THE BIOLOGICAL CHARACTERISTICS OF INTERACTIONS BETWEEN "EPISYRPHUS BALTEATUS DE GEER" INSECTIVORE HOVERFLY ON CERATOVACUNA LANIGERA (ZEHNTNER) IN THO XUAN DISTRICT, THANH HOA PROVINCE

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Abstract: *The growth process of Episyrphus balteatus passes 4 stages of development: egg, larva (maggot), pupa and adult. The average life cycle time of the fly at 27.8 ^{0}C is 18.7 days, at 25.3 ^{0}C is 20.1 days. The average life time of the fly at 27.8 ^{0}C is 25.9 days, at 25.3 ^{0}C is 28.6 days. The fly of E. balteatus lays eggs within 9 days of insemination with an average of 39.5 ± 2.11 eggs/adult fly. On the sixth day, the maximum numbers of eggs are 5,6 eggs/adult/day. At mean temperature condition of 25.3 ^{0}C, mean moisture of 82.5%, an 1-instar maggot eats an average of 17.2 ± 0.37 aphids, a 2-instar maggot eats an average of 69.7 ± 0.62 aphids, a 3-instar maggot eats an average of 196.2 ± 2.15 aphids. At a temperature of 27.8^{0}C, and moisture level of 77.6%, the maggot eats fewer aphids. An 1-instar maggot eats an average of 15.9 ± 0.44 aphids, a 2-instar maggot eats an average of 57.5 ± 0.51 aphids, a 3-instar maggot eats an average of 188.7 ± 1.84 aphids.*

Keywords: *Episyrphus balteatus, hover fly, sugarcane wooly aphid, predation rate.*

1. Introduction

1.1. Background

During the development and growth process, sugar-cane is readily harmed by pests that cause reduction in productivity and quality of the raw sugar-cane. Among these pests, sugarcane wooly aphid (*Ceratovacuna lanigera* (Zehntner)) is the main pest having a rapid life cycle and high rate of increase of populations that can lead to major pest outbreaks. However, in the natural environment, *Ceratovacuna lanigera* (Zehntner) is restrained by natural enermies, especially the ladybird beetle (Coccinellidae), and the aphid-eating hoverfly (Syrphidae), parasitic wasp (Encytidae). The aphid-eating hoverfly (*Episyrphus balteatus* de Geer) plays the most important role in restraining numbers of *C. laniger*. When the density of the larva population of aphid-eating hoverfly is high, it is able to restrain successfully the *C. Lanigera* population. This study examines the intereaction between this hoverfly and the sugarcane wooly aphid in Tho Xuan district, Thanh Hoa province in Vietnam.

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1.2. Monitoring methods in the field

Monitoring procedure was conducted in accordance with QCVN 01-38:2010, monitoring protocols. The varieties of sugar cane in the study field were ROC22, ROC10, VĐ94 -128, MY55 -14.

The study sites were in lowland and highland locations. The planting spacing ranged from 1 m to 1.25ms. We monitored each crop for seven days each session. We assessed two plants every 5ms for presence of aphid-eating hoverfly and sugarcane woolly aphids. We observed the top and lower surface of leaves and the other parts of each plant, counting them and then catching a sub-sample to bring to the laboratory for verification.

2. Research method in the laboratory

2.1. Research method for the biological and ecological characteristics of E. balteatus hoverfly in laboratory's conditions

Mature *E. balteatus* hoverflies were caught in the field then placed into an insect net cage where VDD94-128 variety and sugarcane woolly aphids were established to simulate a natural environment. We monitored daily for fertilized *E. balteatus* eggs then leaves with eggs were placed in a worm bin to assess the duration until hatching. Moist filter paper was also put inside the bin and the the petioles were wrapped with macerated cotton to keep the leaves fresh. The leaves were changed every 2 days.

After recording the egg-openning period, we monitored the feeding stage of the 1st-stage larva (maggot) in the worm bin (n=30). In each "worm" bin there were moist filter papers, sugar cane leaves and sugar cane woolly aphids. Afterthe pupa emerged as adults, we selected breeding pairs of flies of the same emerging-dated and placed them into a net cage where the host plants and aphids were available.

2.2. Method of identifying the predacity of E. balterus flies under laboratory conditions

Daily at 0800 hrs, we added 50 aphids (1st and 2nd instars) in each of 30 worm bins, counting regularly the remaining aphids on leaves. We monitored the predation rate until the larva transformed into a pupa.

