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Immature Development, Longevity and Fecundity of the Larval Parasitoid, *Meteorus pulchricornis* (Wesmael) (Hymenoptera: Braconidae), on Tobacco Cutworm

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This study was performed to investigate the temperature-dependent development, longevity and oviposition of an indigenous larval parasitoid, *Meteorus pulchricornis*, on tobacco cutworm, *Spodoptera litura*. *M. pulchricornis* were reared at nine constant temperatures between 15 and 35°C. The developmental times of each three developmental stage decreased from 38.7 to 16.3 d between 15 and 30°C. However, *M. pulchricornis* showed longer developmental time at 32.5°C (9.5, 7.7 and 17.2 days for each three developmental stage) than at 30°C (8.9, 7.3 and 16.3 days for each three developmental stage). Immature *M. pulchricornis* could not develop any more at 35°C. The lower developmental threshold estimated by linear regression equation for the egg to cocoon, cocoon to adult emergence and egg to adult emergence were 5.1, 4.6 and 4.5°C. The thermal constant for each of the three stages were 217.2, 176.2 and 403.8 degree-days, respectively. When no food or 50% honey solution as a food source is provided for *M. pulchricornis*, the parasitoid survived for 8.3 and 55.9 days at 25°C, respectively. *M. pulchricornis* females laid 5.2 eggs daily and total of 131.6 eggs at 25°C until it died. Peak age-specific fecundity was observed on 14th day (9.6 cocoons) after parasitoid emergence and gradually decreased thereafter.

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Introduction

Spodoptera litura (Fabricius) (Lepidoptera: Noctuidae) is a polyphagous insect pest on several vegetables and flowering plants (Bae *et al*., 1997; Garad *et al*., 1984; Goh *et al*., 1991; Moussa *et al*., 1960; Rao *et al*., 1993). This insect pest has been found in tropical, subtropical and temperate regions worldwide and frequently occurred and damaged in southern agricultural area of Republic of Korea. (Bae *et al*., 2007). Chemical control of *S. litura* has often been difficult because mature larvae of *S. litura* can easily acquire insecticide resistance (Bae *et al*., 2003; Cho *et al*., 1996; Kim *et al*., 1998).

In this reason, instead of chemical control, alternative measures have been considered to control tobacco cutworm. For example, characterization of *S. litura* nucleopolyhedrovirus, bioactivity of new isolate of *Bacillus thuringiensis* and control efficacy of entomopathogenic nematodes have been studied as fundamental research for controlling *S. litura*. (Kim *et al*., 2008; Kim *et al*., 2008; Woo *et al*., 2005). However, more studies on other biological control agents such as larval parasitoid or egg parasitoid of *S. litura* should be considered for more successful biological pest management.

Meteorus pulchricornis (Hymenoptera: Braconidae) is a solitary, larval endoparasitoid of many lepidopteran insects and distributed throughout Western Europe, North Africa, China, Korea and Japan (Berry and Walker, 2004;

Fuester *et al*., 1997). Because the parasitoid has been considered as a promising biological control agent of lepidopteran pest, it had been introduced into the United States for the biological control of gypsy moth, *Lymantria dispar* (L.) (Fuester *et al*., 1997).

Studies on biology including immature development, survival and age-specific fecundity of parasitoids of insect pests are crucial for understanding the host-parasitoid system and could provide useful information on effective mass rearing of promising parasitoids. Therefore, we investigated the temperature-dependent development, longevity and age-specific fecundity of *M. pulchricornis* as a first step of evaluation of the parasitoid.

Materials and Methods

Insect rearing

Parasitized tobacco cutworm was collected in strawberry greenhouse, Nonsan-si, Republic of Korea, and emerged parasitoid was identified as *M. pulchricornis* on the basis of taxonomic trait by Berry (1997). The tobacco cutworm, *S. litura*, was used for culture of *M. pulchricornis*. Emerged 1st larvae of *S. litura* from eggs were transferred into Petri dishes (14 cm × 2.5 cm) containing artificial diet of *S. litura*. For preparing artificial diet of *S. litura*, after 24 g of agar powder (SHOWA) was put to 1 L of distilled water and boiled for 10 minutes. 113 g of Soybean powder, 113 g of malt and 60 g of yeast (Daeheung Yakpum) were mixed with boiled water. Then, 15 g of Vitamin (Seoul Sinyak), 7.5 g of Sorbic acid (SIGMA), 2.3 g of L-arcorbic acid (JUNSEI), 4.5 g of P-Hydroxybenzoic acid methy ester (SIGMA) and 250 ml of Formalin (JUNSEI) were added and mixed for substitute food of *S. litura*. 2nd or 3rd instar larvae of *S. litura* with artificial diet were placed in acrylic cage (25 × 20.5 × 16 cm) and the parasitoid *M. pulchricornis* were allowed for oviposition on *S. litura* for 2 days. After 2 days for oviposition of the parasitoid, *S. litura* larvae were transferred into Petri dishes (14 cm × 2.5 cm). When parasitized *S. litura* larvae become cocoon and the parasitoid adult emerged, emerged parasitoids were used for testing insects.

