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Research Article

Light Responses of *Ricania Shanthungensis* (Hemiptera: Ricaniidae) Adults and Attraction Effect of Capturing Device

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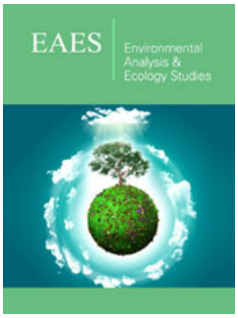

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Abstract

In order to effectively control the *Ricania shanthungensis*, we investigated the light response to adults and developed an adult catching device using light with superior attractiveness. The preference among six light sources such as daylight color, green, etc. for the *Ricania shanthungensis* adult was most favored with daylight color 97 > Black 79 = Red 79 = Blue 79 > Green 24 > Yellow 13. We have developed an adult catching device using the most preferred daylight colors and behavioral habits of the *Ricania shanthungensis*.

The capture device consisted of two daylight compact lamps (30W, 20W), a yellow plate, and a catcher using water, and caught about 700 individuals a day. The capturing device has a large amount of capturing because adult is activity at high nighttime temperatures, but the capturing amount decreased significantly when the temperature dropped below 23 °C. More than 85% of the *Ricania shanthungensis* adults were trapped for 3 hours from 19:00 to 23:00.

Therefore, it is considered that the adult capturing device for the control of *Ricania shanthungensis* is used from middle July to late August when the night temperature is over 23 °C and lights up from 19:00 to 23:00.

Keywords: *Ricania shanthungensis*; Light response; Capturing device; Daylight

Preface

The first find of *Ricania Shanthungensis* in South Korea was in 2010 in Chungcheongnam-do (Gongju and Yesan) and Jeollabuk-do (Gimje and Sunchang) and it expanded rapidly to Chungcheongbuk-do, Jeollabuk-do, Gangwon-do and Gyeongsangnam-do including Jeollanam-do Gurye area in 2011 and after all in 2015 we could find out 6,958ha of the outbreak. The harm damage of it to the various kinds of crops including the orchard is getting worse. Because, at first, the host range for *R. Shantungensis* is wide as the host plants for it are 51 species including 32 of woody plants and 19 of herbaceous plants. In addition, it inhabits in the forest and its imago can fly far away which means that it is difficult to control of the pest. In recent times, *R. Shantungensis* is expected as one of the potential major harmful insects with *Conogethes punctiferalis*, *Gastrolina depressa*, *Metcalfa pruinosa* for the walnut tree which is the main source of income for the forestry farm.

The most damaged fruit trees are apple, blueberry, peach, sweet persimmon, cornus fruit (*Comus officinalis*) and jujube etc. trees. For the effective pest control for these trees, the studies which are the selection of eco-friendly resources and setting model for the predictions of ecological characteristic and hatching time of overwintered egg mass have been done in South Korea. The developmental zero point for *R. Shantungensis* from the egg to nymph is said 9.3 °C and effective cumulative temperature is said 693.3 °C.

The most effective control methods of this pest is removing of the spawning twig before it hatches, but it is difficult to remove all of the spawning twig so We mainly control the young larvae and adults with relatively high insecticidal effect.

In order to control the *R. Shantungensis*, insecticidal effect tests and various attracted or avoided substances are actively searched. All the synthetic pesticides showed excellent insecticidal effect against the nymphs and adults. Among the plant extracts, the *Sophora falvescens* and derris elliptica extracts showed high insecticidal rate. Of the 23 plant-based avoidance substances, only peppermint oil showed a repelling effect of 76% Ryu [1]. Among the seven essential oil components, Artemisia princeps, *Citrus paradish*, *neroli Citrus aurantium*, and *Tagetes patula*, the essential oil has shown its applicability as an environmentally friendly insecticide for larvae and adults Jeon [2]. It was reported that the amount of egg laying in blueberries was reduced to 1/3 by installing yellow sticky traps Kim [3]. Although active research on this kind of control has been made, frequent drug treatment requires high labor costs as well as high control costs. Therefore, this study is to find out the favorite light source of *R. Shantungensis* and to develop an effective control method by developing capture device using behavioral characteristics.

Materials and Methods

Adult response to light

In order to investigate the effect of light on the color of light of adult *R. shantungensis*, it was carried out in a 25 ℃ dark room with external light blocked. At the end of a mesh cage of 47 × 92 × 47cm, host plants and 40 adults were inoculated, and fluorescent light was illuminated at the other end to investigate the number of adults attracted to the color of light. Six types of light sources were tested: daylight, green, yellow, blue, black and red. Twenty minutes after each light source was illuminated, the number of adults gathered toward the light source was investigated. Insects were approached to within 30cm of the lights were attracted, and all tests were conducted in 3 replicates. In addition, a comparative test was performed between the light sources in the same methods. Host plants and 40 adults were inoculated in the center of a net cage with a length of 92cm and irradiated with different light sources at both ends to investigate which light attracts the adults. The number of adults was counted as attracted to less than 30cm from the light source. The illuminance of each light source was measured using a light meter (testo 545) at 50cm and 1meter distance from the dark room for several light sources.

