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Evaluation of the Damage Caused by *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) on Cucumber Leaves (*Cucumis sativus* L., F_1 Kamaron)

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Abstract: During the present study, an evaluation of damage caused by *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) on cucumber leaves is given. The experiment took place in May 1999. For this purpose, 50 cucumber plants (*Cucumis sativus* L., F_1 Kamaron) were used. The plants grew in small pots covered by plastic cages in a glasshouse. Plants with the first real leaf developed (approximately 14 cm^2), were divided in Groups I-V, each consisting of 10 plants. On each plant of the first four Groups, 5, 15, 25 and 35 females of *F. occidentalis* were released respectively, while Group V was used as control. Plants remained covered by the plastic cages in the glasshouse throughout the experiment for 18 days. The number of thrips individuals placed on each plant remained stable during the study. Results showed that, the damage on cucumber leaves increases relatively with the number of thrips. The damaged leaf area was 1.02 cm^2 at 5 thrips individuals, increasing at 7.81 cm^2 at 35 thrips individuals. Photosynthetic capability was also reduced. The chlorophyll content estimation in SPAD units was almost intact when initial number of thrips was 5 individuals in comparison to the control, but readings of the instrument decreased rapidly in greater initial population.

Key words: *F. occidentalis,* damage, SPAD, cucumber leaves

Introduction

Thrips are increasingly recognized as economic pests of a multitude of crops. Injury to leaves, flowers, or fruit occurs because of the destruction of pollen, petal damages, evacuation of cell contents resulting in silvery white streaks, as well as production of galls on leaves (Palmer *et al.*, 1989; Murphy *et al.*, 2004).

Frankliniella occidentalis (Pergande) is a major pest that causes serious damages in greenhouse crops worldwide (Broadbent *et al.*, 1987; Mantel and Van de Vrie, 1988; Lenteren and Woets, 1988). It is an economically important pest of cucumber in Europe and difficult to control because it is resistant to many insecticides (Rijn Van *et al.*, 1995). The life cycle consists of the egg, larval, prepupal, pupal and adult stages (Murphy *et al*., 2004). Female adult western flower thrips live up to 30 days and lay 2-10 eggs per day. At 20°C, development from egg to adult takes approximately 19 days, reducing to 13 days at 25°C. The eggs are inserted into soft plant tissues, including flowers, leaves, stems and

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fruit. In sweet pepper, egg hatch gives the leaves a speckled appearance, with the degree of speckling corresponding to the number of hatched eggs. The larval stage consists of 2 instars that feed and develop on the leaves, flowers and fruit. The prepupal and pupal stages often complete their development on the ground or growing medium, but pupation can also take place on the plant. The pupa is a non-feeding stage during which the wings and other adult structures form (Murphy *et al.*, 2004). The adults are weak fliers, usually taking short flights from leaf to leaf or plant to plant, but dispersing rapidly nonetheless throughout the greenhouse. Adult thrips can be transported on wind currents and will enter the greenhouse through vents and doorways. All thrips stages may be dispersed by the movement of infested plants, growing media, farm implements and on workers' clothing (Murphy *et al.*, 2004). The activity of thrips mainly focuses on adults and larvae I-II. When larvae II complete their development, they seek sheltered places in order to develop into prepupal and pupal stages, when they do not feed and remain mainly immobile (Priesner, 1964; Lewis, 1973).

The polyphagous thrips species, *F. occidentalis* attacks numerous vegetables, ornamentals, cereals, fruit crops and causes serious damages comparable to the damages caused by *Thrips tabaci* Lindeman (Murphy *et al.*, 2004; Broadbent *et al.*, 1987; Mantel and Van de Vrie, 1988; Lewis, 1973; Wolfenbarger and Hibbis, 1958; Yokoyama, 1977; Ananthakrishnan, 1984; Mustafa, 1986; Edelson *et al.*, 1986; Shelton and North, 1987; Kendall and Capinera, 1987; Terry and Degrandi-Hoffman, 1988). *F. occidentalis* can also transmit the TSWV and INSV (Murphy *et al.*, 2004; Mantel and Van de Vrie, 1988; Robb and Parrella, 1987; Cho *et al.*, 1987). The damage on plants is first of all mechanical. During feeding, the epidermis and the mesophyll cells are penetrated by means of the stylets in the mouthcone and the cell sap is sucked out. Depending on the host plant in question, yellow, brown or silver necrotic spots occur as a consequence of air entering the empty cells (Ananthakrishnan, 1971; Chrisholm and Lewis, 1984). These spots are also speckled with dark fecal droppings from the thrips feeding (Murphy *et al.*, 2004). Mechanical damage also occurs when the females saw pockets in the epidermis or mesophyll cells in connection with the oviposition (Yokoyama, 1977; Terrry and Degrandi-Hoffiman, 1988; Jensen, 1973; Stafford, 1974).

