Phototactic Responses of Three Species of *Cryptolestes* (Coleoptera: Laemophloeidae) to Different Wavelengths of Light[1]

Miao Cui, Yi Wu, Liyuan Xia, Dingrong Xue, and Zhongming Wang[2]

Academy of National Food and Strategic Reserves Administration, National Engineering Laboratory of Grain Storage and Logistics, Beijing, China, 100037

J. Entomol. Sci. 58(1): 85–94 (January 2023)
DOI: 10.18474/JES22-24

Abstract Information on insect phototaxis can be applied to the collection, monitoring, and management of insects. This study investigated the phototaxis of three species of *Cryptolestes* (Coleoptera: Laemophloeidae)—*Cryptolestes pusillus* (Oliver), *Cryptolestes turccus* (Grouvelle), and *Cryptolestes ferrugineus* (Stephens)—to light-emitting diode (LED) lights with six wavelengths. The three species had different responses to the different wavelengths, with *C. pusillus* displaying the strongest phototaxis. The taxis of the three species exhibited the same tendency across light waves of different lengths. All showed positive taxis to 450-, 390-, and 530-nm wavelengths, and their highest taxis indices occurred with 450 nm. The taxis indices of all three *Cryptolestes* species were positively correlated to light intensity.

Key Words light source, wavelength, flat grain beetle, phototactic responses

---

Flat grain beetles (Coleoptera: Laemophloeidae) are widely distributed in temperate and tropical areas. They feed on meal and pose little direct harm to whole grain, but their populations can raise the temperature of stored grain and favor the growth of mildew which, coupled with accumulation of beetle fecal material, causes grain contamination. Flat grain beetles are characterized by a high reproductive rate, short life cycle, preference for high temperature and high humidity, and resistance to low temperature and desiccation. Common species of *Cryptolestes* in China include *C. pusillus* (Oliver), *C. turccus* (Grouvelle), and *C. ferrugineus* (Stephens). These three species of *Cryptolestes* have developed resistance to phosphine (Li et al. 2011; Park and Lee 2017). Nonchemical methods, therefore, are being studied for their management (Yang et al. 2010). The lamplight trapping method is widely used in forecasting populations of crop insects and their control. This method, which exploits insect phototactic responses, is also used to trap stored grain insects. Insect phototaxis refers to insect activity responses to a specific range of the light spectrum, which includes visible, infrared, and ultraviolet light, through light-sensitive cells in their visual organs (e.g., compound eyes and simple eyes). Most species of insects exhibit a phototactic response, which has a

---

[1] Received 22 May 2022; accepted for publication 13 July 2022.

[2] Corresponding author: (email: wzm@ags.ac.cn).

Fig. 1. Insect optical analysis box.

role in locating food, mates, and suitable areas for reproduction. Phototaxis can potentially be applied to the collection, monitoring, and management of insects.

The light-emitting diode (LED) has pure light, narrow wavelength, high brightness, low heat, low power consumption, and a long service life. Changing the luminous spectrum range of the single-wave lamp for specific pests can kill pests while protecting beneficial insects. The use of LED light traps to control stored grain insects has been reported (Park and Lee 2017). It has been shown that different species of stored grain pests vary in their responses to LEDs with different wavelengths (Park and Lee 2017). *Liposcelis entomophila* (Enderlein) females and males were not attracted to any of the wavelengths tested, inferring that light of any waveband has no trapping effect (John et al. 2018). *Liposcelis paeta* Pearman females were attracted to two ultraviolet (UV) wavelengths and purple (351 and 400 nm) and green light (527 nm), while males did not respond to any light (John et al. 2018). *Liposcelis brunnea* Motschulsky females and males were attracted to all six wavelengths evaluated (John et al. 2018). Blue LED (84.3%) wavelength was most attractive to *Sitophilus oryzae* (L.), followed by green (74.3%), red (64.3%), UV (63.3%), and infrared radiation (IR) (48.7%) (Jeon et al. 2012). The green LED was significantly more attractive to *Plodia interpunctella* (Hübner) than the black light bulb (Jeon and Lee 2016). Red LED (625 ± 10 nm) was most attractive to *Tribolium castaneum* (Herbst) and *Sitotroga zeamais* Motsch adults (Park et al. 2015; Song et al. 2016). Additionally, UV LED (365 nm) had the highest attraction (67.7%) to *Sitotroga cerealella* (Olivier) adults among six LED monochromatic lights tested (Kim et al. 2014). *Lasioderma serricorne* (F.) and *Stegobium paniceum* (L.) were significantly more attracted to UV than to blue-light LED traps (Kim et al. 2013; Hironaka et al. 2017).

