



## Research Article

# Attraction of Yellow Stem Borer (*Scirpophaga incertulas* Walker) to Different Colored Light-emitting Diodes

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## ABSTRACT

The yellow rice stem borer (*Scirpophaga incertulas* Walker) is a major pests on rice. Light traps have been used for monitoring and controlling *S. incertulas* with white and ultraviolet color light sources. The purpose of this research was to invent trap which uses an effective color that attracts *S. incertulas*. This research begins by sampling female *S. incertulas* pre-oviposition from the field then tested in the laboratory. The experiment was designed with factorial randomized block design with light colors and light intensity as factors. Light-emitting diodes used in this research, consisted of normal red, normal yellow, normal green, superbright red, superbright yellow, superbright green, superbright blue, UV, and white. LED white, UV, and superbright blue were attractive colors to *S. incertulas* when exposure time was 15 minutes. Effective light intensity to attract *S. incertulas* was 1000 lux.

Keywords: colors, LED, light trap, *Scirpophaga incertulas*

## INTRODUCTION

The yellow rice stem borer, *Scirpophaga incertulas* Walker (Lepidoptera: Crambidae) is a major pest of rice in Indonesia. This pest attacks all stages of the rice hence causing significant yield loss. During 2017, damage caused by *S. incertulas* reached 47,745.7 ha with Central Java experiencing the highest damage of 10,493.5 ha (BBPOPT, 2017). Control techniques of rice stem borer are conducted by mechanical, physical, and chemical methods (Roja, 2009). Control decisions are selected based on monitoring data (Reji *et al.*, 2008). Light traps are used for monitoring *S. incertulas* with ultraviolet (UV) light as a light source and white light regulation (Calor & Mariano, 2012; Longcore *et al.*, 2015; Chatterjee *et al.*, 2017). However, light traps have been reported to attracts natural enemies; thus, causing population loss of these beneficial organisms (Rich & Longcore, 2006). Light-emitting Diode (LED) is an electronic device that converts electricity into light efficiently, have variative color selections, produce less heat, safe for plants, resilient structures without gas filler, practical compared to light bulb, and posses higher

clarity levels compared to colored light bulbs (Kozai, 2016; Kim *et al.*, 2016). Besides that, LED have longer lifespans than conventional light bulbs, require less space, practical, lightweight, and could be integrated with other circuit components (Williams & Hall, 1978).

Light traps significantly managed *S. incertulas* population in China (500 insects/light trap overnight) (Huang *et al.*, 2014). LED are able to attract or monitor other pest population, namely UV LED for *Tribolium castaneum*, red LED for *Aedes atlanticus* and *A. infirmatus*, and green LED for *Culiseta melanura* and *Euscepes postfasciatus* (Burkett *et al.*, 1998; Nakamoto & Cuba, 2004, Duehl *et al.*, 2011). Light intensity affects insect attraction to light (Shepherd, 1966). Every insect species have different light intensity preferences (Menzel *et al.*, 1986). Light intensity has a positive correlation with light wavelength. Increasing light intensity at each light wavelength will increase insect attraction to light (Murata *et al.*, 2018). Therefore, this study aimed to investigate the attraction of *S. incertulas* to various LED colors. The results of the study can be used as a reference for light trap application in the field.

## MATERIALS AND METHODS

The study was conducted between February 2017–March 2018 in the Sub-Laboratory of Entomology, Laboratory of Plant Pest Science, Department of Plant Protection, Faculty of Agriculture, Universitas Gadjah Mada.

### LED Partition

LED partition used were type found in the local market. Design and assembly were carried out in the Laboratory of Infineon-Gadjah Mada Research Engineering (I-Green), Departement of Electrical Engineering and Information Technology, Faculty of Engineering, Universitas Gadjah Mada.

### Setting the Light Trap

Light traps were installed 1.5 m above ground with a funnel with a plastic container at the bottom. The LED partition was set to produce stable light intensity of 1000 lux at a distance of 0 m from the light source (Al-Deeb, 2012).