Differences in performance of *F. occidentalis* on cucumber leaves of different age, or different plant parts are reported by de Kogel (2001) and Deligeorgidis *et al.* (2005). Thrips damage is noticed first on the lower leaves of cucumber and tomato, while in sweet pepper it is evident in the upper youngest leaves. Heavy infestations reduce the photosynthetic ability of the plants and, as a result, the yield (Murphy *et al.*, 2004). In cotton, differences in chlorophyll meter readings greater than 3% were found significant and in relation to the effects of N fertilizer management on biomass (Bronson *et al.*, 2003). On vegetable flowers, thrips feeding results in silvery white streaks on the petals. On cucumber, feeding results in severe distortion and curling and is evident by white striations on the fruit. Feeding on sweet pepper causes silvery or bronze streaks or spots on the fruit. Thrips also feed on the calyx causing it to turn up and expose the fruit to bacterial infections. On tomato, ghost-spotting has been observed which is a result of thrips laying eggs in the fruit. Ghost-spotting can also occur with sweet pepper and cucumber (Murphy *et al.*, 2004).

This study presents mainly the results of the damage expressed in cm^2 of affected leaf area on cucumber leaves, which is caused by the feeding and oviposition of *F. occidentalis*.

Materials and Methods

This study was conducted during May 1999. For that purpose 50 cucumber plants (*Cucumis sativus* L., F_1 Kamaron), a most important glasshouse crop in Greece, were used. Each plant was

grown in a pot (13×10 cm) covered by plastic cylindrical cage 12x40 cm, in a glasshouse. Those cages had openings on the top and at the side, covered with fine muslin (0.06 mm opening) for ventilation. When the plants developed their first real leaf (of about 14 cm^2), they were divided in five (I-V) Groups, i.e., 10 plants per Group. At 6/5/99, on each plant of the first four Groups (I-IV), 5, 15, 25 and 35 females of *F. occidentalis* were released, respectively, while Group V was used as control. The female adult thrips individuals (one day-old) were collected from laboratory colonies.

All plants were kept in cages, under the conditions of the glasshouse environment (temperature, relative humidity) that were recorded daily by a thermohygrograph. Our consideration was concentrated on the plants in order to retain only the initial leaves during the whole period of the study, which was realized by deduction of any other leaf whenever it was formed. In order to retain the initial number of thrips any newly hatched larvae was excluded after daily inspections by means of a fine-brush and a portable magnifying glass (10x). Eighteen days after the release of thrips individuals the leaves of the plants were taken away in order to assess the damage. All thrips individuals used were found alive.

The area of each cucumber leaf was measured (in cm^2) by means of an electronic planimeter. The estimation of damage per leaf (in cm^2) was made by means of a millimetric paper on photocopies (in high quality laser copier) of the leaves. The final size of the leaves was approximately 90-100 cm^2. Also, the number of spots per leaf was measured following the same method. The typical symptoms of the infestation on the cucumber leaves were silver-colored spots or scarring and oviposition holes. The percentage (%) of damaged leaf area was calculated (the average size of leaves in each Group was used). Additionally, an estimation of chlorophyll content of original leaves was made using the Minolta SPAD 502 instrument (in SPAD units). Values were calculated as a percentage (%) of the respective SPAD values of the control plants. For statistical analysis of the results only the damage on the cucumber leaves in cm^2 and SPAD readings (%) were used because the percentage of the damage (%) and the number of spots create biased results as: 1) the leaf area of plants differs in each treatment and 2) in many cases during this study, the spots were unified and were counted as one (the diameter of the smallest spot was 0.25 mm). ANOVA and correlations were based on standard analysis described by Snedecor and Cochran (1980).

Results

Daily temperature (°C) and relative humidity (%) in the glasshouse, under which the experiment took place, are shown in Fig. 1. The cucumber leaf damage in this study was assessed by observing the feeding and oviposition of *F. occidentalis* female adults.

Regarding leaf area damage caused by *F. occidentalis* under greenhouse conditions and in an internal of 18 days, results in Table 1 show that there were found statistically significant differences ($p<0.05$) as the increase of thrips number was associated with damage increase (F = 972.76, df = 3/36, $p<0.0001$). The damaged leaf area was 1.02 cm^2 at 5 thrips individuals, increasing at 7.81 cm^2 at 35 thrips individuals.

