Short communication

Within-plant distribution and infestation pattern of the B- and Q-biotypes of the whitefly, *Bemisia tabaci*, on tomato and pepper

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Introduction

Two biotypes (B and Q) of the sweetpotato whitefly, *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae), are present in Spain (Guirao et al., 1997). These whiteflies cause serious damage by feeding on the underside of leaves and by transmitting devastating plant viruses, such as tomato yellow leaf curl viruses (Carnero et al., 1990; Brown & Bird, 1996; Moriones et al., 1993; Bedford et al., 1994; Blua & Toscano, 1994; Markham et al., 1996; Jiang et al., 1999). Although both biotypes are major pests of horticultural crops in many of the tomato and pepper-growing areas, recent studies on some hosts have shown that the Q-biotype infests a higher percentage of plants and develops faster than the B-biotype (Muñiz, 2000; Nombela et al., 2001). Although growers use insecticides to control whiteflies, no monitoring technique has been specifically developed for the Q-biotype. Reliable sampling methods are critical to the development of monitoring programs for pest management application (Naranjo & Flint, 1995; Naranjo, 1996; Ellsworth & Martínez-Carrillo, 2001). Location of whiteflies on the different plant strata and accurate estimation of the infestation capacity (percentage of plants infested by a certain number of insects) of *B. tabaci* are important aspects in the study of its biology and ecology. In the last ten years, several studies have determined the spatial within-plant distribution of immature stages of *B. tabaci* in many important crops such as cotton (Butler & Vir, 1990; Rao et al., 1991; Naranjo & Flint, 1994, 1995), peanut (Lynch & Simmons, 1993), melon (Tonhasca et al., 1994), tomato (Carnero & González-Andújar, 1994; Shuster, 1998), and alfalfa (Yee et al., 1997). The immature stage may be the stage that is most correlated to plant damage, but immatures are difficult and time-consuming to count. Consequently, it is likely that the adult stage will continue to be the center of focus for pest management application (Naranjo, 1996). To our knowledge, no reports exist on the within-plant distribution of *B. tabaci* adults in pepper and tomato.

Another main aspect of the spatial distribution (whose knowledge could help growers to make correct decisions on whiteflies control) is between-plant or within-field distribution which is typically described with a theoretical distribution such as the Poisson or negative binomial, or with models as Taylor’s power law (Taylor, 1961) or Iwao’s patchiness regression (Iwao, 1968) which relate the mean and variance over a range of population densities (Naranjo, 1996). In addition, there has been limited effort to describe the inter-relationships between different biotypes of *B. tabaci* and their host plants (Muñiz, 2000; Muñiz & Nombela, 1997a,b; Nombela et al., 2000, 2001). Our objectives were to obtain, under greenhouse conditions, the within-plant distribution pattern of both B- and Q-biotype adults of *B. tabaci* for tomato plants, and to investigate the relationship between the proportion of infested plants and the number of adults present on pepper or tomato plants by a descriptive model under specific greenhouse conditions.

Materials and methods

Within-plant vertical distribution of *B. tabaci* on tomato plants. Seeds of tomato, *Lycopersicon es-
culentum Miller (cultivar Moneymaker), were germinated in a climatic chamber, and the plants grown in perlite in 1-l plastic pots which were irrigated every other day with a nutritive complex 20-20-20 (Nutrichem 60; Miller Chemical, Hanover, PA). Conditions in the climatic chamber were maintained at a temperature regime of 26 °C:15 °C (L:D), 65–78% r.h., and a photoperiod of L16:D8 h. Adult whiteflies were collected with aspirators from two stock colonies (B and Q biotypes) reared on tomato plants (cultivar Moneymaker) for 30 generations in separated climatic chambers at between 15 and 25 °C with 60–78% r.h. When the potted plants were 60-day-old, one group of 34 plants was placed in each of two insect-free greenhouses in a randomized order. The distance among plants was enough to prevent plants from touching each other. After three days, plants were infested by releasing approximately 1,000 seven-day-old adults into each greenhouse. Biotype B adults were released into one greenhouse and Biotype Q adults were released into a second greenhouse. Adults were released at a point midway between the greenhouse benches on which the experimental plants were located. After seven days (Muñiz, 2000), the numbers of adult whiteflies were counted daily in situ on all leaflets from the top, middle, and bottom thirds of all the plants until the new adults emerged. As the larger size of females can be discerned with the naked eye, we counted male and female adult whiteflies daily on whole plants. Counts were made early in the morning (between 08.00 and 09.00 h) before the adults became active by carefully turning the leaf over rotating the petiole of the leaflet. Data on within-plant distribution of Biotypes B and Q were analyzed separately. Greenhouse experimental conditions were very similar: 21 ± 0.3 °C, 68.0 ± 0.8% r.h. for B biotype; 21.2 ± 0.3 °C, 68.4 ± 1.0% r.h. for Q biotype.