### Trapping of *S. incertulas* Female

Live *S. incertulas* females were trapped in rice fields located in Trotok Village, Wedi District, Klaten Regency, Central Java Province. Then, *S. incertulas* trapped were sexed between male and female.

### Sexing of *S. incertulas* Female

Female adult trapped were separated into pre- and post-oviposition based on morphology identification. The pre-oviposition females have fine hair from their abdomen while on post-oviposition females,

this feature is absent. This fine hair is loose and does not grow back due to its function to wrap eggs (Yunus *et al.*, 2011). This study used pre-oviposition females stored in a refrigerator at 8–10°C for testing the following night after trapping. Each testing used different insects. The testing was conducted at the Sub Laboratory of Entomology, Laboratory of Plant Pest, Department of Plant Protection, Faculty of Agriculture, Universitas Gadjah Mada.

### Testing of the Light Exposure Time to *S. incertulas* Attraction

The design of the test box referred to Oh and Lee (2010) with modification to size and materials used (Figure 1), by using wooden box (60 × 120 × 30 cm) covered with transparent plastic. The right chamber box was mounted with a LED partition as a light source (bright room) and the left room was left dark (dark room). *S. incertulas* were placed in the middle room between the dark and the bright rooms. Seven light exposure times (1, 5, 10, 15, 20, 25, 30 minutes) with 5 replicates were used in this experiment. Each test used a different female adult. This test aimed to determine effective time to test the attraction and rejection of insects. The exposure time test referred to Oh *et al.* (2011). The test was carried out by releasing 10 female of *S. incertulas* in the test box using white light intensity of 700 lux, a similar light intensity used attracting *Chilo suppressalis*, another rice stem borer species (Ryan, 2002). The number of adults attracted to the light was calculated at each specified exposure time.

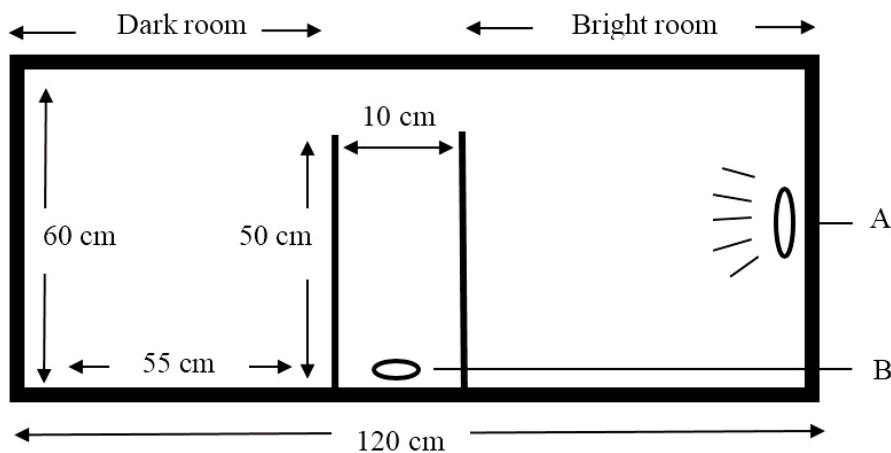


Figure 1. Test box design: (A) LED light source, (B) entrance of the tested insect

### *S. incertulas* Attraction to Various LED Colors

Attractancy and repellency of LED colors were tested. Attraction ratio is the percentage of adult attracted to the light compared to the total test population. The rejection ratio is the percentage of adult which avoided the light compared to the total test population. An attract and avoidance response is a regular insect response to light impulse. Ratios were not counted for insects which moved to the darkroom, yet still used as the total population of dividers (Oh *et al.*, 2011).

The experiment was design as a Factorial Randomized Block Design (FRBD) with 5 replicates. The first factor was 9 LED colors: normal red, normal yellow, normal green, superbright red, superbright yellow, superbright green, superbright blue, UV, and white as control. The second factor was 3 levels of LED light intensity: 500, 1000, and 2500 lux. The tests were done by releasing 10 *S. incertulas* females through the inlet, the observation time according to the results of the light exposure time for each color and light intensity treatment combination. The parameters observed were attraction ratio, repellent ratio, and effective light intensity attracting to *S. incertulas*.