The damage by feeding and oviposition of the adult females of *F. occidentalis* on the leaves of cucumber increases accordingly to the increase of the number of thrips individuals. Regarding the percentage (%) damage, the statistical analysis of data was not possible because of the unequal sizes of leaves. Nevertheless the average values show a difference, which is apparently related to the number of female adult thrips. The damaged leaf area (%) of the total leaf area was 1.05 at 5 thrips individuals, increasing at 8.56 at 35 thrips individuals.
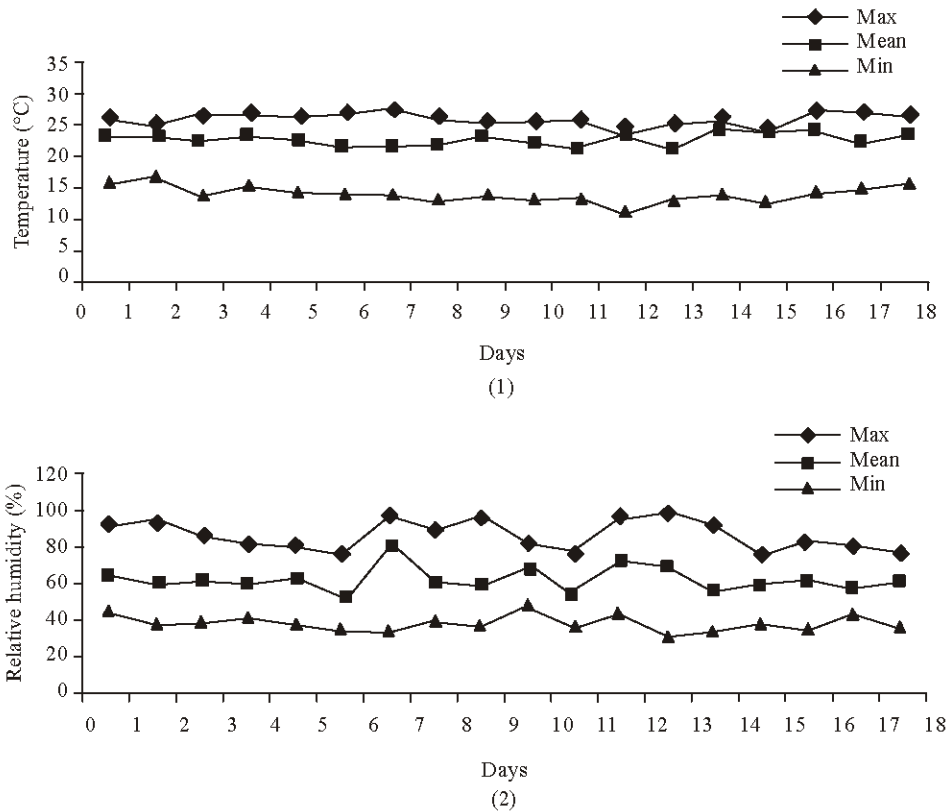
Fig. 1: Fluctuation of the average value per 24 h (max, mean, min) of temperature (1) and relative humidity (2) in the glasshouse, during the 18 days of the experiment

Table 1: Damage of the cucumber leaves in cm^2, percentage (%) of damage and number of spots (± SE) by 5, 15, 25 and 35 adult females of *F. occidentalis* during 18 days

Female number	Leaf damage (cm^2)	Damage (%)	SPAD (% control)	Number of spots
5	1.02±0.03a	1.05±0.04	98.8±2.1a	201.2±4.16
15	3.28±0.09b	3.41±0.09	95.6±2.4b	485.1±4.2
25	5.27±0.11c	5.63±0.13	87.9±3.2c	739.2±6.79
35	7.81±0.12d	8.56±0.27	79.6±3.4d	847.1±4.45

The average values followed by the same letter (s) are not statistically different (Duncan's multiple range test, $p < 0.05$). The control's damage was 0 and SPAD units' percentage was 100 (%)

Statistical analysis was also not performed on the number of spots per leaf, because in many cases two or three spots were unified. However the mean values showed the same trend as before. The number of spots was approximately 201 at 5 thrips individuals, increasing at 847 at 35 thrips individuals.

The chlorophyll content was estimated indirectly in SPAD units and the readings were transformed to the percentage (%) of the control. When the population of initial thrips individuals was 5, there was a slight decrease of the readings in relation to the control. When the number of initial thrips individuals was increased to 35, there was a decrease of the readings about 20%.

The relation of the initial thrips number (x) and the damage on leaves (y) that may occur is described by the following equations (p<0.001): (1) $y = 0.001x^2+0.196x+0.0655$, $R^2 = 0.999$, for damaged area in cm^2, (2) $y = 0.001x^2+0.191x+0.1044$, $R^2 = 0.999$, for damaged area (%) of total leaf, (3) $y = -0.013x^2-0.143x+100.03$, $R^2 = 0.997$, for SPAD readings (%) of the control, (4) $y = -0.44x^2+39.518x+8.79$, $R^2 = 0.997$, for number of spots on the leaves.

