복숭아심식나방 개체군동태에 대한 온도 상승의 영향: 시뮬레이션 연구

김동순[1], 이준호[2]
[1]제주대학교 아열대원예산업연구센터, [2]서울대학교 농업생명과학대학

The effects of elevated temperatures on the population dynamics of *Carposina saskii* (Lepidoptera: Carposiniade): a simulation study

Dong-Soon Kim[1*], and Joon-Ho Lee[2]
[1]*Subtropical Horticultural Research Center, Cheju National University*
[2]*Entomology Program, School of Agricultural Biotechnology, Seoul National University*

1. Introduction

Peach fruit moth (PFM), *Carposina sasakii* Matsumura, is a major insect pest of fruit tree in Korea. There are no previously published models for PFM. Population model could be used for timing spray in practice, and then for the projection of population change by environmental factors like elevated temperatures.

2. Model description

2.1 Model overview

The basic structure of the PFM population model is presented in Fig. 1. The total life span of PFM is divided into five development stages: (1) egg, (2) larva, (3) pupa, (4) winter cocoon (overwintering larva), and (5) adult. The only driving variable was temperatures (soil and air temperature on one day step). An assumption was made in the model that all mortality occurred at the time of transition to the next stage. Also, it was assumed that there were no emigration or immigration of PFM adults, and no population reduction by natural enemies. Major components of the model processes are temperature-dependent development of each stage and probability functions of their development completion times, adult reproduction, mortality during each stage including host plant effects, winter cocoon formation and insecticide effects. The full model was programmed in C^{++} and computed on the PC using Boland® C^{++} (1996).

2.2 Major sub-model and their process functions

The process functions for the spring emergence of overwintering larvae (larval cocoons), adult reproduction (ovipositon model), and stage emergence of each stage were obtained from the previously published data as seen in Table 1 with equations in Appendix 1.

2.3 Parameter estimation of other components

The temporal distribution of host plant effects was expressed as temporal distribution

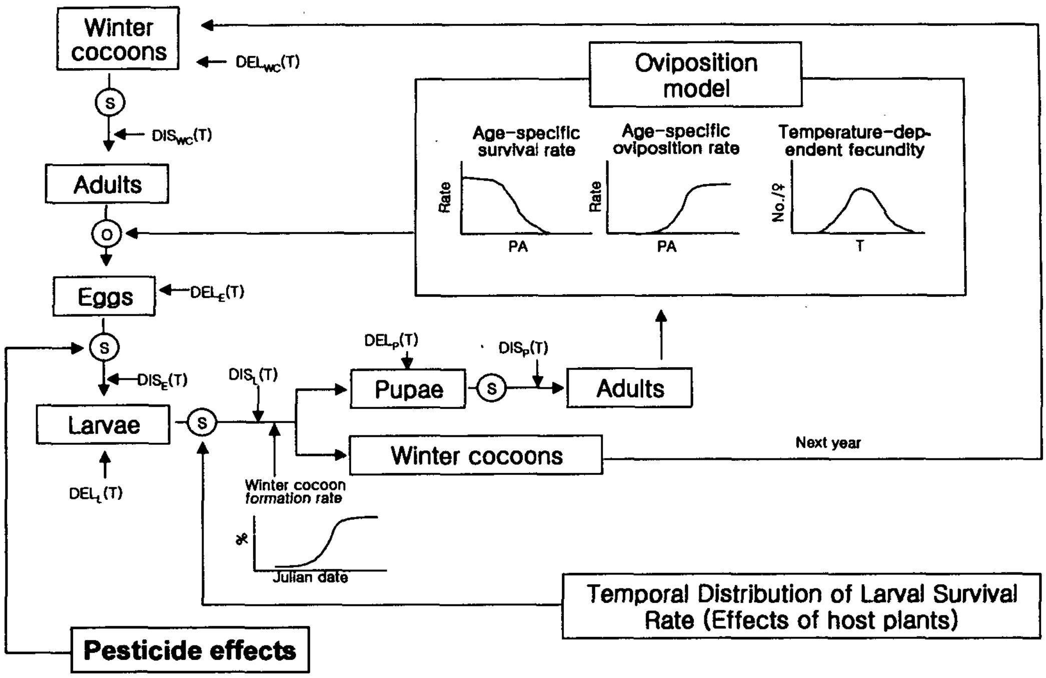

Fig. 1 The structure of PFM model. DEL: development model, DIS: distribution of development time, S: survival rate; O: oviposition model

of larval survival rate, and then it was incorporated into the model. Here, it was assumed different three orchard systems consisted of apple ('Fuji') and peach ('Kurakatawase').

System Ⅰ: A monoculture system of 'Fuji' apple was assumed. The larval survival rates in fruits were estimated using logistic power equation against Julian date (Table 1).

System Ⅱ: A monoculture system of 'Kurakatawase' peach was assumed. The model was operated until Julian date 203 because 'Kurakatawase' was an early cultivar, harvested almost at that time (Table 1). A constant larval survival rate was used, 43.7%.

System Ⅲ: In this system, a poly-culture system consisted of 'Fuji' apple and 'Kurakatawase' peach was assumed. The process function for the proportion of eggs laid between two crops was estimated by field data, using the modified logistic equation against Julian date (Table 1). Then, the survival of eggs on different fruits was separated in calculation processes.

Other componets such as winter cocoon formation and Insecticide effects were incorporated.