We studied the phototactic responses of the stored-product pests *C. pusillus*, *C. turccus*, and *C. ferrugineus* to different wavelengths of light under laboratory conditions.

Materials and Methods

One- or 2-wk-old *C. turccus*, *C. pusillus*, and *C. ferrugineus* were used in these studies. The beetles were cultured on a diet composed of oatmeal, whole wheat flour, and yeast. The beetles were initially obtained from the Academy of National Food and Strategic Reserves Administration. These were maintained at 28 ± 2°C and 50% ± 5% relative humidity (RH); tests were conducted under these same conditions.

Tests were conducted in a self-designed box (136 × 10 × 10 cm) composed of three parts and constructed of dark glass (Fig. 1). A bracket was used to hold a transparent glass tube (3-cm diameter × 100 cm long) within the box. The tube was

D5	D4	D3	D2	D1	Release Center	L1	L2	L3	L4	L5

Fig. 2. Scale division graph of the optical analysis tube.
Note: L1–L5 represents the direction of the light source. D1–D5 represents the dark direction. S is the distance of the test insect from the release center. L1 indicates $0 < S <= 10$ cm, L2 indicates $10 < S <= 20$ cm, L3 indicates $20 < S <= 30$ cm, L4 indicates $30 < S <= 40$ cm, L5 indicates $40 < S <= 50$ cm. D1 indicates $0 < S <= 10$ cm, D2 indicates $10 < S <= 20$ cm, D3 indicates $20 < S <= 30$ cm, D4 indicates $30 < S <= 40$ cm, D5 indicates $40 < S <= 50$ cm.

marked from its central point at 10-cm increments in both directions from the center (Fig. 2), and it was used to determine the response of the insects to the different light treatments. After the completion of the experiment for each species, the glass tube was cleaned and air dried before it was used for additional tests. The right side of the box had a small hole for the LED light source. During each test, the junctures were sealed with black masking paper and fixed with tape.

The source of the light was a UV-LED point light source irradiation machine (Beijing Xinyutai Technology Co., Ltd., Beijing, China) with a frequency-adjustable host UVEC-4II. This produced six kinds of single-wave light with lengths of 630, 590, 530, 450, 395, and 310 nm, and one mixed white light source.

Insect distribution in darkness. Thirty test insects were placed in the middle of the glass tube, and both ends of the tube were sealed with PVC film. The tube was then placed in the box, which was covered to keep the entire tube in darkness. After 10 min, the box was uncovered and the numbers and locations of the 30 beetles were recorded. The experiment was repeated three times for each of the three species.

Response to unilateral natural light. Thirty beetles were placed in the middle of the glass tube, and both ends of the tube were sealed with PVC film. The tube was then placed in the box. The box and the lamp hole were covered, and one side of the box cover was opened. After 10 min, the box was uncovered and the numbers and locations of the 30 beetles were recorded. The experiment was repeated three times for each of the three species.

Response to different light waves. Thirty beetles were placed in the middle of the glass tube, and both ends of the tube were sealed with PVC film. The tube was then placed in the box, which was covered to keep the entire tube in darkness. A single-wavelength light source was placed in the lamp hole on the right side of the box. The light intensity was calculated based on the light source power and box area. After 10 min, the box was uncovered and the numbers and locations of the 30 beetles were recorded. The experiment was repeated three times for each of the three species at each wavelength.

