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Life Cycle of the Perilla Leaf Pyralid Moth, *Pyrausta panopealis* (Lepidoptera: Pyralidae) and Test of Larvicidal Effect of Some Commercial Natural Products

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The perilla leaf pyralid moth, *Pyrausta panopealis* Walker (Lepidoptera: Pyralidae), is a serious pest damaging to leaf perilla. In order to establish the life parameters of *P. panopealis* for eventual purpose of control, the developmental span of each stage was investigated under five temperature regimes (20°C ~ 30°C). The larval period of *P. panopealis* was longest as 26.8 days at 20°C and shortened as temperature goes up to 30°C as 11.3 days. Survivorship of the larval *P. panopealis* was the highest at 27.5°C as 82.5%, whereas that of other temperatures ranged from 40% (20°C) to 60.0% (30°C), indicating that the *P. panopealis* appears to favor somewhat higher temperature. In addition to larval period, the duration of egg, prepupal, and pupal period also were shortened sharply as temperature goes up, whereas the duration of adult stage shortened a maximum of only two days as temperature goes up. After the perilla leaf pyralid moths were successfully stabilized in indoor environment the larvicidal efficacy of ten on-the-market environment-friendly agricultural materials (EFAMs) that were previously selected from the result of other moth species was tested. Seven of the ten tested showed more than 90% of mortality within 12 hrs and reached nearly up to 100% within 24 hrs, but the remaining three showed less than ~70%.

Key words: Laboratory test, Larvicidal effect, Plant extracts, *Pyrausta panopealis*, Life cycle

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Introduction

The perilla leaf pyralid moth, *Pyrausta panopealis* Walker, belonging to an insect family Pyralidae in Lepidoptera is distributed in South-East Asia including China, Japan, and India, and also in South America, damaging perilla and beefsteak plant (Jo *et al.,* 1986). In Korea, the species has not seriously been recognized as a major pest by its relatively small damage and narrow host range until recently. However, the recent expansion in growing area together with the increase in facilitated perilla farms enabled it considered to be a major pest for perilla leaf (Jo *et al.,* 1986; Seol and Goh, 1990). In fact, Choi *et al.* (2007) found that the 4th and 5th instar *P. panopealis* were the most damaging pest to green perilla leaf among several pests occurring in the facilitated perilla farm.

Although several studies regarding field occurrence and damage by the species are available in Korea (see Choi *et al.,* 2007, 2008), no clear information on the life cycle, particularly on the temperature dependency, is available for Korean population as far as we know. On the other hand, Yanagida *et al.* (1996) reported the developmental period of each larval stage, developmental zero point, and effective cumulative temperature of the Japanese populations of the species in the course of the ecological study of the pests occurring in the beefsteak plant. For the eventual control of the insect pests, it would be important to have a closer examination of the respective pest in terms of life cycle, particularly on the perspective of temperature regimes. One way to obtain such information could be an artificial indoor rearing, because it allows us to observe many important biological information that could be undetectable in the field situation. Therefore, in this study, we investigated the developmental duration of the pest at each life cycle stages under five temperature schemes (20°C ~ 30°C).

Furthermore, we tested several on-the-market environment-friendly agricultural materials (EFAMs) that have previously been selected from indoor test against other lepidopteran pests, such as *Plutella xylostella* and *Spodoptera litura* (Jeong *et al.*, 2007, 2009), in order for their applicability to the perilla leaf pyralid moth. Considering the leaf part of perilla is solely consumed a direct application of chemical pesticides to the leaf part concerns pesticide residue. Furthermore, it would be essential to test the applicability of those EFAMs against the perilla leaf pyralid moth, particularly because many EFAMs that are sold on the local markets for the control of the lepidopteran larvae do not specify the applicability of the EFAMs for the control of the perilla leaf pyralid moth.

Materials and Methods

Host plant and test insects

Third or fourth instar larvae of the perilla leaf pyralid moth (*Pyrausta panopealis*) were collected from the perilla leaf farm located in Naju, Jeollanam-do Province, Korea and maintained to stabilize for three generations at 25 ± 1°C, relative humidity (RH) of 60 ± 5%, and a photoperiod of 16L : 8D in a laboratory at Chonnam National University in Gwangju, Korea. Larvae were maintained on the perilla, whereas adults were maintained with 5% of sugar solution in a plastic cage of 35 × 35 × 40 cm. Female adults were forced to lay eggs on the perilla leaves by providing them with the leaves attached on the side of the plastic cage.

