

Effect of host plant on body size of *Frankliniella occidentalis* (Thysanoptera: Thripidae) and its correlation with reproductive capacity

WILLEM JAN DE KOGEL^{1,2,*}, DOMENICO BOSCO³, MARIEKE VAN DER HOEK¹ and CHRIS MOLLEMA¹

¹DLO-Centre for Plant Breeding and Reproduction Research (CPRO-DLO), Dept. of Vegetable and Fruit Crops, P.O. Box 16, 6700 AA Wageningen, The Netherlands

²Institute for Systematics and Population Biology, University of Amsterdam, P.O. Box 94766, 1090 GT Amsterdam, The Netherlands

³Di.Va. P.R.A., Entomologia e Zoologia applicata all'Ambiente "Carlo Vidano", Università di Torino, Via L. da Vinci 44, 10095 Grugliasco (TO), Italy

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Abstract. The effect of different host plants on *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) body size was investigated. Thrips from three different populations, from the Netherlands, Italy, and USA, achieved greater body sizes when reared on cucumber than on bean. The same thrips grew larger when reared on susceptible than on resistant cucumber. On the latter, reproduction was reduced, suggesting that smaller thrips have a lower reproduction. However, no evidence was found for a correlation between size and reproduction in experiments with thrips from four different populations, from the Netherlands, New Zealand, France, and USA that differed significantly in body size. Also when individual thrips from the four populations were tested, there was no correlation between size and reproduction. It is concluded that resistant cucumber affects both size and reproduction of *F. occidentalis*. However, lower reproduction in general is not associated with smaller body size.

INTRODUCTION

Body size can have a great impact on an animal's fitness. It can affect its success as a predator or its risk of being predated on, its physiology and its sexual and reproductive success (Peters, 1983; Forrest, 1987). In many insect species fecundity increases with body size (Marshall, 1988; McLain, 1991; Honěk, 1993; Via & Shaw, 1996), but there are exceptions to this "rule" (e.g., Hollo-way et al., 1987; Leather, 1988; Minkenberg & Ottenheim, 1990; Ohgushi, 1996). When there is a clear relationship between body size and fecundity, body size could be used to predict fecundity, i.e. an important component of fitness. Predicting fecundity from body size is not very reliable (Leather, 1988), because both size and fecundity are dependent on environmental conditions. However, under controlled environmental conditions (i.e. in the laboratory) such predictions should be possible if size and fecundity are correlated (Honěk, 1993). Measurement of body size may then partly replace laborious reproduction tests with insects.

The aim of the present study was to investigate whether there is a correlation between body size and reproduction in the generalist herbivore *Frankliniella occidentalis* (Pergande), the western flower thrips. This species is an important pest on many crops worldwide (Brødsgaard, 1991). It feeds by piercing and sucking plant cells (Hunter & Ullman, 1989) and lays eggs inside the plant tissue (Terry, 1997). After the eggs have hatched there are two larval stages, a prepupal and pupal stage before the adult emerges. Females start reproducing two days af-

ter emergence (van Rijn et al., 1995) and can keep producing eggs for several weeks, although peak oviposition is generally within the first week (van Rijn et al., 1995; Wijkamp, 1995).

Efforts are being made to develop thrips-resistant host plants (van Dijken et al., 1994; Mollema et al., 1995). In these breeding programs reliable test methods are required to measure insect fitness on plants, both to compare susceptible and resistant cultivars, and to study different populations of the insect for biotypic variation (de Kogel et al., 1997a, 1998).

Recently, de Kogel et al. (1997a) reported differences in fitness among western flower thrips populations on susceptible and resistant cucumbers. Bosco et al. (unpubl.) showed that there are significant differences in body size among the same populations of western flower thrips. There are few other reports on intraspecific variation in *F. occidentalis* (Mound, 1997).

Measurement of insect size could be a useful test if there is a correlation with the insect's reproduction rate on the plant. The aims of this study were therefore to investigate the effect on thrips body size and reproduction of (1) different host plant species and (2) resistant and susceptible cultivars of one species. Subsequently, the correlation between body size and reproduction was examined, both among and within populations.

* Present address: Research Institute for Plant Protection IPO, P.O. Box 9060, 6700 GW Wageningen, The Netherlands.

TABLE 1. Origin of *Frankliniella occidentalis* populations.

Population	Origin	Reference
NL1	1988, <i>Cucumis sativus</i> , Wageningen, The Netherlands	Mollema et al. (1990)
UCD'90	1990, <i>Rosa</i> sp., University of California, Davis, USA	Brødsgaard (1994)
FR	1991, <i>Cucumis sativus</i> , Montpellier, France	
IT	1993, <i>Phaseolus</i> sp., Cesena, Italy	
NZ	1994, <i>Solanum melongena</i> , Auckland, New Zealand	Pesticide resistant strain, Martin & Workman (1994)

MATERIAL AND METHODS

Insect and plant material

The origin of the thrips populations used in experiments is summarised in Table 1. Populations NZ and UCD'90 show lower reproduction on several cucumber accessions when compared to populations IT, FR and NL1 (de Kogel et al., 1997a). All populations were reared on bean pods (*Phaseolus vulgaris* cv. Prelude) with additional bee collected pollen in 0.5 l glass jars in a climate chamber (T = 25°C, 16L : 8D, r.h. = 60–70%).