Statistical analysis. The taxis indices of the insects were calculated as follows:

$$\text{Distribution index} = \sum\left(\frac{\text{distribution extreme value} \times \text{number of insects distributed in a level}}{\text{total number of insects} \times \text{highest extreme value}}\right) \times 100.$$

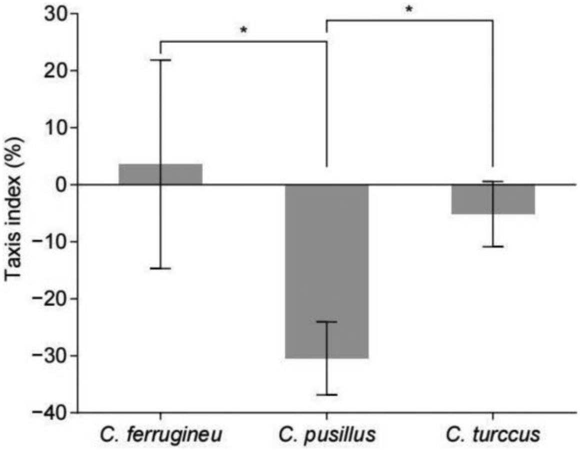

Fig. 3. Taxis indices of *Cryptolestes* species in darkness.

$$\text{Taxis index} = \text{distribution index under single} - \text{wavelength light} \\ - \text{contrast distribution index (dark at both ends)}.$$

All determinations were performed in triplicate unless otherwise stated. The data were analyzed using DPS software (version 2017, Ruifeng Information Technology Co., Ltd., Hangzhou, China). Statistical differences were analyzed using analysis of variance (ANOVA; $P < 0.05$) followed by a least significant difference *t*-test at a 5% significance level in SPSS software (version 20.0, 2012, SPSS Inc., Chicago, IL, USA).

Results

East–west distribution indices in darkness. The optical analysis tube was placed in an east–west direction in order to exclude the influence of orientation on results. The western end was marked L. and the eastern end D. The positive distribution indicated that the test insects were generally distributed in the west. The average distribution indices of *C. ferrugineus* and *C. turccus* were 3.59% and −5.17% in darkness, respectively, indicating that these test insects did not exhibit any obvious taxis (Fig. 3). In contrast, the average distribution index of *C. pusillus* was −30.47% in darkness, indicating that it exhibited taxis toward the east.

Response to natural light. In unilateral natural light, *C. pusillus* showed a distribution index of 86.77% (Fig. 4) and a taxis index of over 120%, indicating strong phototaxis response. The taxis indices of *C. turccus* and *C. ferrugineus* to natural light were 19.87% and 31.83%, respectively. These values were lower than that of *C. pusillus*, although they both indicated a level of phototaxis.

Tropism response to six different light sources. *Cryptolestes pusillus* showed positive taxis to five visible light wavelengths, except for 310 nm UV (Fig. 5). The taxis of *C. pusillus* to the five visible lights, in decreasing order, was as follows: 450 nm > 530 nm > 395 nm > 580 nm > 630 nm. *Cryptolestes pusillus*

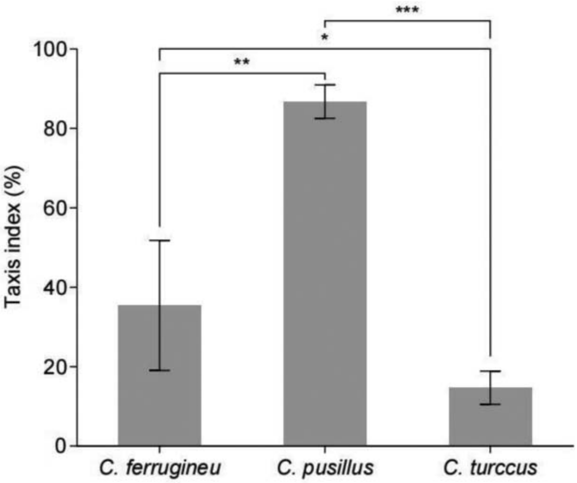

Fig. 4. Taxis indices of *Cryptolestes* in natural light.

showed a strong phototaxic response (>90%) to the three relatively short wavelengths: 395, 450, and 530 nm. However, it showed taxis of only about 10% to the 580- and 630-nm long light wavelengths. The taxis index of *C. pusillus* to white light exceeded 50%.

