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Longevity, fecundity, oviposition frequency and intrinsic rate of increase of the greenhouse whitefly, *Trialeurodes vaporariorum* on greenhouse tomato in Colombia

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Abstract

Longevity, fecundity, oviposition frequency and intrinsic rate of increase (r_m) of the greenhouse whitefly were determined on beef tomato cv. Boris, in an unheated, automated greenhouse with an average temperature of the 16 °C and an average RH of 81%. The mean longevity of females and males was 36.5 and 47.2 days, respectively. The fecundity was 208.5 eggs per female, the oviposition frequency was 5.7 eggs per living female per day, and the intrinsic rate of increase was 0.0645. These values are higher if compared to results of previous research on tomato in general, but it is known that beef tomato cv.'s are better host plants than round tomato cv.'s. When compared to the results of a previous study on beef tomato in The Netherlands, the longevity was shorter, the oviposition frequency was higher and the fecundity was similar. The Colombian whitefly strain shows differences in longevity and oviposition frequency when compared to European whitefly strains. The estimated r_m of *Encarsia formosa*, parasitoid of *T. vaporariorum*, was 0.0974 and is considerably higher than the r_m of the greenhouse whitefly determined under the same experimental conditions. This is a promising indication for biological control of greenhouse whitefly in Colombian greenhouses.

Key words: Beef tomato, fecundity, host plant quality, intrinsic rate of increase, longevity, oviposition frequency, *Trialeurodes vaporariorum*, unheated greenhouse, strain.

Introduction

Biological control of the greenhouse whitefly *Trialeurodes vaporariorum* (Westwood) by *Encarsia formosa* (Gahan) is normal practice on more than 5000 ha in countries with important greenhouse industries (van Lenteren, 1992; 1995). Decades of research have revealed the relationship between *E. formosa* and its host, as well as the host plant. In most cases, *E. formosa* has a higher progeny production – a higher intrinsic rate of increase (r_m) - than *T. vaporariorum*, and can maintain its host well below economic thresholds. Nevertheless, in some cases, biological control is not successful. When host plant quality is excellent for *T. vaporariorum* its r_m increases considerably while the r_m of *E. formosa* remains constant. Low greenhouse temperatures can also have a negative influence on biological control by reducing the r_m of *E. formosa*, and its activity and mobility (van Lenteren *et al.*, 1996).

In Colombia, the production area of greenhouse tomatoes is increasing. The climate of unheated greenhouses on the Bogotá plateau is cool with a mean daily temperature of 15 to 16 ºC. *T. vaporariorum* is an important pest in this production system. Growers would like to use biological control. However, no data are available on the development of *T. vaporariorum* and its parasitoid *E. formosa* under these specific conditions. The present research forms a first step in the development of a biological control system for *T. vaporariorum* under Colombian greenhouse conditions.

Studies by van Es (1982) have shown that the European strains of the greenhouse whitefly develop better on beef tomato than on round tomato. The fecundity on beef tomato cv. Dombo and Portanto was 216 and 219 respectively, more than double as high as the fecundity on a round tomato cv. Moneydor, which was 90. The longevity on the cv.'s Dombo and Portanto was 57 and 69 days respectively, compared to only 37 days on the cv. Moneydor. The immature mortality and the time required for immature development, however, were similar for both types of tomatoes. Other studies have shown differences in population growth parameters of *T. vaporariorum* strains. An example is the difference between Dutch and Hungarian whitefly strains (van Lenteren *et al.*, 1989), where Hungarian whiteflies had an immature mortality of 36.9% compared to 76.7% for Dutch whiteflies, both on Hungarian sweet pepper. Because of this big difference in immature mortality, the net reproduction rate (Ro, number of females/female) was higher for the Hungarian whitefly strain, although the fecundity was lower. The Ro was 9.7 and 15.5 for the Dutch and Hungarian whitefly strains respectively. Average life span, development time and fecundity were, on the contrary, higher for the Dutch whitefly strain. It is assumed that these differences have developed during the past century as *T. vaporariorum* was introduced for the first time in 1856 on the European continent, when it was accidentally imported into the UK, supposedly from the Americas. It may be well possible that the Colombian strain of *T. vaporariorum* differs from the European strains.

In this paper, we present data on longevity, fecundity, oviposition frequency and the intrinsic rate of increase of a Colombian strain of *T. vaporariorum* under local greenhouse conditions on the tomato cv. Boris.

Materials and methods

The experiment took place at the Horticultural Research Centre (CIAA) of the Jorge Tadeo Lozano University in Chia, on the Bogotá Plateau, at 2600 m above sea level in Colombia.