Development of *P. panopealis*

To evaluate the number of egg laid and span of egg period a pair of adult *P. panopealis* was located in a plastic cage of 7 × 7 × 10 cm provided with the 5% sugar solution and perilla leaves until alive. The perilla leaf on which eggs are laid was daily removed from the cage to count egg number, and these were daily examined under the stereoscopic microcopy (model Stemi 2000, Zeizz) to check hatching status. Once hatched, individual larva was transferred using a small hair brush to a round-shaped plastic cage (Φ 5 cm in size), containing one tissue saturated with water on the bottom, one filter paper on the middle, and one three-weeks-old perilla leaf disk (Φ 4 cm in size) on the top. Perilla leaf was replaced for every 48 hrs. Presence of exuvium examined under the stereoscopic microcopy was the criterion to decide age increment. The width of larval head capsule and the body length were measured under the Motic Images Plus 2.0 (Independent Product Ltd, UK). The emerged adults were transferred to a plastic cage of 7 × 7 × 10 cm, provided with the 5% sugar solution, and their lifespan was daily checked. Decision of the death was made when the movement of *P. panopealis* was not detectable for a while when touched with a brush. The RH and photoperiod were fixed to 60 ± 5% and 14L : 10D, whereas temperature was set under five schemes: 20 ± 1°C, 22.5 ± 1°C, 25 ± 1°C, 27.5 ± 1°C, and 30 ± 1°C At each temperature scheme 40 individual larvae were used for start.

Table 1. List of environment-friendly agricultural materials

Product	Company	Insecticidal Range	Source	Recommended dilution*
A	B	ML	Plant extracts	20 mL
B	FM	Insect pests	〃	20 mL
C	F	ML	〃	20 mL
D	K	M, Insect pests	〃	16 ~ 20 mL
E	K	ML, A	〃	16 ~ 20 mL
F	B	ML, L	〃	20 mL
G	NB	ML	〃	13 ~ 20 mL
H	A	T, SE, Be etc.	〃	40 mL
I	A	A, Be, SE etc.	〃	40 mL
J	F	A, other pests	B. thuringiensis	20 mL

*per 20 liter of water.
Abbreviations in insecticide range represent A for aphid, Be for *Benisia tabaci*, M for mite, ML for moth lava, SE for *Spodoptera exigua*, and T for thrips.

Screening bioassay

Previously, we tested several environment-friendly agricultural materials (EFAMs) against the diamondback moth (*Plutella xylostella*) and the tobacco cutworm (*Spodoptera litura*) and found each six among 16 showed more than 90% of larvicidal activity against *P. xylostella* and *S. litura* (Jeong *et al*., 2007; 2009). Among them we selected 10 better EFAMs for this study under the assumption that these may still exert positive efficacy because the *P. panopealis* also is an lepidopteran insect. Nine products are plant extracts and one was microorganism. The details of the products are represented in Table 1.

A spraying method was used to evaluate the activity of the test samples. Twenty individuals of the 4th instar larvae were inoculated to a plastic round cage (Φ 10 cm × 6 cm) provided with one tissue saturated with water on the bottom, one filter paper on the middle, and one four-weeks-old perilla leaf disk on the top. The EFAMs that were diluted to

Table 2. Measurements of the width of head capsule of *Pyrausta panopealis* larvae

Instar	No. larvae	Head capsule width (mm)	
		Mean	Range
1	10	0.21	0.19 ~ 0.23
2	10	0.32	0.30 ~ 0.34
3	10	0.47	0.43 ~ 0.52
4	10	0.64	0.62 ~ 0.68
5	10	0.98	0.96 ~ 1.01

the recommended concentration were sprayed on the larvae with small hand-sprayer (Table 1). Every 12 hrs, the larvae were checked, dead larvae were removed, and eventually mortality was determined 48 hrs after EFAMs are treated. Only distilled water was used for control. Each set of experiment was carried out in triplicate.

Data analysis

Using SAS programs (SAS Institute, 2004), Duncan's multiple range test ($p < 0.05$) was performed to test if any significant difference in the insecticidal effect exists among EFAMs (Duncan, 1955).

