

SIMULATION OF THE POPULATION DYNAMICS OF THE GREENHOUSE  
WHITEFLY, *TRIALEURODES VAPORARIORUM* AND THE PARASITOID  
*ENCARSIA FORMOSA*

H.J.W. Van Roermund <sup>1,2)</sup> and J.C. Van Lenteren <sup>1)</sup>

<sup>1</sup> Department of Entomology, Wageningen Agricultural University,  
P.O. Box 8031, 6700 EH Wageningen, The Netherlands.

<sup>2</sup> Department of Theoretical Production Ecology,  
P.O.Box 430, 6700 AK Wageningen, The Netherlands

### Summary

Biological control of greenhouse whitefly with the parasitoid *Encarsia formosa* has been very successful on vegetables since 1970. Much experimental research has been published on this pest insect and its parasitoid. These experimental results will be used in a simulation model of the population dynamics of the tritrophic system host plant-pest insect-parasitoid. The present paper summarizes experimental results published after 1983 and describes the development in modelling of this system.

### 1. Introduction

Research on greenhouse whitefly control with the parasitoid *Encarsia formosa* had already started circa 1920. After a lapse in interest following the second world war, biological control of this pest received more attention again circa 1970, due to problems of resistance and negative side-effects of chemical pesticides. At the moment, around 120 articles have been published on the pest insect, the parasitoid and/or their relationship as influenced by host plant and environmental factors. Data from these articles will be used to develop a simulation model of the population dynamics of the pest insect and its parasitoid, that includes the relationships between host plant, pest insect, parasitoid and the environment. The aim of this study is to increase the explanatory insight into a tritrophic system in order to improve biological control measures.

### 2. Summary of new research data

Hulspas-Jordaan and van Lenteren (1989) and Yano et al. (1989a, 1989b) developed a simulation model of the population dynamics of the greenhouse whitefly. A simplified, very user friendly version of the model was developed by van Giessen & Mollema (in prep). The main input for the model are autecological parameters, such as longevity, oviposition frequency, immature mortality, development duration from egg to adult and sex ratio. These parameters have been reviewed by, among others, van Lenteren and Hulspas-Jordaan (1983), Hulspas-Jordaan and van Lenteren (1989) and Yano et al. (1989b). A more complete review will be published containing autecological data from 1915-1989 of greenhouse whitefly and *Encarsia formosa* (mean, coefficient of variation, number of replicates, number of individuals per replicate) at different temperatures, host plants (variety) and host insect stages (van Roermund and van Lenteren, in prep). With this more complete data-set the above mentioned autecological parameters will be described as a function of temperature for each host plant (variety) or host insect stage separately. These functions will be the input for the simulation model. Most literature on autecological parameters was published in 1976-1983. New results, if different from information before 1983, are summarized in table 1 and will be discussed below.

Table 1. Summary of new research data if different from publications before 1983. Fecundity in eggs/female/lifetime, oviposition in eggs/female/day, immature mortality in %, development duration from egg to adult in day, temperature in degrees Celcius. Tv= *Trialeurodes vaporariorum*, Bt= *Bemisia tabaci*.

*T. vaporariorum*

<u>Fecundity</u>	<u>Oviposition</u>	<u>Host</u>	<u>Tempera- ture</u>	<u>Reference</u>
52-83	4.2-4.6	Sweet pepper	23.4	10
157	-	Gerbera	30.0	2
-	2.4-6.8	Gerbera	15.0-30.0	2
-	2.8-3.2	Sweet pepper	24.4	15
-	1.7-7.8	Sweet pepper	20.0	6
<u>Longevity</u>				
8-18		Sweet pepper	23.4	10
59-97		Eggplant	24	12
22-60		Gerbera	15-30	2
<u>Mortality</u>				
59.8		Tomato	22.9	10
1.8-6.5		Tomato	15.0-25.0	1
37-95		Sweet pepper	23	10,15
4.2-20.2		Eggplant	24	12
3.3-16.1		Gerbera	15-25	1
50.5		Gerbera	30	2
<u>Duration</u>				
27.4-26.6		Sweet pepper	22.9	10
27.2-27.4		Sweet pepper	24.4	15
29.1-32.4		Sweet pepper	20	6
57.0-22.1		Gerbera	15-30	2