3. Model evaluation

3.1 Typical behaviors of simulation outputs

Typical behaviors of all stages simulated using average temperatures from 1968 to 1997 in the system I, II, and III with an assumption of no insecticide effects were compared. The abundance patterns of all stages were very different according to constituent of host plants (system I, II, and III). There were three peaks of adult emergence in the system I and III, while two peaks were simulated in the system II.

Table 1. Parameter valuesof each equation used for PFM model

Models	Equation	Parameters						Ref.
		α_1	β_1	γ_1	α_2	$\triangle\beta$	γ_2	
Spring emergence model	1	78.2899	888.8454	108.7697	22.9771	653.3927	−17.4520	Kim *et al.*, 2000
Development of each stage		RHO25	HA	TH	HH			
Eggs	2	0.1721	22,734.0	304.6372	47,922.1			Kim *et al.*, 2001
Larvae	2	0.0668	18,455.3	304.2837	46,233.7			Kim *et al.*, 2001
Pupae	2	0.0855	20,025.8	304.5422	131,610			Kim *et al.*, 2001
Distribution of each stage		a	b					
Eggs	3	0.9867	10.2820					Kim *et al.*, 2001
Larvae	3	0.9629	13.8304					Kim *et al.*, 2001
Pupae	3	1.0490	6.9068					Kim *et al.*, 2001
Oviposition model								
		RHO25	HA	TL	HL			
Adult longevity	2	0.1118	12,974.9	285.1304	−64,050			Kim and Lee, 2003
		a	b	k				
Total fecundity	4	105.3434	22.3730	3.9910				Kim and Lee, 2003
		a	b					
Oviposition rate	3	0.6924	3.6124					Kim and Lee, 2003
		γ	δ					
Survival rate	5	0.8882	−0.2002					Kim and Lee, 2003
		a	b					
Winter cocoon formation	6	227.65	−42.15					Kim, 1999
		a	b	c	d			
Larval survival in apple	7	27.45	238.31	10.49	1.00			Kim, 1999
		a	b					
The proportion of eggs laid on apple	6	197.29	−31.66					Kim, 1999
		a	b	c				
Insecticide residual effects	8	10.34	0.022	0.01				Kim, 1999

The overall pattern of adult occurrence was similar between simulation output and actual catch. Also, the second adult peak date was closer to the actual date in output including insecticide effects than in output without insecticide. However, simulation result underestimated the size of the first peak and third peak compared to the actual data.

3.2. Effects of elevated temperatures

Sensitivity of the model outputs to temperature changes was examined by running the model with the driving temperatures increased or decreased by 3℃ from the daily average temperatures of 1968 to 1997 (original run). Higher soil and air temperature led to earlier adult peak dates compared to the original run, while the adult peak dates were postponed by lower soil and air temperature. The largest peak size was observed in the higher soil temperature simulation. In contrast, smaller adult peak size was observed in both lower soil and air temperature simulation. Higher air temperature produced wider last peak. It was somewhat similar to the results of pheromone trap catch in 1994 in which the average air temperature was higher as much as 1.5℃ than the average air temperature for the original run. In field condition, an obscure later peaks (2nd and 3rd peak) were occurred in 1995, with lower soil temperatures.

References

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Kim D. S., J. H. Lee and M. S. Yiem. 2000. Spring emergence pattern of *Carposina sasakii*(Lepidoptera: Carposinidae) in apple orchards in Korea and its forecasting models based on degree-days. *Environ. Entomol.* 29: 1188-1198.

Appendix I. The lists of equations used in the PFM model. The same parameter symbols used in different equations may assume different meanings and value depending on the corresponding equations.

$$f(x) = \alpha_1\left[\frac{1}{1+exp\left[-\dfrac{x-\beta_1}{\gamma_1}\right]} + \left(\frac{\alpha_2}{\alpha_1}\right)\Big/\left[1+\left(\frac{x}{\beta_1+\triangle\beta}\right)^{\gamma_2}\right]\right] --- 1;$$

$$r(T) = \frac{RHO25\dfrac{T}{298.15}\,exp\left[\dfrac{HA}{R}\left(\dfrac{1}{298.15}-\dfrac{1}{T}\right)\right]}{1+exp\left[\dfrac{HL}{R}\left(\dfrac{1}{TL}-\dfrac{1}{T}\right)\right]+exp\left[\dfrac{HH}{R}\left(\dfrac{1}{TH}-\dfrac{1}{T}\right)\right]} --- 2;$$

$$f(x) = 1 - exp(-[(x/a)^b]) ---- 3;$$

$$f(T_c) = a \cdot exp[1+(b-T_c)/k - exp((b-T_c)/k)] --- 4;$$

$$s(Px) = \frac{1}{1+exp[(\gamma-px)/\delta]} --- 5; \qquad w(x) = \frac{100}{1+(\frac{x}{a})^b} --- 6;$$

$$l(x) = \frac{a}{d}\left[1+\exp\left(\frac{x+c\ln d-b}{c}\right)\right]^{\frac{-d-1}{d}}\exp\left(\frac{x+c\ln d-b}{c}\right)(d+1)^{\frac{d+1}{d}} --- 7;$$

$$p(x) = \frac{1}{\left[1+\exp\left(-\dfrac{x-b\ln(2^{1/c}-1)-a}{b}\right)\right]^c} --- 8$$