Infestation pattern of B. tabaci in tomato and pepper plants. The daily numbers of whitefly adults counted on every tomato plant were used to estimate the infestation levels of B. tabaci. Similar methodology was followed in greenhouses containing 45, 60-d-old sweet pepper plants, Capsicum annuum L., (cultivar Morrón). Adult whiteflies were obtained from two stock colonies (B and Q biotypes) reared for 30 generations on sweet pepper plants (cultivar Morrón) in separated climatic chambers maintained at between 15 and 25 °C with 60–78% r.h. Greenhouse experimental conditions were on average: 22.2 ± 0.8 °C, 74.2 ± 1.3% r.h. for B biotype; 21.6 ± 0.6 °C, 73.6 ± 1.2% r.h. for Q biotype.

The relationship between the estimated proportion of plants (p) infested with at least one adult whitefly and the number of B- and Q- adults per plant (x) was described on tomato and pepper by the linear model: 

\[ z = -\ln(1-p), \quad p = 1 - e^{-mx}, \quad \ln(z) = -\ln(1-p). \]

In this relation, \( z \) is the proportion of plants infested, and \( m \) is the slope of the regression line estimated (Nombela et al., 2001). Converted to percentage of infested plants (P), the following relationship is obtained: 

\[ P = 100(1 - e^{-mx}) \]

(Wilson & Room, 1983). The confidence interval (CI) of the estimated number of adults (x) necessary to infest any percentage of plants was calculated as follows: 

\[ CI = (\alpha/2 \pm t_{\alpha/2}(S\epsilon)) [1/(1/n) + (x - \bar{x})^2/\Sigma(x_i - \bar{x})^2]^{1/2}, \]

where \( S\epsilon \) is the standard error of the estimate from the linear regression \( z = -mx; t_{\alpha/2}(S\epsilon) \) is the value of the Student’s t-test at 95%, \( x^* \) and \( \bar{x} \) are the estimated number of adults and the mean number of adults, respectively (Affifi & Azen, 1979).

The experiments with pepper and tomato were conducted during September and October, 1999, respectively. The populations originated from adults collected in La Mayora, Málaga (Spain) in 1996 by removing them from tomato, and identified as B and Q-biotypes by Guirao et al. (1997).

Statistical analysis. Percentages (P) of number of adults on plants (adult density) were transformed by arcsine \((P/100)^{1/2}\). We used the non-parametric Wilcoxon’s matched-pairs test (ranks and signs) to analyze the data, using the individual plants as random elements. Differences in adult density between B and Q biotypes were separated using the Mann-Whitney U test. All tests were performed with SPSS version 10.0 (SPSS, 2000).

Results and discussion

Within-plant vertical distribution of B. tabaci. For both B- and Q-biotypes of B. tabaci, the Wilcoxon’s test indicated that the daily adult densities were significantly different \((P < 0.01)\) among the three strata of the tomato plants over the days of the experiments. Mann-Whitney U-test, however, indicated that the distribution of adults within the plant did not vary significantly \((P > 0.05)\) between the B- and Q-biotypes of B. tabaci. Although there was variation among plants over the experimental period, on average, leaflets from the middle stratum had the greatest \((P < 0.05)\) number
Table 1. Estimates of parameter m for equation $z = -mx$, where $z = \ln(1 - p)$ describing the relationship between proportion of infested plants (p) and B- and Q-biotype adults (males+females) of B. tabaci (x). N = days of observation, $r^2 =$coefficient of determination, and $s =$ standard error of estimate.