An unheated greenhouse with automated ventilation and continuous climate monitoring was used for the experiment. The climate computer calculated and saved mean temperature and relative humidity measurements every ten minutes. Based on these data, hourly mean temperature, relative humidity were calculated and the mean and standard deviation of the temperature and relative humidity for each hour of the day, with days as replicates.

Seven-week-old tomato plants of the cv. Boris (Bruinsma Seeds, 's Gravenzande, The Netherlands) were transplanted into two beds on March 6, 1998. At the beginning of the experiment (23/4), the plants measured 77 cm and had 17 leaves. Fertilisation took place based on regular soil analyses. The soil was fertilised prior to transplant and as of 16 April, weekly until the end of the experiment.

Adult whiteflies were removed three times a week with an aspirator to prevent them from ovipositing on the leaves that would be used for the experiment The tomato russet mite, *Vasates lycopersici* (Massee) was controlled two times with sulphur (Elosal, 4 ml/l). The application was done in two stages. Before spraying, the clip cages in which we kept the whiteflies for the experiment were moved to the plants of one bed and the other bed was spayed. Two days later, the whiteflies were all transferred to clean clip cages and placed on the plants of the previously treated bed and the untreated bed was sprayed.

Tomato leaves containing whitefly pupae from the CIAA's rearing unit were placed in a climatized room at 23 ºC on April 22. The following day, whiteflies were collected and separated into pairs, one male and one female. Fifty pairs were mounted on the tomato plants in the greenhouse, using clip cages of two cm in diameter. The cages were mounted on the third expanding leaf of the plant, where the whiteflies would normally be found, one clip cage per plant. Every two days, the clip cages with the whiteflies were moved to a new leaf of the same plant. Before moving, the new leaflet was controlled for the presence of whitefly eggs and if eggs were found, the leaflet was rejected. Mortality was recorded and if a male died before the female, a new male was introduced into the clip cage. The leaflets used the previous 2 days, were detached and brought to the laboratory where the number of deposited eggs were counted using a stereomicroscope. The trial ended on July 18.

The mean and standard deviation of the longevity of males and females was calculated, assuming that an individual died the day before it was found dead in the clip cages. The mean and standard deviation of the number of eggs per introduced female per two days, the number of eggs per living female per two days, and total fecundity were also calculated. The average oviposition frequency was calculated as mean fecundity/mean longevity. The intrinsic rate of increase (r_m) was calculated using the two equations of Andrewartha *et al.* (1954):

1. $r_{m1} = (\ln R_{o1})/T_1$

   where R_{o1} is the net reproductive rate (or number of females produced by one female) and T_1 the generation time. R_{o1} is calculated as the product of fecundity, immature survival rate and the sex ratio. T_1 is calculated as the sum of the immature development time and the time required until 50% of the eggs are laid.
2. $r_{m2} = (\ln R_{o2})/T_2$

   where R_{o2} is the net reproductive rate and T_2 the mean generation time calculated as:

   $R_{o2} = \Sigma L_x M_x$ and $T_2 = \Sigma L_x M_x X / \Sigma L_x M_x,$

   where L_x and M_x are the age-specific survival rate and the age-specific fecundity, respectively (x = age).

Table 1. Longevity, fecundity, oviposition frequency and intrinsic rate of increase (r_m) of *T. vaporariorum*.

Authors, year	Tomato cv.	Type	Temperature (min-max) ºC	Longevity days	Fecundity eggs $female^{-1}$	Oviposition frequency $eggs \cdot female^{-1} \cdot day^{-1}$	r_m
Burnett, 1949	Bonnie Best	-	15.0	50.5	93.6	1.9	
Hussey and Gurney, 1957	-	-	15.6	31.3	131.5	4.2	
Loyd, 1922	-	-	17.3 (6.1-37)	34.0	92.0	2.7 [a]	
van Es, 1982	Dombo Portanto Moneydor	Beef Beef Round	22.5 (16-24)	57.4 68.6 37.1	215.6 219.0 90.4	3.7 [a] 3.2 [a] 2.7 [a]	0.0742 [b] 0.0744 [b] 0.0633 [b]
This trial, 1998	Boris	Beef	16.0 (5.4-30)	36.5	208.5	5.7	0.0645-0.0666

[a] Recalculated: fecundity/longevity

[b] Estimated

Results

The mean temperature during the trial was 16.0 ± 5.1 ºC and the mean relative humidity was 81 ± 13.3%. The mean temperature curve (figure 1A) showed that the mean night temperature was slightly above 10 ºC with a small standard deviation. During the day, the temperature reached a platform of almost 23 ºC with a higher standard deviation than at night.