Susceptible cucumber G6 and partially resistant cucumber 9140 (previously selected for low level of damage after infestation with thrips (Mollema et al., 1995) were grown in a green house (Soria & Mollema, 1995).

Measurement of thrips body size

Adult female thrips were killed by exposing them to ethyl acetate fumes. Insects were heated at 100°C for 12 s in lactic acid and put on a slide. Specimens were observed with a Zeiss Axioskop microscope at 100× magnification and, with the aid of video equipment, the image was sent to a Macintosh computer. Body size was measured using image analysis software "Technical Command Language for Image Processing System, version 4.6", developed by TNO Institute of Applied Physics, Delft, The Netherlands. Female thrips were not used till three days after emergence from the pupae.

Effect of host plant species on thrips body size

Body sizes were measured of thrips from populations NL1, IT and UCD'90 that were either reared on bean pods or reared for one generation on cucumber (G6) leaf discs. Results were analysed with a two-way ANOVA with treatment factors population and host plant.

Effect of host plant resistance on thrips body size

Thrips of populations NL1, IT and UCD'90 were reared for one generation on leaf discs of susceptible cucumber G6, or partially resistant cucumber 9140. Body sizes of adult females were measured, and results were analysed with a two-way ANOVA with treatment factors population and host plant.

Correlation between reproduction and body size of four thrips populations

Reproduction of thrips from populations NL1, NZ, FR and UCD'90 that were reared for one generation on leaf discs of susceptible cucumber G6 was measured on small leaf discs ($\phi = 1.2$ cm, one female/disc) of the same accession according to Soria & Mollema (1995). Reproductive rate (number of larvae/female/day) was measured over three successive days starting three days after adult emergence. For each population mean number of larvae/female/day was calculated. The body sizes of all females used in the reproduction experiment were also measured. Data on individual reproduction and individual body size were both analysed with a one-way ANOVA. A Linear Pearson correlation was calculated between mean reproduction and mean body size of the four populations.

Correlation between reproduction and body size of individual thrips

A Linear Pearson correlation between reproduction on cucumber (G6) leaf discs (diam. 1.2 cm, one female/disc) on day 4, 5 and 6 after emergence, and body sizes were calculated for individual thrips from each of the populations NL1, NZ, FR and UCD'90.

RESULTS

Effect of host plant on thrips body size

Food source had a significant effect on body length of thrips. Thrips were bigger when reared on cucumber than on bean (Table 2; population: d.f. = 2, 224, $F = 10.11$, $P < 0.001$, host plant: d.f. = 1, 224, $F = 26.29$, $P < 0.001$, interaction: d.f. = 2, 224, $F = 0.23$, $P = 0.799$). Since the interaction term is not significant, it is assumed that the effect of host plant is not different for the three populations.

TABLE 2. Effect of host plant species on female *Frankliniella occidentalis* body length (mm) in three populations.

Population	Bean			Cucumber		
	mean	s.e.	n	mean	s.e.	n
NL1	1.538	0.013	31	1.588	0.007	84
IT	1.592	0.014	34	1.633	0.010	26
UCD'90	1.594	0.012	30	1.654	0.018	26

Thrips reared on partially resistant cucumber 9140 were smaller than thrips reared on susceptible cucumber G6 (Table 3; population d.f. = 2, 119, $F = 19.05$, $P < 0.001$, host plant d.f. = 1, 119, $F = 50.72$, $P < 0.001$, interaction d.f. = 2, 119, $F = 2.51$, $P = 0.085$.) Sample size was small in this experiment as pre-adult survival on 9140 was very low (see also Soria & Mollema, 1995).

TABLE 3. Effect of host plant resistance of cucumber on female *Frankliniella occidentalis* body length (mm) in three populations; G6 = susceptible cucumber, 9140 = resistant cucumber.

Population	G6			9140		
	mean	s.e.	n	mean	s.e.	n
NL1	1.569	0.009	47	1.469	0.012	31
IT	1.635	0.010	26	1.542	0.029	8
UCD'90	1.569	0.033	8	1.560	0.031	5

Correlation between thrips reproduction and body size

There was a negative but not significant correlation between reproduction and body length among the four

TABLE 4. Reproduction (number of larvae/female/day) and body length (mm) of *Frankliniella occidentalis* females from four populations.

Population	Reproduction		Body length		
	mean	s.e.	mean	s.e.	n
NL1	4.32	0.23	1.613	0.010	35
NZ	3.90	0.25	1.671	0.010	33
FR	3.79	0.56	1.688	0.029	8
UCD'90	3.04	0.32	1.698	0.017	16

populations NL1, NZ, FR and UCD'90 (Table 4; $r = -0.847$, $n = 4$, $P = 0.153$). However there were significant differences among the populations in reproduction (d.f. = 3, 88, $F = 3.103$, $P < 0.05$) and in body length (d.f. = 3, 88, $F = 9.429$, $P < 0.0001$).