<table>
<thead>
<tr>
<th>Plants</th>
<th>biotype</th>
<th>N</th>
<th>$r^2$</th>
<th>m</th>
<th>s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pepper</td>
<td>B</td>
<td>24</td>
<td>0.967</td>
<td>0.01558</td>
<td>± 0.00056</td>
</tr>
<tr>
<td></td>
<td>Q</td>
<td>24</td>
<td>0.972</td>
<td>0.01228</td>
<td>± 0.00044</td>
</tr>
<tr>
<td>Tomato</td>
<td>B</td>
<td>25</td>
<td>0.983</td>
<td>0.01137</td>
<td>± 0.00030</td>
</tr>
<tr>
<td></td>
<td>Q</td>
<td>24</td>
<td>0.972</td>
<td>0.00783</td>
<td>± 0.00032</td>
</tr>
</tbody>
</table>

Figure 1. Daily variation of the within-plant vertical distribution (top, middle, and bottom strata) of B- and Q-biotype adults of B. tabaci on tomato plants.

of B. tabaci adults, followed by the upper and bottom strata (Figure 1). This distribution pattern agrees with that described for B. tabaci immatures on peanut (Lynch & Simmons, 1993) but differs from that obtained on cotton (Butler & Vir, 1990; Rao et al., 1991; Naranjo & Flint, 1995), where adults were most abundant on younger leaves near the top of the plant. These differences are probably related in part to different crops and experimental conditions. This confirms that determination of distribution patterns of a certain insect species on a particular host is a prerequisite for developing effective techniques to monitor B. tabaci populations (Lynch & Simmons, 1993).

Because the percentage of adults on each stratum of tomato plants varied with time and was mostly higher than 10% throughout the experimental period (Figure 1), insect counts on this crop should be made on the three strata. However, sampling time can be...
reduced by counting adults mainly on the leaves of the middle stratum, because there were statistically lower percentages of adults on the upper and bottom strata of tomato plants.

Investigations on insect-plant interactions (particularly those related to host plant selection), have demonstrated the existence of marked differences between B and Q biotypes of *B. tabaci* in terms of their reproductive activity and development (Muñiz & Nombela, 1997a,b; Muñiz 2000). Our results also show that the development of immature stages of the Q biotype was shorter than that for the B-biotype, as previously noted (Muñiz, 2000). The duration of the developmental cycle (egg-adult) of the Q biotype was 14 days, whereas the B biotype required 17 days to complete the development under the test conditions (Figure 1).

**Infestation pattern of *B. tabaci* on tomato and pepper plants.** The behavioral diversity of biotypes is one of the most important ecological aspects to be addressed in insect-plant interaction studies. Severe infestations of crop plants can result from a failure to recognize the existence of insect biotypes (Smith et al., 1994) and their different host adaptation capabilities (Bernays, 1999). The linear expression $z = -mx$, where $z = \ln(1 - p)$, was selected to describe, separately, the infestation of tomato and pepper plants by the B- and Q-biotype of *B. tabaci*, with at least one or more adults, because it includes only one parameter and fits the data on the proportion of infested plants ($p$) in relation to the number of adults ($x$). The high $r^2$ values and the plots of residuals indicate the good fit of the infestation rates of both B and Q biotypes of *B. tabaci* on these horticultural crops (Table 1). With this function it was possible to describe the kind of relationship between the percentages of infested pepper and tomato plants and the numbers of total adults, under certain experimental conditions, as well as its strength (Figures 2 and 3). Similar results were obtained when the female whiteflies were separately considered (data not shown).

As Lynch & Simmons (1993) pointed out, efficient sampling techniques are essential for studying the basic biology, ecology, population dynamics, and economic importance of an insect. Our findings provide information that should prove useful to describe the infestation levels of the adults on tomato and pepper plants, under greenhouse conditions. However, further studies are needed to determine the distribution and infestation patterns of both B and Q biotypes on these and other crops under field conditions, before reliable and cost-effective sampling plans can be developed.

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**References**