Results and Discussion

Larval development of *P. panopealis*

The mean width of the head capsule measured for 10 individual larvae of *P. panopealis* was 0.21, 0.32, 0.47, 0.64, and 0.98 mm, respectively, at each larval stage (Table 2). This result is highly similar to that of Yanagida *et al.* (1996), wherein the width was measured to be 0.22, 0.33, 0.49, 0.67, and 1.01 mm, respectively. The developmental length of the *P. panopealis* larvae at different temperatures are presented in Table 3. In comparison among five instars the first and fifth insatrs were relatively longer than other instars in all temperatures (Table 3). The larval duration of *P. panopealis* continued for a total of 26.8 days at 20°C, 19.3 days at 22.5°C, 13.2 days at 25°C, 11.8 days at 27.5°C, and 11.3 days at 30°C, respectively (Table 4). Thus, developmental length shortened as temperature goes up, showing more than two-fold shorter length at 25°C compared to that of 20°C. This result is most similar to that obtained by Yanagida *et al.* (1996) in that the total larval period was 29.1 days at 20°C and 11.2 days at 30°C. In the case of the cotton caterpillar, *Palpita indica*, which belongs to the same family of *P. panopealis*, the total larval period was 29.1 days at 20°C, but it abruptly decreased to 14.5 days at 30°C, shortening about two-folds of larval period.

The survivorship of the larval *P. panopealis* was in the order of 40% at 20°C, 42% at 22.5°C, 55% at 25°C, 82.5% at 27.5°C, and 60% at 30°C (Table 3). Thus, somewhat higher survivorship was obtained as temperature goes up. On the other hand, Yanagida *et al.* (1996) has shown that the survivorship of larval *P. panopealis* was 60%, 90%, and 90% at 20°C, 25°C, and 30°C, respectively, evidencing that much higher ratio of individuals were survived compared to our study. Nevertheless, this result still is compatible with ours in that higher survivorship was obtained at a higher temperature, indicating that the *P. panopealis* larvae appear to favor higher temperature.

Developmental span of each stage

In order to establish the life parameters of *P. panopealis*, the developmental span of each stage was investigated under five temperature regimes (Table 4). Egg period continued for 6.3, 4.7, 4.0, 3.2, and 3.0 days at 20°C, 22.5°C, 25°C, 27.5°C, and 30°C, respectively (Table 4), indicating that it shortens approximately two-folds between the temperatures 20°C and 30°C. Very similar trend also was found in terms of larval period. The pre-pupal period and pupal periods were more sharply shortened between the two temperature schemes: 4.4 days at 20°C vs. 1.1 days at 20°C in pre-pupa and 19.8 days at 20°C vs. 5.2 days at 30°C in pupa (Table 4). On the other hand, the adult

Table 3. Length of larval period of *Pyrausta panopealis* under different temperature regimes

Temp. (°C)	Duration (days ± SD)									
	1st		2nd		3rd		4th		5th	
	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD
20	35	6.4 ± 0.82	28	3.5 ± 0.69	23	4.2 ± 0.96	17	4.8 ± 0.60	14	7.9 ± 0.83
22.5	36	4.6 ± 0.84	30	3.4 ± 0.73	26	2.9 ± 0.65	20	2.9 ± 0.55	15	5.5 ± 0.92
25	38	4.0 ± 0.23	32	2.0 ± 0.25	27	1.9 ± 0.13	23	1.8 ± 0.49	21	3.4 ± 0.51
27.5	40	3.5 ± 0.64	39	1.4 ± 0.75	38	1.7 ± 0.53	37	2.1 ± 0.82	33	3.1 ± 0.70
30	20	3.0 ± 0.00	17	1.0 ± 0.17	15	2.1 ± 0.28	12	2.0 ± 0.14	12	3.1 ± 0.58

Table 4. Developmental periods of *Pyrausta panopealis* under different temperature regimes

Temp. (°C)	Duration (days ± SD)									
	Egg		Larvae		Prepupa		Pupa		Adult	
	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD	n	Mean ± SD
20	40	6.3 ± 0.46	14	26.8 ± 1.77	12	4.4 ± 0.67	11	18.9 ± 0.94	11	4.1 ± 1.45
22.5	40	4.7 ± 0.46	15	19.3 ± 1.16	13	2.5 ± 0.78	11	9.4 ± 0.69	11	8.2 ± 1.79
25	40	4.0 ± 0.28	21	13.2 ± 1.02	19	1.1 ± 0.32	16	7.4 ± 0.62	16	6.3 ± 1.92
27.5	40	3.2 ± 0.39	33	11.8 ± 0.90	31	1.2 ± 0.57	30	6.1 ± 0.28	25	6.3 ± 0.99
30	20	3.0 ± 0.00	12	11.3 ± 0.84	9	1.1 ± 0.33	8	5.2 ± 0.46	8	6.1 ± 2.42