*E. formosa*

<u>Fecundity</u>	<u>Oviposition</u>	<u>Host</u>	<u>Tempera- ture</u>	<u>Reference</u>
290	5.6	L1-P Tv/Bean	20	9
<u>Longevity</u>				
52		L1-P Tv/Bean	20	11
18.7		L3L4 Bt/Bean	25	
<u>Mortality</u>				
10.2		L3L4 Bt/Bean	25	11
<u>Duration</u>				
9.4-13.5		L1-P Bt/Bean	25	

The oviposition frequency of greenhouse whitefly on sweet pepper published by van Lenteren et al (1989), Laska et al. (1986), and van Vianen et al. (1987) is higher than published earlier. This could be due to adaptation of the whitefly to the host plant. A difference has been found between Dutch and Hungarian whitefly strains (van Vianen et al., 1987; van Lenteren et al., 1989). New results on tomato and eggplant are the same as those

published earlier. On gerbera results are comparable with tomato, except for at high temperatures where oviposition frequency is higher (Dorsman and van de Vrie, 1989). In general, the variation between individuals used in the same experiment is high: in 57 experiments the average CV (coefficient of variation) is 54 %.

The **immature mortality** varies quite a lot among different experiments and seems to be rather sensitive to the host plant variety (as shown for eggplant by Malausa, 1988) and it varies between whitefly strains (van Lenteren et al., 1989). On gerbera mortality was higher than on tomato, although in that experiment mortality on tomato was quite low (Dorsman and van de Vrie, 1987). Van Lenteren et al. (1989) found a much higher mortality on (another variety of) tomato. The CV between individuals is 19 % averaged over 6 experiments.

The **longevity** of greenhouse whitefly on sweet pepper and eggplant is higher than published earlier (van Lenteren et al., 1989; Malausa et al., 1988). On tomato new results do not differ from previously published data. On gerbera the longevity seems to be higher than on tomato (Dorsman and van de Vrie, 1989). The CV between individuals is 50 % averaged over 64 experiments.

The **developmental duration** on sweet pepper is shorter than in earlier publications (Laska et al. 1986; van Vianen et al., 1987; van Lenteren et al., 1989). Again whitefly adaptation could be the cause. On tomato and eggplant it is the same as published earlier. New results were published for gerbera (Dorsman and van de Vrie, 1989). The CV between individuals is low: 7 % averaged over 26 experiments.

New results for *Encarsia formosa*. The **fecundity** of *Encarsia formosa* as observed by van Lenteren (1987) is high compared with data in most other publications. The host stage parasitized seems to be important; fecundity and oviposition frequency are lower when second instead of third or fourth host instars are offered. The CV between individuals is 32 % averaged from 29 experiments.

Also van Lenteren (1987) observed a high **longevity**. The longevity when emerged from *T. vaporariorum* seems to be the same as when *Bemisia tabaci* acts as host (Lopez Avila, 1988). In general, the longevity is higher without hosts, but with honeydew. The CV between individuals is 34 % averaged over 30 experiments.

There are no new results on **immature mortality** on *T. vaporariorum*. It seems to be higher when *Bemisia tabaci* is offered (Lopez Avila, 1988). In general, mortality is influenced by the host stage; it is lowest in the second and third host instar.

New results on **developmental duration** are not different. The developmental duration seems to be the same when *Bemisia tabaci* is used as host (Lopez Avila, 1988). Here also the host stage is important: the developmental duration is shortest on third and fourth instar nymphs. The CV between individuals is 8 % averaged over 68 experiments.