The mean relative humidity (figure 1B) was above 90% during the night showing hardly any variation. During the day, the mean relative humidity showed a minimum of 65% with a standard deviation up to 12.5%. During the first two weeks of the experiment and during day 28-35, the temperature was higher than the mean temperature (figure 1C). The mean daily relative humidity was lower during the first month and oscillated between 74 and 92%.

The mean longevity of the females was 36.5 ± 18.2 days with a minimum of 7 and a maximum of 85 days. The mean longevity of the males was 47.2 ± 20.0 days with a minimum of 7 and a maximum of 89 days. The total fecundity was 208.5 ± 146 eggs per female with a maximum of 581 and a minimum of 20 eggs. The average oviposition frequency was 5.7 eggs per living female per day.

The first females died after 10 days and the mortality is almost constant until day 56 (2% / day) and then becomes smaller (0.33% / day) (figure 2A). The number of eggs per introduced female per two days increased fast to a maximum of 15.5 on day 8 after the start of the trial to decline slowly afterwards. The number of eggs per living female reached its maximum at the same day and then declined stepwise (figure 2B). The standard deviation of the oviposition frequency was most of the time above 7 (figure 2C).

Sex ratio, immature mortality, and the time required for immature development were not determined in this study. However, van Es (1982) didn't find differences between immature mortality, sex ratio, and development duration from egg to adult when determined on beef tomato or when determined on a round tomato.

Van Roermund and van Lenteren (1992) summarised all data for immature mortality an sex ratio. From their review we conclude that their is also variability in these characteristics, which might be related to whitefly strain differences, but as we could not trace a clear trend between host plant quality, sex ratio and immature mortality, we will use the average data of van Roermund and van Lenteren (1992) for our calculations: 16.7% for the immature mortality and 0.483 for the sex ratio. The time required for immature development (48.5 days) was calculated based on the hourly temperature data and the equation of van Roermund and van Lenteren (1992). The time until 50% of the eggs were laid was 18 days. According to the first calculation method, the generation time, T_1, was 66.5 days; the net reproduction rate, R_{o1}, 84.1; and the intrinsic rate of increase, r_{m1}, 0.0666. According to the second equation, the generation time, T_2, was 69.9; the net reproduction rate, R_{o2}, 91.2; and the intrinsic rate of increase, r_{m2}, 0.0645.

