Appl. Entomol. Zool. 41 (4): 573–575 (2006)
http://odokon.org/

Development and reproduction of an exotic pest mealybug, *Phenacoccus solani* (Homoptera: Pseudococcidae) at three constant temperatures

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(Received 2 February 2006; Accepted 23 June 2006)

Abstract

The developmental and reproductive characteristics of a mealybug, *Phenacoccus solani*, were investigated at 20, 25, and 30°C and a photoperiod of 16L : 8D. The total developmental periods of the immature stages and the pre-reproductive period of adults decreased significantly with increased temperatures. Survival rates of immature stages were high at all temperatures. The number of offspring produced per female was significantly lower at 30°C than at other temperatures. Adults lived significantly longer at 20°C than at other temperatures. Generation time was longest at 20°C. The net reproductive rate and the intrinsic rate of natural increase were highest at 25°C.

Key words: Intrinsic rate of natural increase; generation time; net reproductive rate; survival; longevity

INTRODUCTION

The mealybug *Phenacoccus solani* Ferris, which is distributed worldwide, is a polyphagous species (Ben-Dov, 2005). This species is a serious insect pest of tobacco in Zimbabwe (Williams et al., 1985) and ornamentals in the USA (Hamlen, 1974). *P. solani* recently invaded Japan (Kawai, 2003), and has become a serious pest of the sweet pepper in greenhouses (Okabayashi, 2003). In Kochi Prefecture, Japan, *P. solani* is often found in pepper greenhouses where biological control is conducted to suppress other pests (Okabayashi, 2003). In these greenhouses, neonicotinoid granules and sprays that are non-selective systemic pesticides are applied to control plant-sucking pests including *P. solani*, and a deleterious side effect is observed on the predatory bug *Orius strigicollis* Poppius, which is released to control two thrips, *Thrips palmi* (Karny) and *Frankliniella intonsa* (Trybom) (Nakahira, unpublished). Therefore, biological, selective systemic, or selective non-systemic chemical controls that do not have side effects on natural enemies will eventually replace control with neonicotinoids. To select such alternative methods, the developmental characteristics of *P. solani* should be investigated, because the natural enemies may prefer specific developmental stages of the mealybug, and selective non-systemic chemical treatments may be effective just after molting of insects when the wax layer is still so thin that the chemical can penetrate the cuticle easily. In this study, the development and reproduction of *P. solani* were investigated under three temperatures.

MATERIALS AND METHODS

Insect. *P. solani* adults and nymphs were collected from sweet pepper plants in greenhouses in Kochi Prefecture, Japan in 2004. The adults and nymphs were maintained on young sweet pepper plants, at room temperatures of 20–30°C. *P. solani* shows thelytokous parthenogenesis (Lloyd, 1952); therefore, adults were individually reared on a strip of sweet pepper leaf (about 7×5 cm) to obtain the first instar female nymphs. The strip was put on agar medium (0.5%) in a plastic petri dish (9.0 cm in diameter, 2 cm high) to prevent desiccation, and maintained under 25°C and 16L : 8D.

Experiment. Newly-hatched nymphs (<24 h) were individually placed on a leaf strip on the agar medium in a dish. Experiments were carried out at three constant temperatures of 20, 25, and 30°C under a photoperiod of 16L : 8D. The developmen-

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DOI: 10.1303/aez.2006.573

Table 1. Developmental period and survival rate of the nymphal stage of *P. solani* at three constant temperatures under 16L : 8D

Temperature (°C)	n[a]	Developmental period in days (Mean±SD)				Survival rate (%)
		First instar[b]	Second instar[b]	Third instar[b]	Total[b]	
20	12	12.6±0.8 a	8.8±1.3 a	12.1±1.4 a	33.5±1.1 a	91.7
25	11	7.2±0.4 b	5.8±0.9 b	6.1±1.3 b	19.1±0.9 b	90.9
30	14	5.1±0.6 c	4.2±0.4 c	6.3±0.9 b	15.5±1.3 c	92.9

[a] Number of insects tested.
[b] Values in a given column followed by the same letter are not significantly different at the 5% level (Bonferroni multiple comparison test).

Table 2. Pre-reproduction period, number of offspring per female, and adult longevity of *P. solani* at three constant temperatures under 16L : 8D

Temperature (°C)	n[a]	Pre-reproduction period in days (Mean±SD)[b]	No. of offspring per female (Mean±SD)[b]	Adult longevity in days (Mean±SD)[b]
20	11	26.9±0.9 a	299.5±70.0 a	69.4±7.7 a
25	10	14.8±0.4 b	347.5±67.1 a	41.7±7.1 b
30	13	13.0±2.3 c	83.8±43.1 b	39.3±6.1 b

[a] Number of insects tested.
[b] Values in a given column followed by the same letter are not significantly different at the 5% level (Bonferroni multiple comparison test).

tal stage of nymphs was observed daily until they either died or became adults. After adult emergence, fertility was monitored daily until death. Offspring were counted and removed daily, and the leaf strip and agar medium were changed every three days.