Discussion

F. occidentalis female adults can cause indirect damage on fruit production by feeding on foliage and stems and direct one by feeding on developing fruits. The results of this study show that standard initial numbers of released adult females of *F. occidentalis* on cucumber leaves, cause damage in relation to the initial population. There was a significant positive relation between number of thrips released and the leaf area damaged within 18 days.

Five adult females of *F. occidentalis* cause damage on 1.02 cm^2 on the cucumber leaves by feeding and oviposition. By increasing thrips number into 35 adult females, the damage is greater, because more thrips are fed and lay eggs. These findings indicate that the continuous increase of thrips numbers may result to the death of the cucumber plants.

It is known that the relationship between feeding damage by plant-feeding insects and plant response to that damage, involves number of insects per plant and additionally parameters as: plant stage, plant biotype (or species), insect biotype (or species), plant part, duration of insect feeding (e.g., insect days), time of herbivory, site-specific weather patterns, as well as many other environmental factors (Pedigo *et al.*, 1986; Maschinski and Itham, 1989). *T. tabaci*, one of the major pests that attack cotton seedlings, in years of severe infestation (12-48 thrips per plant) can cause the death of many young plants and the stand may be destroyed or reduced to the point where the crops must be replanted (Hassanein *et al.*, 1970). Also, *T. tabaci* indicates that high populations (e.g., 20 thrips per plant) on onion seedlings will cause death to plants, whereas the same populations on mature onions may actually be beneficial, killing the leaves and promoting curing of the onion bulb (Shelton *et al.*, 1987).

Kawai (1990) reports that, for cucumber, injuries on leaves from *Thrips palmi* Karny are economically important, whereas for sweet pepper injuries on fruits are more important. In case of eggplant, both fruits and leaves are injured but damages on fruit are of practical importance from economic viewpoint. The economic injure level is low when the host plants are directly injured in their fruits. However, when the plants are injured in other parts, the economic injury levels are generally high. The economic injury levels for eggplant and cucumber were calculated near 0.1 and 4.4 adults per leaf respectively and for sweet pepper 0.1 adult per flower, on the assumption that the acceptable level of yield loss of uninjured fruits is 5% of the maximum yield.

A wide range in feeding damage levels defined by leaf scars among 27 cultivars of florist's chrysanthemum was apparent for the western flower thrips, *F. occidentalis*. The test periods for 2-4 weeks can give significant results if thrips numbers are sufficiently high and reach 16-20 thrips per plant (Broadbent *et al.*, 1990). In crop leek (*Allium porrum* L.), the variability of *T. tabaci* populations per plant causes problems in regard to the attainable accuracy of the population estimates. Mean population density of thrips per plant, in plants showing severe symptoms were 79.2, light symptoms 13.0 and no symptoms 0.4 (Theunissen and Legutowska, 1991).

The present study indicates that increased number of adult females of *F. occidentalis* on young cucumber leaves may cause a total destruction. This may be also due to the fact that

F. occidentalis prefers more the young leaves for both feeding and oviposition, which is in agreement with (Gillespie, 1989; Steiner, 1990; Salguero Navas *et al.*, 1991; Higgins, 1992).

The percentage of damage and the number of scars increase with the number of adult female thrips on cucumber leaves. It is, therefore, necessary to examine the cucumber plants, which are on the first stages of development for potential thrips presence, because, 8 thrips per 200 cm^2 leaf area are sufficient to increase cucumber scarring by 10% (Rosenheim *et al.*, 1990). Extensive spotting is reported by Murphy *et al.* (2004), which may lead to necrosis of leaves.

The total population (larvae I-II and adults) of *F. occidentalis* and *T. tabaci* was found significantly greater in cucumber than in tomato (Deligeorgidis and Ipsilandis, 2004). The thrips preference probably is due to the attractiveness of colour, smell, taste, leaf construction, as well as the low resistance of the plant. Relative studies have also shown the preference of *F. occidentalis* in cucumber than in tomato and pepper (Higgins, 1992; Deligeorgidis and Ipsilandis, 2004; Krause, 1990). The thrips preference is also shown among varieties of the same plant. Lall and Singh (1968) ascertained that *T. tabaci* prefers varieties of onion, which are less resistant. Similar behavior of thrips was reported for varieties of cotton (Gawaad and Shazli, 1969). Studies on the resistance of the cucumber varieties against *F. occidentalis* have shown satisfactory results. Varieties selected for their resistant properties reached up to 50% less damage than a cucumber variety sensitive in thrips (Mollema *et al.*, 1993).

Differences in chlorophyll meter readings greater than 3% were considered significant in previous studies for cotton and cucumber (Bronson *et al.*, 2003; Hayashi *et al.*, 2002). In this study, differences were even greater indicating reduced photosynthetic capability. Heavy infestation with 35 thrips per leaf may reduce the photosynthetic ability of the plants and, as a consequence, the yield (Murphy *et al.*, 2004).

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