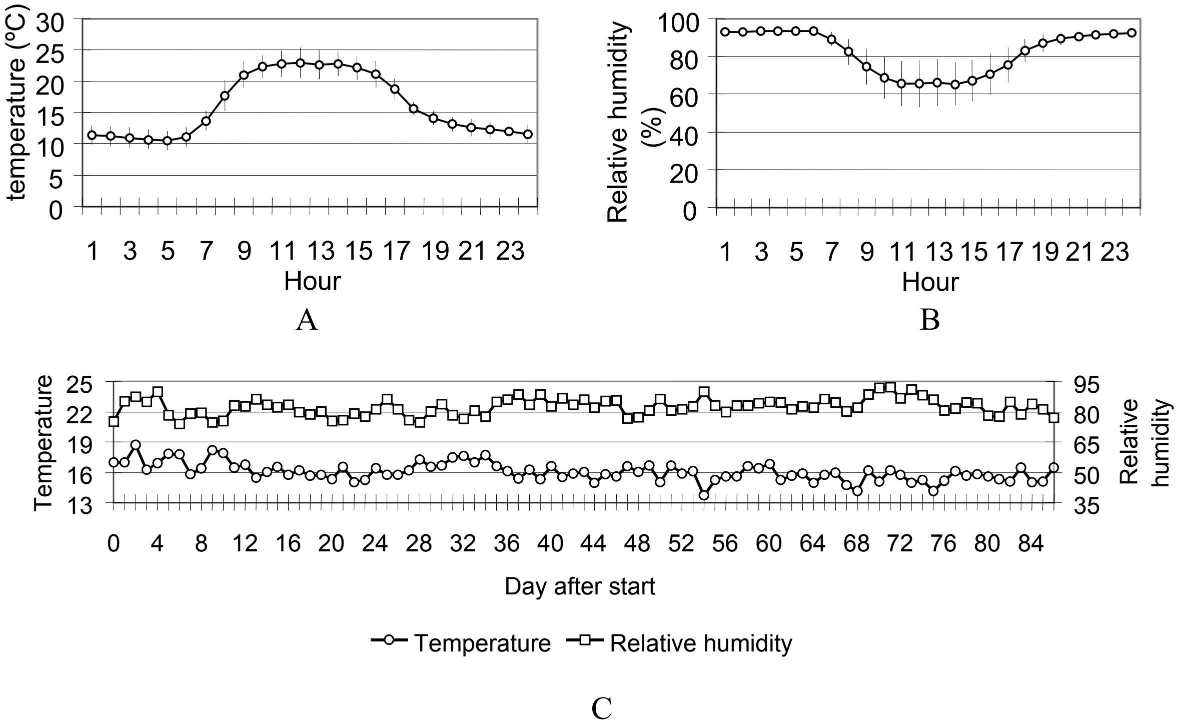

Figure 1. Hourly mean temperature (ºC) with standard deviation (A), relative humidity (%) with standard deviation (B) and mean daily temperature and relative humidity (C) in the automated plastic greenhouse conditions of the Horticultural Research Centre.

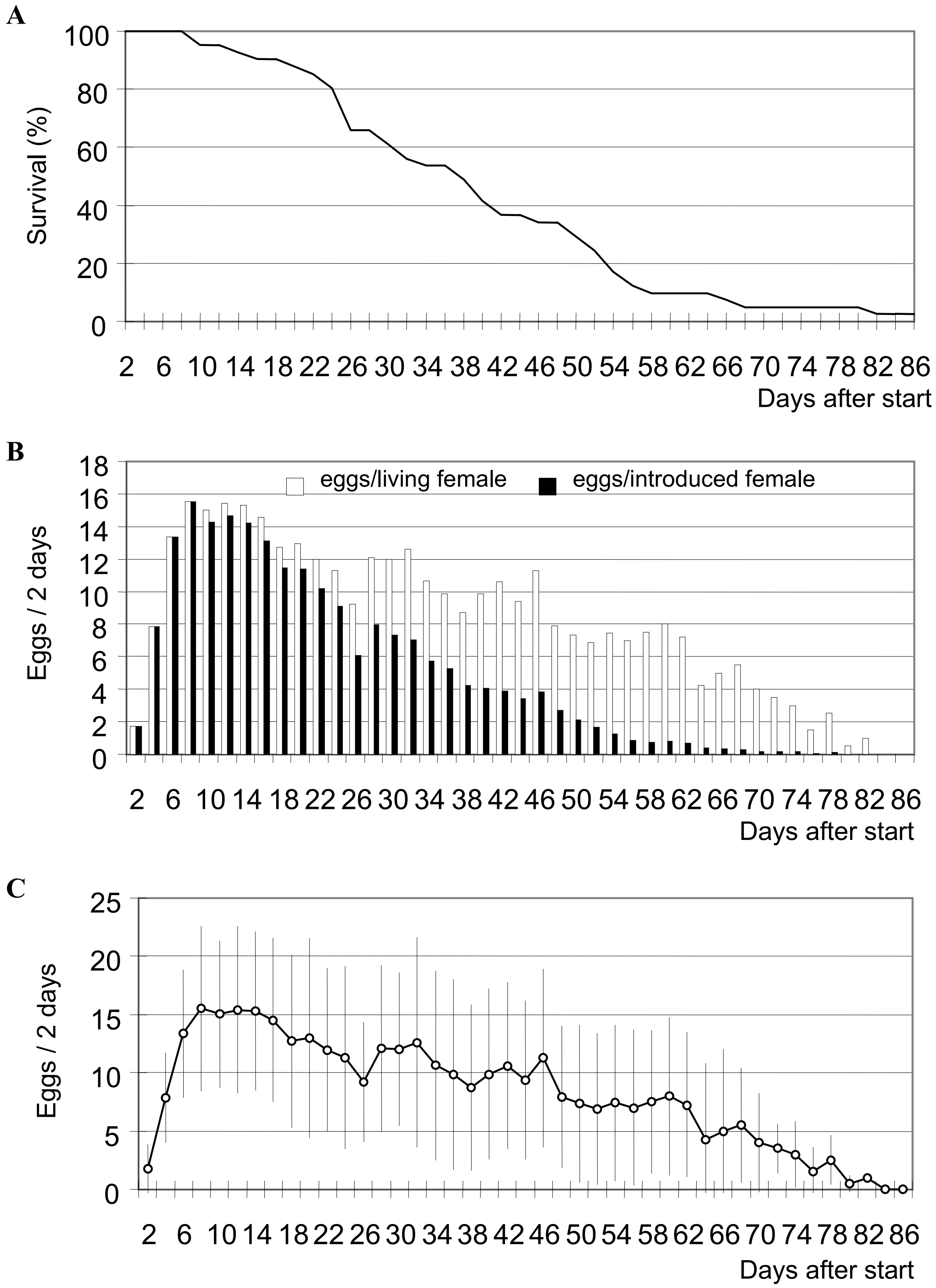

Figure 2. Percentage whitefly females surviving (A), the number of eggs per introduced and per living whitefly female per two days (B) and the variation of the number of eggs per living whitefly female (C) of *T. vaporariorum.*