Capture effect of adult capturing device

In order to compare the attractiveness of adult *R. shantungensis* by color of light source, they were carried out at Aronia Farm in the mountain of Nam-gu, Gwangju Metropolitan City between Aug. 1 and 10, 2016. 20W daylight, yellow, and black compact lamps were installed 1.5m high and 5m apart at the Aronia farm adjacent to the forest, and the insects were lighted for 6 hours from 18:00 to 24:00 using a timer. At this time, water was placed in a plastic container with a diameter of 30cm under the lamp, and 3 drops of the kitchen detergent were dropped so that the insects could die without being able to escape. The next day, dead insects were removed with tweezers and the number of trapped insects was examined. The lamp position was changed daily and tested with 3 repetitions. In addition, the difference in insect attracting amount according to the shape of the light source, that is, the compact lamp and the fluorescent lamp, was compared. Two types of black lamps were installed in the same place, 10m apart, and tested for 2 days in mid-August 2016.

An adult capturing device was constructed using the preferred light source the adult of *R. shantungensis* (Figure 1). Using this device, we set up on Aronia farm in the forest area of Gwangju metropolitan city in August 2017 to investigate the amount of catch per day and to investigate the relationship between adult catches and daily minimum temperature using weather data from Kwangju Regional Meteorological Agency. In addition, on August 12 and 13, the number of adults caught seven times from 18:00 to 24:00 every six hours and the next morning was examined (Table 1).

Figure 1: Attraction device the adult of *Ricania shantungensis*.

Table 1: Attraction effect the adult of Ricania shantungensis by independent light source in the lab.

Rep	No. of Tested	Color of Light Source					
		Daylight	Green	Yellow	Blue	Black	Red
No. of attracted adults (mean±SD) Attraction rate (%)	40	24.3	9.3	8.7	14.7	26.3	24.3
		±1.15	±1.53	±0.58	±2.52	±1.53	±0.58
		62.4	23.9	22.2	37.6	67.5	62.4

Result and Discussion

Adult response to light

As a result of investigating the attracting effect on the brown winged moths adults by color of light source, the attracting effect was high in black, daylight and red, whereas it was very low in yellow and green. As a result of comparing the attractiveness between two light sources (Table 2), daylight color was superior to any light source, but black was more than green and yellow but less than daylight and red. Redness was higher than green, yellow, and black, but less than daylight and blue. Blue was higher than green, yellow, black and red but lower in daylight. Total luminous amount of light

source was 97-day color, and black, red, blue color 79, 24 green color and 13 yellow color were the most attracted daylight colors. Among the individual light sources, black was the most attractive, but compared with the light sources, the attractiveness of daylight was higher than that of black. In addition, black showed a lower attraction than blue and red. It is presumed that the preferred color is involved in attracting the *R. shantungensis*, but other factors such as the illuminance of the light source are assumed.

Table 2: Compare the attraction effect the adult of Ricania shantungensis between two light sources in the lab.

Division	No. of Attracted Adults between Two Light Sources				
	Green	Yellow	Blue	Black	Red
Daylight	3 / 18	2 / 22	2 / 19	9 / 20	13 / 18
Green		2 / 10	16 / 3	22 / 2	18 / 6
Yellow			23 / 4	24 / 3	25 / 2
Blue				14 / 15	6 / 23
Black					17 / 10
Total	24	13	79	79	79

As shown in Table 3, daylight color was the brightest at 1m distance at 63lux, and the attraction rate was the highest, while the yellow color was the lowest at day 1 from distance 51lux to daylight, but the attractiveness was the lowest. In conclusion, it is considered that the illuminance does not have an absolute effect on the attractiveness of insects. From the above results, it is concluded that the light source suitable for attracting the adult of *R. shantungensis* is the daylight color having both attractiveness and brightness (Table 4).

Table 3: Illuminance the compact lamp of different light source color.

Distance from Light Source	Illuminance according to Light Source Color(lux)			
	Black	Yellow	Daylight	Blue
50cm	2	189	235	56
1m	1	51	63	15

Table 4: Number of attracted insects when turn on the same time at different color of compact lamp (survey periods: 1 to 10. Auguest, 2016).