Data analysis. The intrinsic rate of natural increase (r_m) was estimated using the equation provided by Birch (1948). The net reproductive rate (R_0) and mean generation time (T) in days were also calculated. Means were compared among temperatures using the Bonferroni multiple comparison test (SPSS Inc., 2002).

RESULTS AND DISCUSSION

The total developmental period of the immature stage of *P. solani* significantly decreased with increased temperatures, but there was no significant difference in the third instar period between 25°C and 30°C (Table 1). The survival rate of the immature stage was high (90.0–92.9%) at all temperatures tested. The pre-reproductive period after adult emergence also decreased significantly with increased temperatures (Table 2). The total number of offspring per female was significantly lower at 30°C than at other temperatures. Adults lived significantly longer at 20°C than at other temperatures (Table 2). The initial drop in the age-specific survival rate was later at 20°C than at 25 and 30°C (Fig. 1). The peak for the age-specific fecundity rate was the highest at 25°C (Fig. 1). Mean generation time (T) was longest at 20°C, followed by 25°C, and the net reproductive rate (R_0) was highest at 25°C (Table 3). The optimum temperature for *P. solani* among the three temperatures tested was 25°C in terms of the intrinsic rate of natural increase (r_m) (Table 3).

Another exotic pest mealybug of sweet pepper in Japan, *P. madeirensis* Green, has a wide host range and worldwide distribution like *P. solani* (Williams and Granara de Willink, 1992; Ben-Dov, 1994). This species is sometimes found with *P. solani* in greenhouses (unpublished), which seems to make their control difficult. According to Chong et al. (2003), *P. madeirensis* is oviparous and reproduces bisexually. Its nymphal development proceeds much slower compared with that observed for *P. solani* in this study. The two species also show large differences in reproductive performance and nymphal survival under certain conditions. These differences indicate that selective systemic chemi-

Table 3. Parameters related to potential rates of population increase of *P. solani* at three constant temperatures under 16L : 8D

Temperature (°C)	n^a	Mean generation time (T)	Net reproductive rate (R_0)	Intrinsic rate of natural increase (r_m)
20	12	69.1	274.5	0.081
25	11	40.1	315.9	0.144
30	14	33.1	77.9	0.131

[a] Number of insects tested.

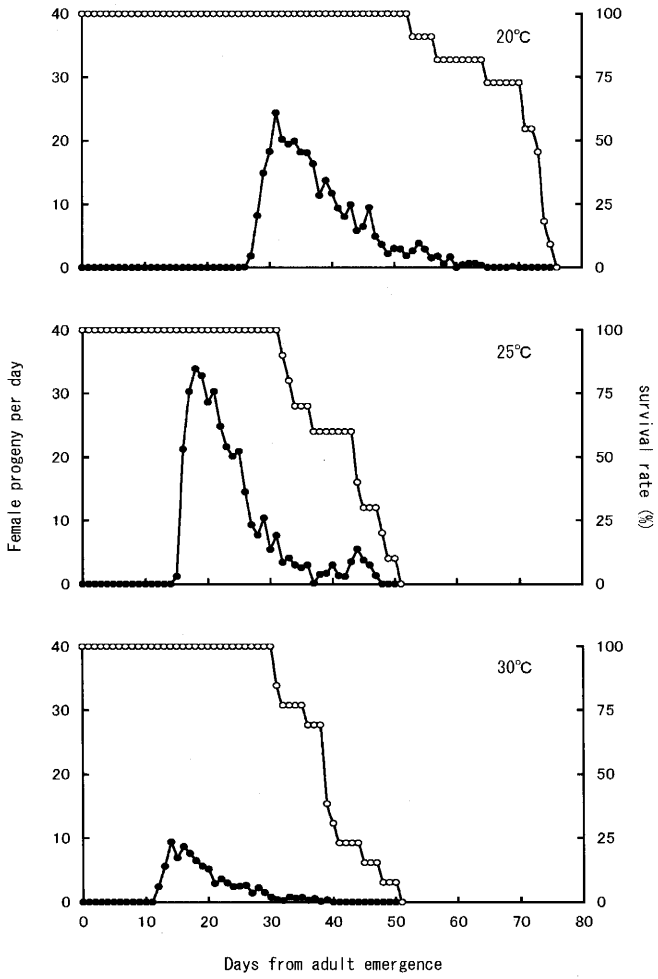

Fig. 1. Female progeny per day rate (closed circle) and survival rate (open circle) of *P. solani* adults at three constant temperatures under 16L : 8D.

cals and natural enemies, which kill a wide range of developmental stages, may be more effective in controlling these mealybugs than non-systemic chemicals that need to be sprayed at specific developmental stages of the insects.

ACKNOWLEDGEMENTS

The authors would like to thank Mr. I. Yamashita for instruction in the identification method of *P. solani*, and Mr. T. Okabayashi for guidance in *P. solani* collection. This study was supported in part by a Grant-in-Aid from the Japan Society for the Promotion of Science (no. 15208007).

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