Cryptolestes turccus showed negative taxis indices to three light wavelengths: 310, 580, and 630 nm (Fig. 6). Its photophobism indices to the 310- and 630-nm wavelengths were >20%. This indicated that *C. turccus* exhibited photophobism to the 310- and 630-nm wavelengths. *Cryptolestes turccus* showed positive taxis indices to the 530-, 450-, and 395-nm light wavelengths, and <10% to the 395-nm wavelength, over 20% to the 530-nm wavelength, and up to 30% to the 450-nm wavelength. Thus, *C. turccus* showed the strongest taxis to the 450-nm light

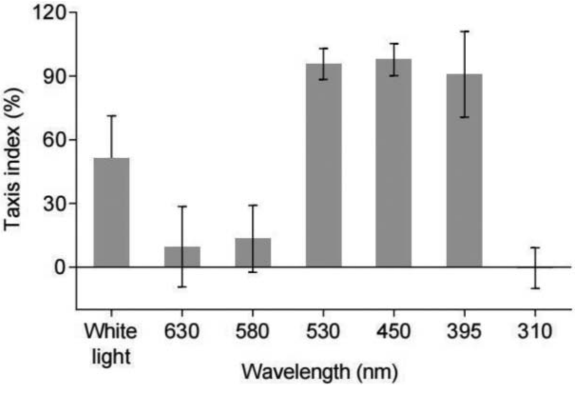

Fig. 5. Taxis indices of *C. pusillus* to different light wavelengths.

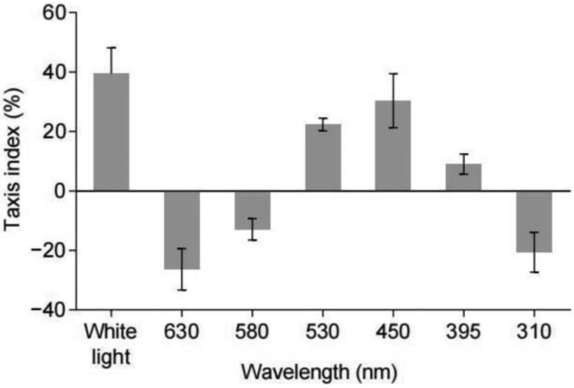

Fig. 6. Taxis indices of *C. turccus* to different light wavelengths.

wavelength. Its taxis was the strongest of the three species in white light, with a taxis index of nearly 40%.

The taxis indices of *C. ferrugineus* to the 630- and 580-nm light waves were negative, although their photophobism indices did not exceed 20%. This indicated that the effect of photophobism was not obvious (Fig. 7). The taxis indices of *C. ferrugineus* to other light wavelengths were positive. Its taxis was strongest in the 450-nm light wave, with a taxis index of approximately 30%, which was similar to that in natural light. Its taxis indices to the 530-, 395-, and 310-nm light wavelengths were all below 11%, indicating the absence of strong taxis. Strong taxis was not observed in white light, where its taxis index was only 7%.