Scientific Name	Daylight				Yellow				Black			
	1	2	3	Total (rate)	1	2	3	Total (rate)	1	2	3	Total (rate)
Ricania shantungensis	138	139	150	427(100)	70	108	29	207(48)	203	157	111	471(110)
Meimuna opalifera	1	1	1	3	3	7	9	19	45	6	24	75
Halyomorpha halys	3	7	6	16	3	3	3	9	12	15	10	37
Plautia stali	5	10	7	22	0	7	2	9	6	7	10	23
Geisha distinctissima	0	1	2	3	0	1	0	1	1	3	4	8

Capture effect of adult capturing device

As a result of investigation of various insect pests such as *R. shantungensis*, 427 were captured in daylight, 48% in yellow color and 110% in black color. In addition, most of the pests such as *Meimuna opalifera*, *Halyomorpha halys*, and *Plautia stali* were also captured in black. However, the yellow color was captured only about half compared with daylight or black color. As a result of insect trapping test according to the type of lamp, compact lamps and fluorescent lamps, the *R. shantungensis* captured 411 at compact lamps, 26% more than 326 fluorescent lamps (Table 5). Most of the pests such as *Meimuna opalifera*, *Plautia stali*, and *Metcalfa pruinosa* are trapped in compact lamps rather than fluorescent lamps, so compact lamps are considered efficient.

Table 5: Compare with the captured pests between the black compact lamps and black fluorescent lamps.

Insects Name	Black Compact Lamps			Black Fluorescent Lamps		
	A	B	Av.(rate)	A	B	Av.(rate)
Ricania shantungensis	463	358	411(126)	351	301	326 (100)
Meimuna opalifera	115	57	86 (134)	66	62	64 (100)
Halyomorpha halys	5	18	12 (100)	15	9	12 (100)
Plautia stali	3	9	6 (200)	2	4	3 (100)
Geisha distinctissima	6	11	9 (243)	1	6	4 (100)

Kim et al. [4] reported that lamps with excellent attracting effect of chestnut weevil and peach moth moth, which are the main pest of chestnut, are mercury-based lamps, but since they have the disadvantage of attaching a stabilizer, next, a compact fluorescent lamp Recommended. Compared with the catch of *R. shantungensis* in the adult catching system, the catches were higher when the daily minimum temperature was high, but the catches were relatively low when the daily minimum temperature was high (Table 6). When the minimum temperature was 23 ℃ or higher, the amount of capture was 465 ~ 892, but at 21.6 ℃, 268 were relatively low.

Table 6: The number of captured Ricania shantungensis adult in attraction device and Daily minimum temperature.

Division	Survey Times					
	8. Aug.	9. Aug.	10. Aug.	11. Aug.	12. Aug.	13. Aug.
No. of captured adult	797	494	465	892	811	268
daily minimum temperature (℃)	26.4	25.5	24.6	23.9	24.6	21.6

Observation of the flight behavior of the *R. shantungensis* adults showed that the high temperature of the night moves actively between the light and the host plants, but the movement decreases with the low temperature (Table 7). The majority of catches were captured between 20:00 and 21:00, and more than 94% were captured between 19:00 and 24:00 around this time period. Although the time of emergence of the *R. shantungensis* will vary depending on the region, in Chonnam Province, it becomes an adult at the beginning of July and feeds for one month and starts spawning from the beginning of August Choi [5,6].

Table 7: Number of captured the adult of Ricania shantungensis as different time interval in attraction device.

Division	Survey date	Survey Times							
		18-19	19-20	20-21	21-22	22-23	23-24	after 24	Total
No. of captured adult	12. Aug.	3(0.4)	103(12.7)	351(43.3)	176(21.7)	114(14.1)	48(5.9)	16(2)	811(100)
	13. Aug.	7(2.6)	20(7.5)	131(48.9)	43(16)	33(12.3)	25(9.3)	9(3.4)	268(100)

July and August are the hottest days in Korea, and the number of days when the daily minimum temperature exceeded 25 ℃ was 10 days in 2015 [7-11], 23 days in 2016, and 21 days in 2017 (Table 8). The days of 23 ℃ and above were 29, 46, and 52 days, respectively. At this time, *R. shantungensis* adults are expected to act actively at night [11-13].

Table 8: Number of days the daily minimum temperature was over 23 □ from 2015 to 2017.

Years	Above 25 ℃ of Day Minimum Temperature		Above 23 ℃ of Day Minimum Temperature	
	Range	No. of Dates (days)	Range	No. of Dates (days)
2015	25. Jul. ~ 8. Aug.	10	11. Jul.~ 24. Aug.	29
2016	24. Jul. ~ 22. Aug.	23	1. Jul. ~ 5. Sep.	46
2017	2. Jul. ~ 24. Aug.	21	1. Jul. ~ 25. Aug.	52

*Data sourced by KMA homepage.

In conclusion, it was most effective to catch the adult of *R. shantungensis* by using the adult capturing device by catching them at 19 o'clock until 24 o'clock in July and August when the nighttime minimum temperature was 23 ℃ or higher.

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