 c  | 118                            | 86.67             | 6.33±0.33 a               | 21.67±1.20 a     |
| CK          | 235.33±8.25 a  | 251                            | 93.33             | 3.33±0.33 b               | 17.00±0.58 b     |

*Note: 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).

In Fig. 1 it showed that both the two different wavelength spectra have certain effects on the oviposition dynamics of the adults. First, the total amount of oviposition was significantly lower than that of the control. Second, the peak period of oviposition was both delayed than that of the control. The peak periods of oviposition of the control group were mainly 3. The first peak appeared on the 9th day. The average single female oviposition amount was 72. The second peak appeared on the 2nd day and the amount of oviposition was 53. The third peak appeared on the 6th day and the number of oviposition was 41. After being treated with 370~375 nm, there were peak oviposition on the 14th day and the 16th day, the amount of oviposition was 42 and 34 respectively. The oviposition dynamic of 420~425 nm treatment showed that there was no obvious peak oviposition period, only during the 13th to the17th day, the amount of oviposition was consistent, the average single female oviposition amount was 14, and the difference between the two different wavelength treatments and the control was significant.

Figure 1. Effects of wavelength spectra on oviposition of S. subpunctaria
3.2. Effect of different wavelengths spectra on hatching rate of the Scopula subpunctaria

It can be seen from Fig. 2 that the hatchability of the eggs was influenced greatly when treated with different wavelengths. The hatchability of the eggs treated with control is the highest, 84%, which is significantly different from that of the other two treatments. The hatchability of the eggs treated with 370–375 nm is decreased by 11.10% (74.67%), while that of the eggs treated with 420–425 nm is decreased by 15.90% (70.67%). The hatchability of the eggs treated with 370–375 nm was more than 420–425 nm, and the variance analysis showed that the difference was at the same level.

Figure 2. Effects of wavelength spectra on egg hatching rate of S. subpunctaria

3.3. The influence of different wavelength spectra on the life span of the adult of the Scopula subpunctaria

From Table 2 we can see, the growth period of female and male adults was both over 20 days, and the generation cycle was long. The two wavelength spectral treatments had a significant effect on the life span of Scopula subpunctaria, compared with the control, the main effect was to prolong the growth period. Under the treatment of 370–375 nm and 420–425 nm, the significance of difference between male and female was at the same level, which were both significantly different from that of the control. The growth period of male adults was lengthened 6 days and 5 days, while that of female adults were 7 days d 4 days, respectively.

Table 2. Effects of wavelength spectra on adult longevity of S. subpunctaria

| Treatment   | Male (d) | Female (d) |
|-------------|----------|------------|
| 370–375 nm  | 27±0.58 a| 30±1.15 a  |
| 420–425 nm  | 26±1.15 a| 27±0.75 a  |
| CK          | 21±1.15 b| 23±1.06 b  |

As can be seen from Fig. 3 and Fig. 4, two wavelength spectral treatments reduced the survival rate of the adults of Scopula subpunctaria. The survival rate of both male and female adults was both lower than that of control. The survival rate decreasing of female adults treated with 420–425 nm was earlier than that treated with 370–375 nm. And its survival rate during 21th day to 15 day was higher than that treated with 370–375 nm while was the same at any other time. The survival rate of male adults treated with 370–375 nm decreased earlier than that treated with 420–425 nm and there was the no difference in the late stage.
3.4. **The influence of spectra on the population density of the adult inchworm of the Scopula subpunctaria**

3.4.1. **Effect of population density on life span of the Scopula subpunctaria.** Under the condition of constant spectrum, change the way of feeding, the life span of the adult was changed (Table 3). In the treatment of 370–375 nm, the life span of the female was significantly different between the two feeding conditions which mainly reflected in the prolonged growth period in group feeding. There was no difference in the growth period of males. Under 420–425 nm light, the growth period of male and female were both prolonged, but the difference was at the same level. The growth period of both males and females in the control group was prolonged, especially the difference of males was significant, but the difference of females was not significant. It can be seen that the way of feeding has certain influence on the life-span of the *Scopula subpunctaria*. 