### Measurement of Physical Parameters

The experiment was conducted in laboratory conditions ( $\pm 24.8^\circ\text{C}$ ;  $\pm \text{RH}$ : 72.6%). Multiple correlation regression was used to determine the effect of physical factors on the attraction of *S. incertulas*.

### Data Analysis

Data were analyzed using an ANOVA. If the significant difference were present, further post-hoc test using DMRT at 5% was done. All test were performend using SPSS.25.

## RESULTS AND DISCUSSION

### Type of *S. incertulas* Female Adult

*S. incertulas* adults trapped from the field have two types of females based on their oviposition stages. Pre-oviposition and post-oviposition types could be distinguished based on abdominal morphology. Pre-oviposition females were characterized by the presence of fine hair in the dorsal abdomen (Figure 2A) while post-oviposition females do not have fine hair (Figure 2B). *S. incertulas* females from the field have the habit to lay eggs and then cover the eggs with fine hair from the dorsal of the female abdomen. The yellowish fine hair produced from the anal tufts to protect the eggs from their predator. After laying eggs, *S. incertulas* female will lose the fine hair (Chen & Wu, 2014).

*S. incertulas* trapped from the field were kept in cold temperatures to delay their metabolism. Suitable low temperatures range for *S. incertulas* was 10–15°C (Rahman & Khalequzzaman, 2004). Low temperatures stimulate insects to inactivate enzyme processes, reduce female to oviposition probability, and resulted in longer pre-oviposition periods (Howe, 1967; Manikandan *et al.*, 2016). Female adults will maintain their energy and vital organs performances by reducing activity related to hormone performance (Ivanovic, 2018).

### Light Exposure Time Effects to *S. incertulas* Attraction

*S. incertulas* attraction to light exposure increased respectively to time until it reached a stable point and plateaued. The stable point occurred in the 15th minute (Figure 3). Light exposure time was used to determine the time efficiency and to our knowledge these results are the first for *S. incertulas*, emphasizing



Figure 2. Female *Scirpophaga incertulas* (A) pre-oviposition, (B) post-oviposition

its importances to be .Previous exposure time studies were conducted to different species, i.e. *Spodoptera exigua* and *S. litura* for 60 minutes (Oh *et al.*, 2011; Yang *et al.*, 2012).

### S. *incertulas* Attractancy to Various LED Colors

The LED color and light intensity had no interaction hence the color treatment and light intensity will be discussed separately ( $F_{16.135} = 0.624$ ;  $P = 0.05$ ). The criteria used to justify the effect of LED color were the attraction ratio, the repellent ratio, and the light intensity. Various LED colors showed high attraction ratio on white, ultraviolet, and superbright blue LED. Other LED colors were lower with the lowest amount was normal yellow. White LED demonstrated low repellency compared to other colors. White LED was the most attractive to *S. incertulas* ( $F_{8.135} = 5.28$ ;  $P = 0.05$ ) (Table 1).

*S. incertulas* adults are active during 18.00–01.00 Western Indonesian Time with the highest activity occurring at 20.00–22.00 Western Indonesian Time

(Yunus *et al.*, 2011). After this time period, there was no attraction to light traps hence testings were done during 20.00–22.00 Western Indonesian Time due to their a circadian clock Each treatment was carried out for 15 minutes. Insect acitivity follows a species specific circadian clock deterring accurately their active and rest periods. Insect circadian clock is related to physiological hormone productions, such as prothoracicotropic hormones, ecdysteroids, and juvenile hormones (Lazzari & Insausti, 2008). Insect behaviour in approaching light is influenced by its navigation system named the transverse orientation, the same system that determines their behavior to follow natural light sources including light of the moon and stars (Fraenkel & Gunn, 1961). The incoming light is captured and then translated as a signal to light photons, influenced by retinal cells in the eyes of insect facets. Each insect has a different tendency to gene expression. Changes in attraction to light may occur due to environmental adaptation. According to Inger *et al.* (2014), nocturnal