3. Findings and discussion

3.1. Morphological characteristics and dimensions of the development phases of Episyrphus balteatus insectivore hoverfly on Ceratovacuna lanigera

In each different development period, *E.balteatus* eggs varied in shape, dimension, and color. To identify exactly every development phase of this fly, 10 individuals of each phase were fed at an average temperature: 26.5 ^{0}C and average huminity of 83.5%, which achieved the results as follows:

Eggs: the eggs were tubular-shaped, new-laid eggs were white color, then turned into milkiness color when eggs were close to hatching. Dimensions of eggs: 1.57 ± 0.08 mm in length, 0.66 ± 0.10 mm in width.

Larva: referred to as maggot type with 3 instars. Pure white color when emerging from eggs 3.5-4 mm in length and 1-1.5 mm in width. Full-grown maggots were 10.5 ± 0.45 mm long and 2.45 ± 0.16 mm wide, double-end oblong and flat-body shape, mouthpart pull-back into the front end.

Pupa: at the begining of puparation time, pupae were the same color as larva. When nearly emerging as adult, the color turned darker. Pupae have large head and a smaller tail with a mean length of 7.23 ± 0.35 mm and mean width of 2.91 ± 0.25 mm.

Adult: the female has a larger abdomen than the male, with an egg sticking tray. The male has a flat abdomen, and thinner and longer body than the female. The female mean body length was 8.7 ± 0.58 mm, mean width 2.44 ± 0.22 mm, with a mean wing span of 17.44 ± 0.74 mm. The mean body length of a male was 9.43 ± 0.5 mm, the mean width was 2.49 ± 0.23 mm, and mean wing span 17.81 ± 0.73 mm. The compound eyes are red brown color and occupy most of the size of the head.

Figure 1. *Photo of development stages of E. balteatus (de Geer) fly*

	
Aldult stage	Egg stage
	
Pupa stage	Larva stage

(Photo: Taken in June/2013)

3.2. Biological particularity of aphid-eating E. balteatus hoverfly

Characteristics of development stages

Egg stage: eggs of *E. balteatus* hoverfly are laid scatteredly on the surface of sugarcane leaves. Eggs are laid near, or on, the aphids. Development stage of egg was from 1 to 3 days.

Larva (Maggot) stage: maggots began to consume prey 3hrs after emerging. They showed preference for eating the 2-instar aphids than the 1-instar aphids. The larva stage has 3 instars.

Pupa stage: pupa's color is like that of the larva at the begining, with 2 black bands on its back. When nearly emerging to be an adult, the pupa's color tends to be darker, and turns to light brown when the adult body can be seen through the cocoon.

Adult stage: adult emerge in the morning and is the most active in the early morning or in the late afternoon. When coming out of the cocoon, the adult's body is weak. After a few hours, the body is harder and the body's color turns darker and darker but cannot fly yet. The adults prefers light so it often moves toward the bin's cover.

Table 1. *The development time of stages of E. balteatus fly which is fed C. Lanigera in the laboratory*

Development Stages	**Development time of stages of E. balteatus fly (day(s))**					
	1st Feeding Period			**2nd Feeding Period**		
	Max.	**Min.**	**Average**	**Max.**	**Min.**	**TB ± Se**
Egg	3	1	2.35 ± 0.203	3	1	2.18 ± 0.205
Larva	8	4,5	7.4 ± 0.266	8	4	6.98 ± 0.345
Pupa	9	7	8.45 ± 0.24	8	6	7.87 ±0.147
Adult	10	6	8.55 ± 0.378	8	5	7.28 ± 0.248
Before laying	3	1,5	1.87 ± 0.202	3	1	1.75 ± 0.207
Life cycle	24	16	20.07 ± 0.543	22	12	18.7 ± 0.617
Life	34	20	28.62 ± 0.759	29	17	25.93 ± 0.75
Average Temp. (ºC)	25.3 ± 0.75			27.8 ± 0.78		
Average Humidity (%)	82.5 ± 1.83			77.6 ± 1.77		

(Note: n = 30 individuals)

3.3. Fecundity and frequency of birth of the flies of E balteatus

The fecundity of *E. balteatus* and its frequency of laying batches of eggs depend on the environmental temperature and moisture conditions. We raised 10 couples of the adults. The daily quantity of eggs and total of hatched eggs are shown in table 2.