Light intensity effect on phototaxis. The 450-nm light wavelength, which captured the largest number of the three species of *Cryptolestes*, was selected in this experiment. The taxis indices of the three *Cryptolestes* species were measured at light intensities of 180, 90, and 18 lm under the light source powers of 100%, 50%, and 10%, respectively. At the same light wavelength, the taxis indices of the

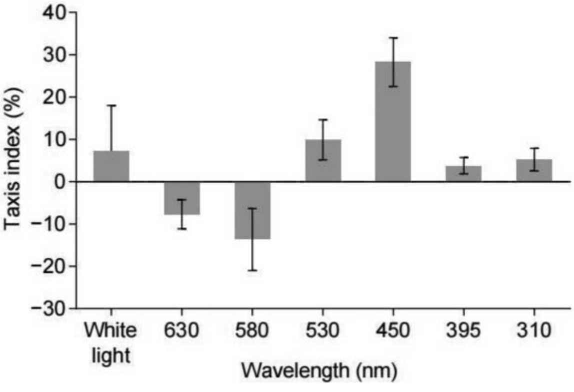

Fig. 7. Taxis indices of *C. ferrugineus* in different light wavelengths.

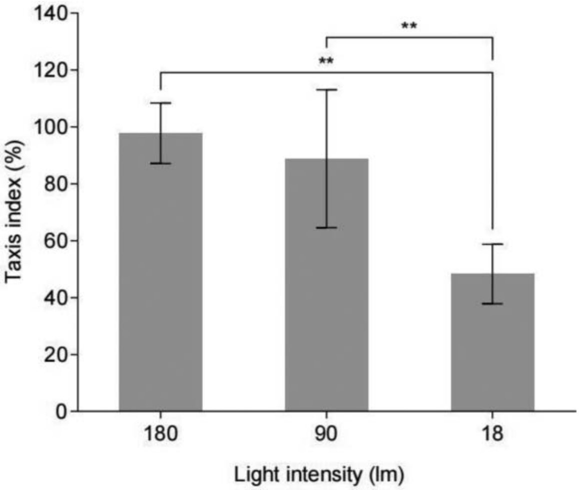

Fig. 8. Taxis indices of *C. pusillus* to the 450-nm light wavelength under different powers.

three *Cryptolestes* species changed as light intensity changed (Figs. 8–10). The taxis indices dropped sharply as the light intensity decreased.

Discussion

Much is known about the taxis behavior of insects to components of the light spectrum, especially agricultural and forest pests. The phototaxis of stored-grain insects is less well known, and the phototaxis of *Cryptolestes* grain beetles is unreported. We studied the taxis behavior of three species of *Cryptolestes* found in China to different light wavelengths. *Cryptolestes pusillus*, *C. ferrugineus*, and *C. turccus* exhibited phototaxis to most light wavelengths, and all exhibited different phototactic behaviors. Even the same species of *Cryptolestes* showed different phototactic behavior to different light wavelengths, which was consistent with the reported phototaxis of other insects (Park and Lee 2017). Nevertheless, the three species of *Cryptolestes* showed a similar trend in their taxis index curves to the six light wavelengths. This phenomenon could be attributed to their classification. The photoreceptive organs of most insects include the compound eyes and the ocelli (Shimoda and Honda 2013). Most insects have UV, blue, and green color receptors maximally sensitive at ~350 nm, ~440 nm, and ~530 nm, respectively (Briscoe and Chittka 2001). The physiological mechanism of phototaxis, however, is unclear. In our research, the three *Cryptolestes* species are closely related and exhibit similar behaviors. The three species showed the most obvious taxis to the 450-nm wavelength followed by the 530-nm wavelength. In addition, the taxis indices of the three *Cryptolestes* species were low both in long- and short-light wavelengths, and they showed a slight degree of photophobism. Thus, among the six monochromatic light sources tested, the blue light source with a wavelength of 450 nm had the best trapping effect on the three species. *Cryptolestes* grain beetles appear to have