Temperature-dependent development

For oviposition of the parasitoid, emerged *M. pulchricornis* females were placed in acrylic cage (16 × 16 × 10 cm) containing twenty 2nd or 3rd instar larvae of *S. litura* with artificial diet for 24 hours. After 24 hours, *S. litura* was individually moved into Petri dishes (6 cm × 1.5 cm) and placed in the incubator set to hold at nine temperatures: 15, 17.5, 20, 22.5, 25, 27.5, 30, 32.5 and 35°C (photo period 16L:8D). Cocoon formation and adult emergence were recorded every 24 hours. Effect of temperatures on developmental rate of egg to larva, pupa and egg to pupa stages were analyzed by using linear regression. Used model was $Y = bX + a$, where Y is developmental rate (1/(number of days required for development)); X is temperature, a and b are the intercept and slope parameters obtained from linear regression analysis. The lower developmental threshold (T^0) is the intercept of the temperature axis of the regression (i.e., $T^0 = -a/b$) and the thermal constant (degree-days, DD) is reciprocal of the regression coefficient (i.e., $DD = 1/b$) (Campbell *et al*., 1974).

Longevity of the parasitoid when no food or honey solution provided

One emerged *M. pulchricornis* female was put into acrylic cage (16 × 16 × 10 cm) with no food or 50% honey solution. Cages were maintained in the incubator set at nine temperatures: 15, 17.5, 20, 22.5, 25, 27.5, 30, 32.5 and 35°C (photo period 16L:8D). Mortality of the parasitoid was observed every 24 hours.

Age specific fecundity

For 24 hours, emerged parasitoids were allowed for oviposition in acrylic cages (16 × 16 × 10 cm) containing twenty 2nd or 3rd instar larvae of *S. litura* with 50% honey solution in the incubator set to 25°C, relative humidity 50 ± 10% and photoperiod 16L:8D. After parasitoid oviposition for 24 hours, *S. litura* were changed new one until parasitoid died. The number of cocoons formed was recorded every 24 hours.

Results and Discussion

M. pulchricornis were maintained at nine temperatures between 15 and 35°C. The developmental times from egg to pupa decreased from 38.7 to 17.5 d between 15 and 32.5°C. The developmental times from egg to cocoon, cocoon to adult emergence and egg to adult emergence at 25°C were 10.6, 7.6 and 18.2 days, respectively (Table 1). The developmental times of each three developmental stage decreased from 38.7 to 16.3 d between 15 and 30°C (Table 1). However, *M. pulchricornis* showed longer developmental time at 32.5°C (9.5, 7.7 and 17.2 days for each three developmental stage) than at 30°C (8.9, 7.3 and 16.3 days for each three developmental stage) (Table 1). Immature *M. pulchricornis* could not develop any more at 35°C (Table 1). The lower developmental threshold estimated by linear regression for the egg to cocoon, cocoon to adult emergence and egg to adult emergence were 5.1, 4.6 and 4.5°C (Table 2). The thermal constant for each of the three stages were 217.2, 176.2 and 403.8 degree-days,

Table 1. Development time (days ± SE), cocoon formation rate (%) and adult emergence rate (%) of *M. pulchricornis* on tobacco cutworm reared on artificial diet at nine constant temperatures and photoperiod 16L : 8D

Temp. (°C)	n	Egg to cocoon		Cocoon to adult emergence		Egg to adult emergence
		Development time	Cocoon formation rate	Development time	Adult emergence rate	
15	51	20.98 ± 2.02	38.89	17.71 ± 2.71	72.86	38.69
17.5	61	19.18 ± 2.18	22.67	14.41 ± 1.59	91.17	33.59
20	50	14.54 ± 0.54	27.73	11.58 ± 0.58	93.44	26.12
22.5	142	12.31 ± 1.69	50.00	9.56 ± 1.56	94.67	21.87
25	123	10.57 ± 2.43	41.75	7.64 ± 1.36	86.83	18.21
27.5	135	9.53 ± 2.47	54.33	7.61 ± 1.61	81.82	17.14
30	117	8.93 ± 1.93	37.22	7.32 ± 1.32	57.78	16.25
32.5	34	9.47 ± 1.53	20.24	7.68 ± 1.32	41.48	17.15
35	125	0	0	0	0	0

- Relative humidity 50 ± 10 %, photoperiod 16(L) : 8(D)