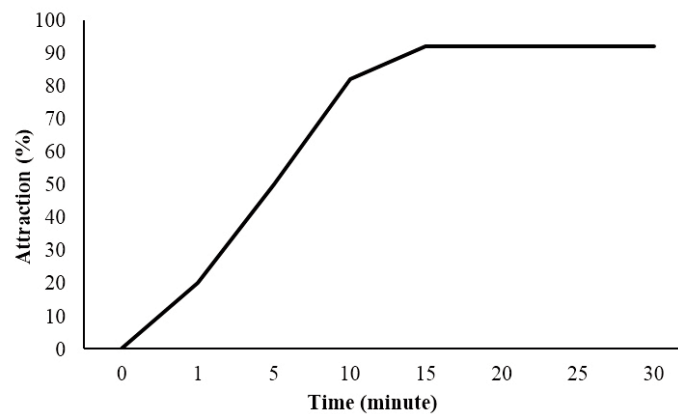


Figure 3. The attraction of *Scirpophaga incertulas* female in laying eggs to white LED exposure

Table 1. Attraction and repellent ratio to light trap color

Color	Attraction ratio (%)	Repellent ratio (%)
Red	22.00c	52.00d
Yellow	20.00c	47.33d
Green	20.67c	44.00cd
Red Superbright	27.33bc	34.67bcd
Yellow Superbright	38.00b	20.67ab
Green Superbright	40.00b	27.33abc
Blue Superbright	62.00a	18.00ab
Ultraviolet	62.67a	17.33ab
White	65.33a	13.33a

Remark: Means followed by the same letter in each treatment were not significantly different according to DMRT ( $\alpha = 0.05$ ).

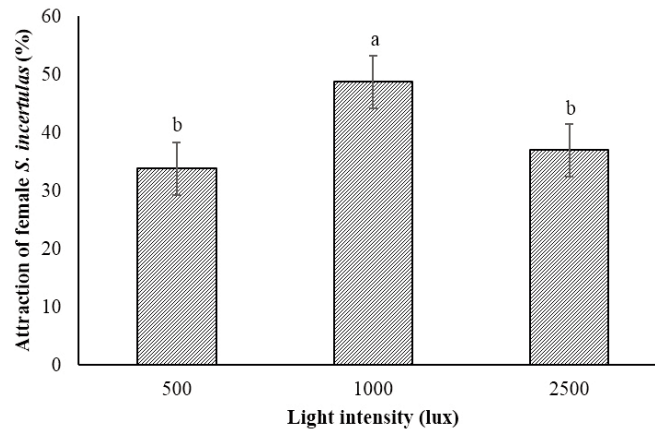


Figure 4. The attraction of *Scirpophaga incertulas* to various light intensity

insects live in habitats with artificial light source from human activities have different behavior than insects that live in nature, as an adaptation behavior to the environmental change.

Various LED colors have different wavelengths. The wavelengths are produced according to manufacture standards. For example, 650 nm for red LED, 520 nm for green LED, 460 nm for blue LED, 570 nm for yellow LED, < 400 nm for UV LED (Abrate, 2014; Guo & Suo 2017; Hwang *et al.*, 2017). White LED is a UV LED with the addition of phosphorus in the semiconductor hence it has a wavelength range of 520–660 nm (Jüstel, 2007). The attraction of insects to certain types of light is influenced by vision receivers of insects eyes. Insects have dominant visual pigments, namely green, blue, and UV (Menzel & Blakers, 1976) and additional pigments of red and yellow in some insects (Bernays & Chapman, 1994). The most interesting color is white because white light is polychromatic light which consists of a mixture of several color spectra (Millán *et al.*, 1992) thus all all vision receptors would be able to capture light. The attraction pattern of one species might be influenced by the dominance of one pigment than others. Insects attracted to one color may not be attracted to another color, or attracted to several colors yet more dominant to a certain color (Briscoe & Chittka, 2001).