The correlation between reproduction and body length of individual females from population NL1 is again not significant: $r = -0.216$, $n = 35$, $P = 0.212$. The same holds for individual thrips from three other populations, NZ: $r = -0.239$, $n = 33$, $P = 0.18$, FR: $r = 0.569$, $n = 8$, $P = 0.141$, UCD'90: $r = 0.134$, $n = 16$, $P = 0.622$ (Fig. 1).

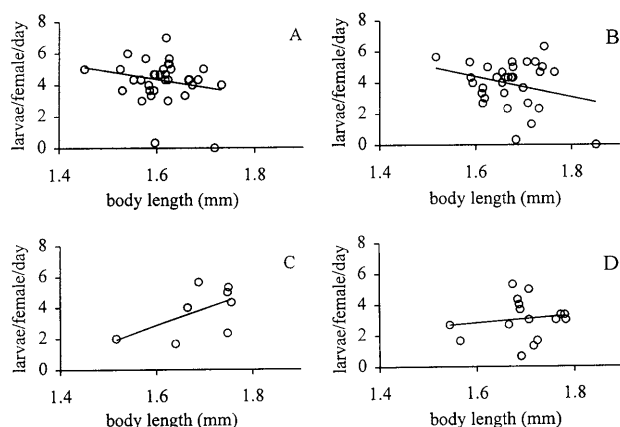


Fig. 1. Relationship between body length (mm) and reproduction (number of larvae/female/day) on cucumber leaf discs of individual *Frankliniella occidentalis* females from 4 populations. A: NL1, $r = -0.216$, $n = 35$, $P = 0.212$; B: NZ, $r = -0.239$, $n = 33$, $P = 0.18$; C: FR, $r = 0.569$, $n = 8$, $P = 0.141$; D: UCD'90, $r = 0.134$, $n = 16$, $P = 0.622$.

DISCUSSION

Host plant species or cultivar had a significant effect on thrips body size. Thrips from three populations achieved a greater body length on cucumber than on bean, but other populations may show different responses. Other studies have found differences in body size associated with host plant; e.g. Leddy et al. (1993) found differences in forewing length of *Siphoninus phillyreae* (Haliday) on ash and pear, but not among other hosts that differed in suitability for these whiteflies.

Body length of *F. occidentalis* was smaller on resistant cucumber 9140 than on susceptible cucumber G6. Soria & Mollema (1995) and de Kogel et al. (1997b) showed that reproduction of *F. occidentalis* on the resistant cultivar is lower than on G6, suggesting a positive relationship between body length and reproduction. Also the develop-

mental period of *F. occidentalis* is longer on 9140 (Soria & Mollema, 1995). Yet, thrips are smaller on these resistant plants. If smaller thrips produce fewer eggs than larger thrips and thrips are smaller on resistant plants, then body size could be used as a marker for host plant resistance.

However, the present study indicates that there is no positive correlation between body size and reproduction. In a recent study, Klingenberg & Spence (1997) examined five fitness components of the water strider *Gerris buenoi* (Kirkaldy) for their correlations with female size. Neither lifetime fecundity, nor reproductive life span, average volume per egg, total volume of eggs laid, or the proportion of eggs hatched, was correlated with female size. They suggest that in this case, size is not an adaptive trait, but a correlated response to selection on other traits.

In our study we did not measure life-time fecundity, but reproduction of females at day 4, 5 and 6 after emergence from pupae. This is the period of peak reproduction (van Rijn et al., 1995; Wijkamp, 1996). Measuring only part of the life-time fecundity could obscure the relationship between size and fecundity (Leather, 1988) especially when there is an effect of size on longevity. In general, reproduction early in life has a greater impact on r_m than reproduction at a later stage. Therefore, we have chosen initial rate of reproduction as parameter for fecundity. In *Drosophila melanogaster* it has been shown that the relationship between fecundity and size is qualitatively independent of the period over which fecundity is measured, indicating that size affects daily production of eggs (Roff, 1981).

In the present study, no correlations between female body sizes and reproduction of *F. occidentalis* were found. Differences in average body size among populations were rather small (approx. 5% difference, Table 4), while differences among body sizes of individuals within populations were larger (approx. 20% difference, Fig. 1). The relative small size differences might explain why no correlations between size and reproduction were found. From these results, it has to be concluded that body length is not a good predictor for reproduction. This suggests that turnover speed from food to egg, more than body size, is the limiting factor for thrips reproduction. This is illustrated by the effect of host plant resistance as described in this paper. On resistant cucumber, thrips reproduction is lower, and thrips body size is smaller. We suggest that the lower reproduction of thrips on resistant cucumber is not due to the smaller size of the insect. It is more likely that host plant resistance has a negative impact on thrips metabolism, resulting in lower reproduction and smaller size. Therefore, reproduction and body size appear to be affected independently by host plant quality, at least in our restricted set of experiments.

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