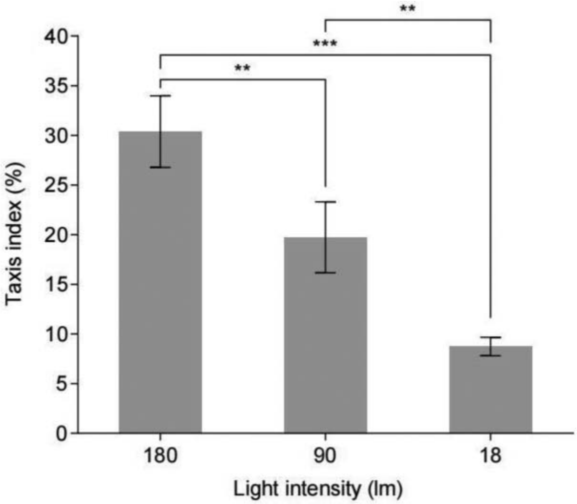

Fig. 9. Taxis indices of *C. turccus* to the 450-nm light wave under different powers.

similar phototactic behavior, and the results presented here may be useful to design effective light traps for these insects.

Both natural and white lights are sources of light with hybrid wavelengths. We found that the three *Cryptolestes* species showed strong phototaxis to natural light.

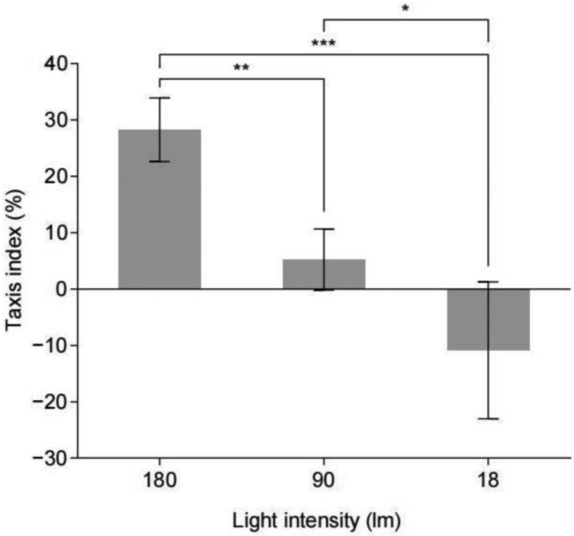

Fig. 10. Taxis indices of *C. ferrugineus* to the 450-nm light wave under different powers.

In particular, *C. pusillus* had the highest taxis index to natural light. The three species also showed a certain degree of taxis in white light, although their taxis indices were smaller to white light than to natural light. This was possibly due to the intensity of the white light given off by the point light source irradiation machine, which was weaker than that of natural light. The taxis indices of *C. pusillus* and *C. ferrugineus* to natural light were also higher than those to the light sources of other light wavelengths. Thus, the hybrid light consisting of different wavelengths had a better trapping effect on *C. pusillus* and *C. ferrugineus*. Similar findings have been documented with other insects. The taxis behavior of *Drosophila melanogaster* Meigen and *Propylea japonica* (Thunberg) to the light spectrum showed several peaks (Bian et al. 2012). Optimization of compound light waves, which could be used in designing light traps, should be further explored. The taxis index of *C. turccus* to natural light was lower than that to other monochromatic lights. *Cryptolestes turccus* also showed photophobism to the 630- and 310-nm light waves. Thus, the combination of light waves with good trapping effect and photophobism could reduce trapping effectiveness.

In darkness, *C. pusillus* showed obvious taxis to the west, possibly because of the direction taxis of some insects caused by geomagnetism. In the trapping experiment using *Acantholyda posticalis* Matsumura, the position factor affected the experimental result (Gao et al. 2011). Thus, the effect of the position factor must be eliminated, or minimized, when designing trapping experiments.

Cryptolestes exhibit strong insecticide resistance and are difficult to kill using conventional fumigation. Therefore, the use of light trapping technology for monitoring or controlling *Cryptolestes* is recommended. Light traps are also an alternative integrated pest management (IPM) approach. Our results provide a basis for the application of light trapping technology in the management of pest populations of *Cryptolestes*.