Table 2. Linear regression equations of developmental rate in relation to temperatures, estimated lower developmental threshold (T^0) and thermal constant (*DD*) for immature stage of *M. pulchricornis*

Period	Linear regression equation	R^2	T^0 (°C)	*DD* (°C days)
Egg to larva	Y=0.0046X–0.0241	0.99	5.12	217.23
Pupa	Y=0.0058X–0.0292	0.95	4.63	176.19
Egg to pupa	Y=0.0026X–0.0132	0.98	4.48	403.82

Table 3. *M. pulchricornis* longevity (days ± SE) when no food or 50% honey were provided at nine constant temperatures and photoperiod 16(L) : 8(D)

Temp. (°C)	Adult longevity			
	n	No food	n	50 % Honey solution
15	28	9.89 ± 2.11	40	104.43 ± 22.70
17.5	25	7.88 ± 2.12	34	125.82 ± 30.09
20	36	5.32 ± 2.36	28	123.93 ± 18.00
22.5	36	4.61 ± 1.61	29	67.62 ± 9.75
25	35	8.31 ± 4.31	45	55.95 ± 22.37
27.5	35	3.71 ± 3.29	30	43.9 ± 11.13
30	37	3.35 ± 1.35	28	17.5 ± 14.48
32.5	34	3.68 ± 1.68	30	9.73 ± 2.21
35	25	3.48 ± 1.48	45	17.71 ± 12.27

respectively (Table 2). The period from egg to cocoon (10.6 days), cocoon to adult emergence (7.6 days) and egg to adult emergence (18.2 days) at 25°C in this study was longer than that reported by Chhangan *et al*. (2008) (9.3 days for egg to larva, 6.7 days for pupa and 16.0 days for egg to adult at 25°C). They used painted apple moth, *Teia anartoides*, as host insect of *M. pulchricornis*. This difference between two results may attribute to different

Table 4. The number of cocoons formed on tobacco cutworm reared on artificial diet by *M. pulchricornis* female at 25°C, 50 ± 10% humidity and photoperiod 16(L) : 8(D)

Host	Number of cocoons (means ± SE)		
	n	per day	until died
Spodoptera litura	5,060	5.2 ± 4.5	131.6 ± 74.4

lepidopteran host.

When no food or 50% honey solution as a food source was provided for *M. pulchricornis*, the parasitoid survival was longer in 50% honey solution than in no food at all tested temperature (9.9, 7.9, 5.3, 4.6, 8.3, 3.7, 3.4, 3.7 and 3.5 days in no food source; 104.4, 125.9, 123.9, 67.6, 56.0, 44.0, 17.5, 9.7 and 17.7 days in 50% honey solution) (Table 3). It implies that honey solution can be a good food source for long survival of *M. pulchricornis*. A number of studies showed that any of a number of sugar sources obtained by parasitoid feeding is necessary for adult maintenance and survival of parasitoid (Heimpel and Collier, 1996; Heimpel *et al*., 1997; Jervis and Kidd, 1986, 1996; Jervis *et al*., 1996). In our study also showed *M. pulchricornis* can have longer life time by feeding honey solution than no feeding.

M. pulchricornis females laid 5.2 eggs daily and total of 131.6 eggs at 25°C until it died (Table 4). Fecundity of the parasitoid was steadily increased during the first 12 days after emergence. Then, peak age-specific fecundity was observed on the 14th day (9.6 cocoons a day) after parasitoid emergence and gradually decreased thereafter (Fig. 1).

The present study was carried out to investigate effect of temperature on development, effect of honey solution on the longevity and age-specific fecundity of *M. pulchricornis*. Our results can provide fundamental information (i.e., biological characteristics) for evaluating *M. pulch-*

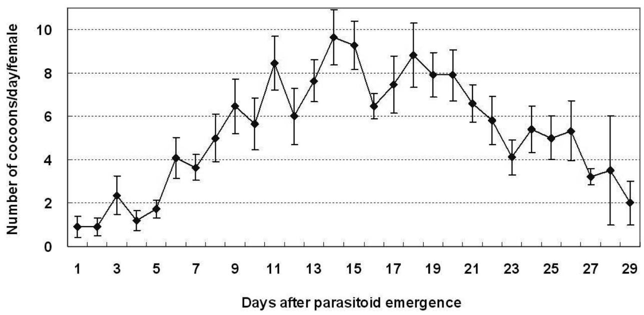

Fig. 1. Daily fecundity of *M. pulchricornis* females when provided with *S. litura* during its life span.

ricornis. However, for more comprehensive evaluation, additional researches such as intrinsic rate of increase, functional response, foraging behavior and semi-field trial for control of lepidopteran pests should be performed in the near future.

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