Table 2. *Fecundity of E. balteatus raised by feeding on the aphis of C. lanigera under different temperature condition in the laboratory.*

Date of egg dropping	**Quantity of eggs (number/mature/day)**			**Temp. (ºC)**	**Moisture (%)**
	Minimum	**Maximum**	**Average**		
1	1	3	2,4± 0,50	26,7	81
2	2	4	3,2 ± 0,56	28,2	83

3	3	5	3,8 ± 0,56	27,5	79
4	3	6	4,2 ± 0,66	29,2	74
5	4	7	4,6 ± 0,69	28,1	68
6	5	8	5,6 ± 0,69	29,3	85
7	5	7	5,4 ± 0,67	29,1	83
8	3	5	3,5 ± 0,51	26,8	79
9	1	2	1,28 ± 0,30	27,3	80
Egg dropping ability	27	43	39,4 ± 2,11	27,6	81,2

(Note: n = 10)

The flies of *E. balteatus* drop eggs within 9 days, the frequency of egg dropping gradually increased and reached the maximum quantity on the sixth or seventh day (5.3 - 5.6 number/mature/day), then decreased to the minimum of 1.28 ± 0.38 number/adult/day on the next day. At the temperature and moisture conditions of the laboratory, their average egg dropping ability is 39.5 ± 2.11 number/adult (Table 3.3).

3.4. The rate of hatching of E. balteatus in the laboratory

The rate of hatched eggs is an important biological criterion to identify the quantity of flies of the next litter that are likely to develop in the field. If the rate of hatched eggs is low, even though the fecundity of the adult is high, if the quantity of prey in the field is high, then the quantity of flies is not sufficient to manage the pest population. Therefore, we examined the rate of egg production of adults raised in the laboratory. The results are shown in table 3.

Table 3. *The rate of hatched eggs of the fly of E. balteatus in the laboratory*

Checking date	**Total of check eggs (nos)**	**Total of hatched eggs**		**Average temperature (ºC)**	**Average moisture (%)**
		Quantity (nos)	**Rate (%)**		
10/5 - 12/5	38	34	89,5	26,4	87,4
15/5 - 17/5	32	26	81,2	25,8	77,9
19/5 - 21/5	35	28	80,0	25,6	83,4
23/5 - 25/5	33	30	90,9	26,7	87,8
28/5 - 30/6	40	34	85,0	28,6	81,4
2/6 - 4/6	34	24	70,6	29,7	75,9

At different temperature and moisture conditions, the rate of successfully hatched eggs is different. At the average temperature condition of 27.1^0C and humidity of 87.8%, the rate of

hatched eggs reached 90.9%. At 29.7^{0}C and humidity of 75.9%, the rate of hatched eggs was 70.6% (Table 3.4). Therefore, temperature and moisture are two factors which affect the rate of hatched eggs in the labortory.

3.5. Identifying the ability of eating the aphis (C. lanigera) of the flies of E. balteatus

The flies of *E. balteatus* play an important role in controlling the quantity of the aphis of *C. lanigera*. In order to examine the consumption by *E. Balteatus* of the aphids, we assessed the level of consumptions of 1,2 -instar aphids. The consumption by *E. balteatus* of both instar stages is high (Table 4).

Table 4. *Predacity of the E. balteatus fly on aphids (C. lanigera)*

Age	Predacity of maggots through the raising stages					
	Stage 1			Stage 2		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Maggot at 1-instar	15	19	17.2 ± 0.37	13	18	15.9 ± 0.44
Maggot at 2-instar	62	73	69.7 ± 0.62	51	67	57.5 ± 0.51
Maggot at 3-instar	175	207	196.2±2.15	168	192	188.7±1.84
Average temperature (^{0}C)	25.0 ±0.75			27.8±0.78		
Moisture (%)	82.5±1.83			77.6±1.77		

4. Conclusions and recommendations

4.1. Conclusion

The growth process of *E. balteatus* passes through 4 stages of development: egg, larva (maggot), pupa and adult. The average life cycle time of the fly at 27.8 ^{0}C is 18.7 days, at 25.3 ^{0}C it is 20.07 days. The average life time of the fly at 27.8 ^{0}C is 25.93 days, at 25.3 ^{0}C it is 28.62 days. The flies of *E. balteatus* lay eggs within 9 days with an average of 39.5 ± 2.11 eggs/adult fly. The maximum numbers of eggs are laid on the sixth day (5.6 eggs/adult/day).

At the average temperature condition of 25.3 ^{0}C, and average moisture of 82.5%, an 1-instar maggot eats an average of 17.2 ± 0.37 aphids, a 2-instar maggot eats an average of 69.7 ± 0.62 aphids, a 3-instar maggot eats an average of 196.2 ± 2.15 aphids. At the average temperature condition of 27.8^{0}C, and average moisture of 77.6%, the maggot eats less aphids.

An 1-instar maggot eats an average of 15,9 ± 0,44 aphids, a 2-instar maggot eats an average of 57.5 ± 0.51aphids, a 3-instar maggot eats an average of 188.7 ± 1.84 aphids.

4.2. Recommendation

The findings from this study provide a reference document for students whose major is crop protection at universities and colleges.

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