Table 5. Larvicidal activity of ten EFAMs against P*yrausta panopealis* larvae

Products	% mortality (± SD) after			
	12 hrs	24 hrs	36 hrs	48 hrs
A	96.7 ± 5.77^{a}	96.7 ± 5.77^{a}	96.7 ± 5.77^{a}	96.7 ± 5.77^{a}
B	93.3 ± 5.77^{a}	100.0 ± 0.0^{a}	100.0 ± 0.0^{a}	100.0 ± 0.0^{a}
C	93.3 ± 11.55^{a}	96.7 ± 5.77^{a}	100.0 ± 0.0^{a}	100.0 ± 0.0^{a}
D	96.7 ± 5.77^{a}	100.0 ± 0.0^{a}	100.0 ± 0.0^{a}	100.0 ± 0.0^{a}
E	100.0 ± 0.0^{a}	100.0 ± 0.0^{a}	100.0 ± 0.0^{a}	100.0 ± 0.0^{a}
F	96.7 ± 5.77^{a}	100.0 ± 0.0^{a}	100.0 ± 0.0^{a}	100.0 ± 0.0^{a}
G	93.3 ± 5.77^{a}	100.0 ± 0.0^{a}	100.0 ± 0.0^{a}	100.0 ± 0.0^{a}
H	40.0 ± 10.00^{d}	76.7 ± 11.55^{b}	76.7 ± 11.55^{c}	76.7 ± 11.55^{c}
I	80.0 ± 0.0^{b}	83.3 ± 5.77^{b}	86.7 ± 5.77^{b}	86.7 ± 5.77^{b}
J	56.7 ± 15.28^{c}	66.7 ± 5.77^{c}	70.0 ± 0.0^{c}	70.0 ± 0.0^{c}
H2O	0.0 ± 0.0^{e}	0.0 ± 0.0^{d}	0.0 ± 0.0^{d}	0.0 ± 0.0^{d}
Free	0.0 ± 0.0^{e}	0.0 ± 0.0^{d}	0.0 ± 0.0^{d}	0.0 ± 0.0^{d}

Mean values with the same alphabet are not significantly different ($p > 0.05$, Duncan's Multiple Range Test).

period did not show such trend in that the temperature scheme at 22.5°C was longest as 8.2 days, whereas it was 4.1 days at 20°C, 6.3 days at 25°C , 6.3 days at 27.5°C, and 6.1 days at 30°C (Table 4). Considering the estimate of the standard deviation at 22.5°C, which was calculated as ± 1.79 days, the two estimates obtained at 22.5°C and at 25°C basically are in fact not statistically different to each other. Thus, the span of adult stage seems essentially to have no difference among temperature regimes excluding the temperature regime at 20°C. This may indicate that the mature *P. panopealis* better tolerate temperature fluctuation compared to other life stage. Previously, Yanagida *et al.* (1996) also found similar result in that the egg, larval, pre-pupal, and pupal periods shortened as temperature increases. Somewhat different aspect from our result was adult period. Yanagida *et al.* (1996) has shown the span of adult period was relatively longer at 20°C and 25°C, but substantially shortened at 30°C, although our data do not clearly indicate this trend. As more information from repeated experiment possibly using further diverse host plant species or varieties is accumulated, further decisive conclusion might be possible.

Insecticidal efficacy

For the test of insecticidal efficacy a total of ten EFAMs that were previously selected from the test of the diamondback moth (*Plutella xylostella*) and the tobacco cutworm (*Spodoptera litura*) larvae (Jeong *et al.*, 2007; 2009) were used against the 4th instar larvae of *P. panopealis* (Table 5). Among them, seven products showed more than 90% of larvicidal activity against *P. panopealis* larvae within 12 hrs and almost 100% mortality within 48 hrs (Table 5). These include the products A, B, C, D, E, F, and G. Considering prompt larvicidal efficacy these products may be very useful for the control of *P. panopealis* larvae. Because our experiment was solely obtained from the indoor test, subsequent field experiment to obtain the control efficacy of the products would be essential to list

these products as the control agency of the *P. panopealis* larvae. However, the products H, I, and J never reached to 90% even until 48 hrs. Considering the fact that field environment might be much harsh for the EFAMs to exert efficacy, these products are questionable for the field application. Our data are solely based on larvae, not for the adult, so future experiment should be aimed at *P. panopealis* adults.

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