Discussion and conclusions

Whitefly strain

Longevity, fecundity and oviposition frequency changes with temperature, tomato cultivar and whitefly strain. To evaluate whether a difference between the Dutch and the Colombian strain exists, the results of this experiment were compared with those of van Es (1982) who undertook a similar study on beef tomato cv.'s Dombo and Portanto at 22.5 ºC (table 1). The longevity was 57.4 and 68.6 days on the cv.'s Dombo and Portanto respectively. This is 57 and 87% more than the longevity of 36.5 days of this trial on the cv. Boris. This difference can not be explained only by the difference in temperature. Both 16 and 22.5 ºC are sub-optimal temperatures for *T. vaporariorum* longevity. The optimal temperature for longevity is between 16 and 18 ºC and at 16 ºC the longevity is higher than at 22.5 ºC (van Roermund and van Lenteren, 1992). A second difference between the two trials is the frequency with which the whiteflies were changed to new leaves: van Es (1982) changed whiteflies every week compared to every two days in this experiment. The more frequent manipulation of whiteflies by us could have influenced the longevity negatively. It seems, however, that the difference in longevity is too high to be explained only by temperature and/or manipulation.

Compared to van Es (1982), a shorter longevity but a higher oviposition frequency was found in this study: 5.7 eggs per living female per day compared to 3.7 and 3.2 van Es found on the cv.'s Dombo and Portanto respectively, which is equivalent to 65 and 78% more. Van Roermund and van Lenteren (1992) found that oviposition frequency reaches its maximum at 22 ºC. The trial of van Es (1982) was done at 22.5 ºC while this trial was done at 16 ºC. As both experiments were done on beef tomato cv.'s, we suppose that this large difference in oviposition frequency are due to a difference in whitefly strain.

The total fecundity in van Es' and our trial was almost the same because the lower longevity found by us was compensated by a higher oviposition rate. Van Es (1982) found a fecundity of 215 and 219 eggs/female on the cv.'s Dombo and Portanto respectively at 22.5 ºC, compared to 209 eggs/female on the cv. Boris in this trial at 16 ºC. The temperature for maximum oviposition of *T. vaporariorum* is between 17 and 20 ºC (van Roermund and van Lenteren, 1992).

It can be concluded that the whiteflies in this experiment laid a similar number of eggs at a higher rate and in a shorter (life) time compared to the results of van Es (1982). It is, however, difficult to believe that simply temperature and whitefly-handling differences can explain this. Rather, we assume that a difference exists between the Dutch and the Colombian whitefly strain. Further research, using the same tomato cv. the same experimental temperatures and reducing the whitefly manipulation should confirm this.

Tomato cultivars

To identify the differences with other, non-beef tomato cv.'s, we compared our results with other trials at low temperature (Burnett, 1949, Hussey *et al.*, 1957 and Loyd, 1922). All previous trials at low temperature found a lower fecundity (table 1). As no difference between the fecundity of the Dutch and the Colombian whitefly strain was found, we can conclude that the beef tomato cv. Boris is a better host plant than the cv.'s used in the other trials. Van Es (1982) also found this. She found a fecundity of more than double when comparing the beef tomato cv.'s Dombo and Portanto with the round tomato cv. Moneydor.

Intrinsic rate of increase

The r_m for *T. vaporariorum* on round tomato cv.'s at 16 ºC estimated by van Lenteren *et al*. (1996) is 0.0663, close to the r_m we calculated. We would expect a higher r_m in this experiment because of the higher fecundity as result of better host plant quality (beef tomato cv.). The estimates of van Lenteren *et al*. were, however, done for a constant temperature while this experiment was done at varying temperatures and reproduction and development have a non-linear relation with temperature (van Roermund and van Lenteren, 1992). At 16 ºC, the r_m estimated for *E. formosa* is 0.0974 (van Lenteren *et al.*, 1996), considerably higher than the r_m we found for *T. vaporariorum* in this study. Considering only the potential population growth, then biological control of *T. vaporariorum* with *E. formosa* under the specific conditions should be possible. However, the commercially available *E. formosa* strains do not disperse very well at temperatures below 18 ºC (van Roermund, 1995). Therefore, the next step in our research will be to study the capacity of *E. formosa* to control *T. vaporariorum* under the Colombian greenhouse conditions characterised by a low average temperature.

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