### 3. Development of simulation model

The simulation model developed by Hulspas-Jordaan and van Lenteren (1989) and Yano (1989a) is the basis for further development. The model for whitefly population dynamics has been rewritten in FORTRAN and structured into different submodels (subroutines). FORTRAN has been chosen because it is the most widely used computer language in mathematical and physical science; libraries with subroutines have been published and are available. This model will be extended by a model of *Encarsia formosa* population dynamics. These two (sub)models will be coupled by a functional response. As a start the functional response as measured experimentally can be taken (Fransen and van Montfoort, 1987; Yano, 1989). Some parameters, like the searching efficiency and the handling time can be related to environmental factors (temperature) or internal state of the parasitoid (number of mature eggs in ovariole). It is also possible to make a separate model to simulate the functional response by integrating behavioural components at the individual level (e.g. walking

speed, host acceptance, oviposition, host feeding). Simulation results generated at different host densities but at constant environmental conditions will be used to derive a functional response. Thus these equations derived by simulation at the individual level will be input for the model at the population level. In this way a simulation model for population dynamics of pest insect and parasitoid at the leaf level can be developed. It will only be used to simulate population dynamics within one patch, in which the insect density can be assumed to be constant (one-patch model).

To simulate the population dynamics at the canopy level, total canopy area will be divided into compartments. For every compartment, population dynamics will be calculated separately by using the first model as subroutine (multiple-patch model). If a vertical differentiation is desired, the canopy can be divided into leaf layers. If computation time appears to become too long, population density as simulated by the one-patch model can be used to fit a function (or table) which will be the input for the multiple-patch model. Insects can be divided among the compartments by a statistical distribution as measured experimentally. As this is unknown for the parasitoid, several distribution patterns can be assumed to study their effect.

A next step in the development of the multiple-patch model is the simulation of the dispersion processes to explain the spatial development instead of describing it by a statistical distribution in order to increase the explanatory character of the model. The data of Noldus et al. (1986) can be used for whitefly but experiments need to be done on the dispersion of *Encarsia* adults.

#### 4. Aim of the modelling approach

The advantages of a simulation model approach to biological control is that it indicates shortages in knowledge, gives a better understanding of complex systems, enables distinction between important and less important factors influencing population dynamics, and allows predictions to be made. In our case it will be used to predict whether or not biological control will be feasible in a certain combination of host plant, pest insect, parasitoid and environment, and if not, to understand which factors are responsible for the failure. Additional possibilities are to extend the model with other natural enemies of whitefly, e.g. the fungus *Aschersonia aleyrodis*, or with other host insects, such as *Bemisia tabaci*.

#### Acknowledgement

The first author is financially supported by the Netherlands Technology Foundation (STW), and is coordinated by the Foundation for Biological Research (BION).

#### 5. References

- DORSMAN, R. & VRIE, M. VAN DE, 1987. Population dynamics of the greenhouse whitefly *Trialeurodes vaporariorum* on different gerbera varieties. Bull. IOBC/WPRS 1987/X/2: 46-51.
- DORSMAN, R. & VRIE, M. VAN DE, in prep. Population dynamics of the greenhouse whitefly on gerbera.
- FRANSEN, J.J. & MONTFORT, M.A.J. VAN, 1987. Functional response and host preference of *Encarsia formosa* Gahan (Hym., Aphelinidae), a parasitoid of greenhouse whitefly *T. vaporariorum* (Westwood) (Hom., Aleyrodidae). J. Appl. Ent. 103: 55-69.
- GIESSEN, W.A. & MOLLEMA, C., in prep. A computer simulation model as a tool to develop a testing method for resistance to whitefly (*Trialeurodes vaporariorum* Westwood) in tomato.
- HULSPAS-JORDAAN, P.M. & LENTEREN, J.C. VAN, 1989. The parasite-host relationship between *Encarsia formosa* (Hymenoptera: Aphelinidae) and *Trialeurodes vaporariorum* (Homoptera: Alcyrodidae). XXX. Modelling population growth of greenhouse whitefly on tomato. Wag. Agric. Univ. Papers 89-2: 1-54.
- LASKA, P., BETLACH, J. & HAVRANKOVA, M., 1986. Variable resistance in sweet pepper, *Capsicum annuum*, to glasshouse whitefly, *Trialeurodes vaporariorum* (Homoptera, Alcyrodidae). Acta ent. bohemoslov. 83: 347-353.