Acknowledgments

This work was supported by the National Engineering Laboratory for Grain Storage and Logistics and Research and two funded projects: Integrated Demonstration of Comprehensive Prevention and Control of Stored Grain Insects and Low Temperature Storage Technology (ZX2229) and Research and Development of High-Power Deep Ultraviolet Chip Technology and Application Equipment (H22030). We thank LetPub (www.letpub.com) for its linguistic assistance during the preparation of this manuscript.

References Cited

Bian, L., X.L. Sun, Y. Gao, Z.X. Luo, S. Jin, Z.Q. Zhang and Z.M. Chen. 2012. Research on the light tropism of insects and the progress in application. Chin. J. Appl. Entomol. 49: 1677–1686.

Briscoe, A.D. and L. Chittka. 2001. The evolution of color vision in insects. Annu. Rev. Entomol. 46: 471–510.

Gao, F., W.Y. Zhong, X.S. Yu, L.F. Cao and C.G. Zhou. 2011. Trapping *Acantholyda posticalis* Matsumura with sticky traps of different colors in the forest. Chin. J. For. Pest Dis. 3: 33–35.

Hironaka, M., T. Kamura, M. Osada, R. Sasaki, K. Shinoda, T. Hariyama and T. Miyatake. 2017. Adults of *Lasioderma serricorne* and *Stegobium paniceum* (Anobiidae: Coleoptera) are attracted to ultraviolet (UV) over blue light LEDs. J. Econ. Entomol. 110: 1911–1915.

Jeon, J.H., M.S. Oh, K.S. Cho and H.S. Lee. 2012. Phototactic response of the rice weevil, *Sitophilus oryzae* Linnaeus (Coleoptera: Curculionidae), to light-emitting diodes. J. Korean Soc. Appl. Bi. 55: 35–39.

Jeon, Y.J. and H.S. Lee. 2016. Control effects of led trap to *Sitotroga cerealella* and *Plodia interpunctella* in the granary. Appl. Biol. Chem. 59: 203–206.

John, D.M., J.F. Campbell, T.W. Phillips and J.E. Throne. 2018. Evaluation of light attraction for the stored-product psocids, *Liposcelis entomophila*, *Liposcelis paeta*, and *Liposcelis brunnea*. J. Econ. Entomol. 111: 1476–1480.

Kim, M.G., J.Y. Yang and H.S. Lee. 2013. Phototactic behavior: Repellent effects of cigarette beetle, *Lasioderma serricorne* (Coleoptera: Anobiidae), to light-emitting diodes. J. Korean Soc. Appl. Bi. 56: 331–333.

Kim, M.G. and H.S. Lee. 2014. Phototactic behavior 5: Attractive effects of the Angoumois grain moth, *Sitotroga cerealella*, to light-emitting diodes. J. Korean Soc. Appl. Bi. 57: 259–262.

Li, Y.Y., Y. Cao and G.T. Li. 2011. Research on the inert dust against phosphine resistance of *Cryptolestes ferrugineus*. Chin. Bull. Life Sci. 5: 5.

Park, J.H. and H.S. Lee. 2017. Phototactic behavioral response of agricultural insects and stored-product insects to light-emitting diodes (LEDs). Appl. Biol. Chem. 60: 137–144.

Park, J.H., B.K. Sung and H.S. Lee. 2015. Phototactic behavior 7: Phototactic response of the maize weevil, *Sitotroga zeamais* Motsch (Coleoptera: Curculionidae), to light-emitting diodes. J. Korean Soc. Appl. Biol. 58: 373–376.

Shimoda, M. and K.I. Honda. 2013. Insect reactions to light and its applications to pest management. Appl. Entomol. Zool. 48: 413–421.

Song, J., E.Y. Jeong and H.S. Lee. 2016. Phototactic behavior 9: Phototactic behavioral response of *Tribolium castaneum* (Herbst) to light-emitting diodes of seven different wavelengths. J. Appl. Biol. Chem. 59: 99–102.

Yang, E.C., D.W. Lee and W.Y. Wu. 2010. Action spectra of phototactic responses of the flea beetle, *Phyllotreta striolata*. Physiol. Entomol. 28: 362–368.