*S. incertulas* adults tend to be attracted to LED of the superbright type than normal colors because the clarity of produced light. Light produced by superbright LED is brighter and more stable than normal LED (Watanabe *et al.*, 1992). The use of

superbright LED is more effective than normal LED which showed by the number of insects trapped. Insect repellency to light is because certain light disturb insects causing negative phototaxis, the activity of insects to avoid negative effects of light (Gorostiza *et al.*, 2016). Light can disrupt insect development, circadian rhythms, and even cause mortality (Sahayaraj & Auxelia, 2012; Hori *et al.*, 2014; Rivas *et al.*, 2018).

#### Light Intensity

The attraction level of *S. incertulas* to various light intensities experiment aimed to obtain the effective light intensity used to attract this pest. The female of *S. incertulas* was attracted to light intensity of 1000 lux (Figure 4;  $F_{2,135} = 8.598$ ;  $P = 0.05$ ). *S. incertulas* adults attracted to 2500 lux decreased because adults tends to avoid high intensity light. Light photoreceptors in *S. incertulas* are constrained to certain light intensities. Yunus *et al.* (2011) stated that during the day, *S. incertulas* tends to avoid sunlight and move randomly when disturbed. A factor that attracts insects to light is the level of light intensity captured by visual receptors. Higher populations of insects are attracted correspondingly to higher light intensity (Barr *et al.*, 1960). Certain color types and light intensity may be able to be repellences to several insects (Kim *et al.*, 2013).

Nocturnal insects have behavior to avoid high-intensity lights because their eye structures are designed to be sensitive to small light photons. The high exposure of photons will interfere with insect vision receptors performance. Nocturnal insects tend to be attracted to certain light intensity (Kelber

Table 2. Regression correlation of physical factors

Treatment	Attraction	R <sup>2</sup>
T + RH	$Y = -10.878(\text{ns}) + 5.826^* X_1 - 1.293(\text{ns}) X_2$	-
T ( $24.8 \pm 1.332^\circ\text{C}$ )	$Y = -80.673(\text{ns}) + 4.857^* X$	0.06
RH ( $72.6 \pm 1.862\%$ )	$Y = -28.695(\text{ns}) + 0.943(\text{ns}) X$	0.04

Remarks: T = temperature, RH = relative humidity

*et al.*, 2002). According to Pathak and Khan (1994), rice stem borer is most attracted to ultraviolet colors. Shimoda and Honda (2013) stated that insects have receptors to receive UV exposures, especially for nocturnal insects. The negative impact of using UV as a light traps is an increase of stress on plants (Kuhlmann & Müller, 2009). The UV exposure may damage plant DNA, disrupt its physiological functions, disrupt vesicle performance, damage lipid membranes in plant cells, and change the structure of vegetation and increase secondary metabolites (as a form of adaptation to stress) (Murphy, 1983; Hays & Pang, 1994; Rozema *et al.*, 1997). In this experiment, the colors which effectively attracted *S. incertulas* according to their level of effectiveness starting from highest, were white, UV, and superbright blue. Blue light could be replaced with white and UV as a light source in setting up the light trap. However, further studies to tests various colors of light trap impacts on natural enemies in field conditions are essential information and need to be conducted.

#### **Effect of Physical Factors on the Attraction of *S. incertulas***

*S. incertulas* attraction in light is affected by temperature and humidity. Results showed that temperature and humidity have a very low impact, 6% for temperature and 8% for humidity (Table 2). The optimum temperature of *S. incertulas* is 17–35 °C (Pathak & Khan, 1994) and humidity in laboratory setting was 70% (Rahman & Khalequzzaman, 2004). Generally, the suitable humidity of insects is 60–70% (Andrewartha, 1970). Based on observations, the effect of temperature and humidity was low due to the experiment was conducted under laboratory conditions hence the stability of the physical factors were maintained. Changes in temperature and humidity are not different, thus it does not have a significant effect.

## CONCLUSION

Effective LED colors to attract *S. incertulas* are white, ultraviolet, and superbright blue. The light exposure time for *S. incertulas* is 15 minutes. Effective light intensity of *S. incertulas* is 1000 lux.

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