- LENTEREN, J.C. VAN & HULSPAS-JORDAAN, P.M., 1983. Influence of low temperature regimes on the capability of *Encarsia formosa* and other parasites in controlling the greenhouse whitefly, *Trialeurodes vaporariorum*. Bull. IOBC/WPRS VI/3: 54-70.
- LENTEREN, J.C. VAN & HULSPAS-JORDAAN, P.M., 1987. *Encarsia formosa* can control greenhouse whitefly at low temperature regimes. Bull. IOBC/WPRS X/2: 87-91.
- LENTEREN, J.C. VAN, VIANEN, A. VAN, GAST, H.F. & KORTENHOFF, A., 1987. The parasite-host relationship between *Encarsia formosa* Gahan (Hymenoptera: Aphelinidae) and *Trialeurodes vaporariorum* (Westwood) (Homoptera: Aleyrodidae). XVI. Food effects on oogenesis, oviposition, life-span and fecundity of *Encarsia formosa* and other hymenopterous parasites. J. Appl. Ent. 103: 69-84.
- LENTEREN, J.C. VAN, VIANEN, A. VAN, HATALA-ZSELLER, I. & BUDAI, Cs., 1989. The parasite-host relationship between *Encarsia formosa* Gahan (Hymenoptera, Aphelinidae) and *Trialeurodes vaporariorum* (Westwood) (Homoptera, Aleyrodidae) XXIX. Suitability of two cultivars of sweet pepper, *Capsicum annuum* L., for two different strains of whiteflies. J. Appl. Ent. 108: 113-120.
- LOPEZ AVILA, A., 1988. A comparative study of four species of *Encarsia* (Hymenoptera: Aphelinidae) as potential control agents for *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae). PhD-thesis, University of London, 302 pp.
- MALAUSSA, J.C., DAUNAY, M.C. & BOURGOIN, T., 1988. Recherches préliminaires sur la résistance de l'aubergine à l'aleurode des serres, *Trialeurodes vaporariorum* Westwood, (Homoptera, Aleyrodidae). Agronomie 8: 693-699.
- NOLDUS, L.P.J.J., XU, R.M. & LENTEREN, J.C. VAN, 1986. The parasite-host relationship between *Encarsia formosa* Gahan (Hymenoptera: Aphelinidae) and *Trialeurodes vaporariorum* (Westwood) (Homoptera: Aleyrodidae). XVIII. Between-plant movement of adult greenhouse whiteflies. J. Appl. Ent. 101: 159-176.
- ROERMUND, H.J.W. VAN & LENTEREN, J.C. VAN, IN PREP. An estimation of autecological parameters of *Trialeurodes vaporariorum* Westwood and *Encarsia formosa* Gahan as input for a simulation model of the population dynamics.
- VIANEN, A. VAN, BUDAI, Cs. & LENTEREN, J.C. VAN, 1987. Suitability of two strains of sweet pepper, *Capsicum annuum* L., for the greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood), in Hungary. Bull. IOBC/WPRS X/2: 174-179.
- YANO, E., 1989. A simulation study of population interaction between the greenhouse whitefly, *Trialeurodes vaporariorum* Westwood (Homoptera: Aleyrodidae) and the parasitoid *Encarsia formosa* Gahan (Hymenoptera: Aphelinidae). I. Description of the model. Res. Popul. Ecol. 31: 73-88.
- YANO, E., LENTEREN, J.C. VAN, RABBINGE, R. & HULSPAS-JORDAAN, P.M., 1989a. The parasite-host relationship between *Encarsia formosa* (Hymenoptera: Aphelinidae) and *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae). XXXI. Simulation studies of population growth of greenhouse whitefly on tomato. Wag. Agric. Univ. Papers 89-2: 55-73.
- YANO, E., LENTEREN, J.C. VAN, RABBINGE, R., VIANEN, A. VAN & DORSMAN, R., 1989b. The parasite-host relationship between *Encarsia formosa* (Hymenoptera: Aphelinidae) and *Trialeurodes vaporariorum* (Homoptera: Aleyrodidae). XXXII. Simulation studies of population growth of greenhouse whitefly on eggplant, cucumber, sweet pepper and gerbera. Wag. Agric. Univ. Papers 89-2: 75-99.