*Figure 3.* Effects of wavelength spectra on female adult survival rate of *S. subpunctaria*

*Figure 4.* Effects of wavelength spectra on male adult survival rate of *S. subpunctaria*
Table 3. Effects of spectra on adult longevity of S. subpunctaria under different feeding manners

| Treatment  | Matched feeding | Group feeding |
|------------|-----------------|---------------|
|            | Female(d)       | Male(d)       | Female(d)       | Male(d)       |
| 370~375 nm | 30 ± 1.15 aB    | 27± 0.58 aA   | 27.33±2.03 aA   | 30±2.31 aA    |
| 420~425 nm | 27 ± 0.75 aA    | 26 ± 1.15 aA  | 29.67±2.33 aA   | 30±2.32 aA    |
| CK         | 23 ± 1.06 aA    | 21 ± 1.15 bB  | 25.33±2.60 aA   | 30±2.33 aA    |

Note: 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. While different capital letters following the data in the same row indicate significant difference among 0.05 treatments, the same letter indicates no significant difference among treatments, and the same below.

3.4.2. Effect of population density on single female oviposition amount of the Scopula subpunctaria.
Under the same spectral treatment, different feeding methods had certain effect on the single oviposition of female adults Scopula subpunctaria (Table 4). The average single female oviposition under the two spectral treatments of group feeding was as follows: group feeding was more than pair feeding (1 pair). Under the 370~375 nm treatment, the difference significance of single female oviposition of the two feeding methods were at the same level, but the difference was significant between that under the 420~425 nm photoluminescence treatment and control. From this, it can be inferred that the group feeding is more suitable for Scopula subpunctaria.

Table 4. Effects of spectra on egg production of S. subpunctaria under different feeding manners

| Treatment  | Matched feeding | Group feeding |
|------------|-----------------|---------------|
| 370~375 nm | 167.33±11.14 bA | 173.33±8.11 bA |
| 420~425 nm | 109.33±5.93 cB  | 177.67±7.22 bA |
| CK         | 235.33±8.25 aB  | 287±8.66 aA   |

4. Discussion
In recent years, related studies have been done on the prevention and control of field pests, and various methods such as chemical substances and pesticides, plant extracts and microorganisms, light trapping and light interference have been investigated [17-22]. Using light to disturb the field pests by taking advantage of their phototaxis features is a convenient and effective measure, which can not only save energy and protect the environment but also kill the pests directly before the outbreak [23]. In this study, by continuous illumination at night with different wavelengths, the single female oviposition of Scopula subpunctaria decreased by 28.9% (370~375 nm) and 53.5% (420~425 nm), respectively, and the difference was significant. The hatchability of eggs decreased by 11.10% and 15.90%, respectively. At the same time, the two kinds of wavelengths had certain effects on the pre-oviposition and the average oviposition period of the adults, but no significant effects on the life span of the adults. The results showed that the two kinds of spectra had adverse effects on the biological habits of the Scopula subpunctaria, which mainly showed that the number of the next generation population decreased. Under the condition of population feeding and paired feeding, there was no difference in the life span of the adults, but the number of egg-laying under the two treatments in group feeding was higher than that in paired feeding, and the difference under 420~425 nm treatment was significant compared to the control, which showed that the Scopula subpunctaria had the characteristics of clustering. The results of this study are different from those spectrum (350, 348 and 452 nm) that the Scopula subpunctaria had good phototaxis showed by Wang Chaowei et al., and the reasons may be related to the different species and biological habits of the pests. The specific reasons need to be further studied.

In this study, the phototaxis of insects were used to interfere with their reproductive rhythm in order to control their population. Lighting treatment reduces the spawning amount, shortens the life...
cycle, reduces the hatching rate and so on, finally reduces occurrence rate of the next generation larvae so as to control it below the allowable level which causes economic loss, eliminates the threat of harm. With the application of green prevention and control technology of tea tree improves the yield and quality of tea leaves and ecological environment of tea garden, and the pests’ natural enemies were also protected [24, 25]. At present, most of the trapping lumps used in production are usually mixed continuous light sources. Although they can achieve good effects in pest monitoring and trapping, they also cause certain harm to non-target insects such as natural enemies [26]. Therefore, it is of great practical significance to design and develop a special lamp according to the specific sensitive spectrum of insect pests occurrence.

5. Conclusion
Spectral treatments of 370–375 nm and 420–425 nm have varying degrees of effects on the early oviposition, average oviposition period, single female oviposition, hatchability and life span of *Scopula subpunctaria*, and 420–425 nm spectra has significant effects on its biological habits. Before eclosion of *Scopula subpunctaria*, providing light source in the tea garden from 7:00 pm to 7:00 am can effectively interfere its population development and provide reference for the green prevention and control technology in the tea garden.

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