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Populations of *Frankliniella occidentalis* Pergande (Thysanoptera: Thripidae) in a Greenhouse Pepper Crop in the Region of Moknine (Tunisia) in Relation to Environmental Conditions

Mohamed Elimem • Ahlem Harbi • Brahim Chermiti*

Laboratoire d'Entomologie, Département des Invertébrés, Microorganismes, Malherbes Nuisibles, Méthodes Alternatives de Lutte, Institut Supérieur Agronomique de Chott-Mériem (ISA CM). 4042, Université de Sousse, Tunisia

Corresponding author: * chermiti.ibrahim@iresa.agrinet.tn

ABSTRACT

Populations of *Frankliniella occidentalis* were monitored in a greenhouse pepper crop in the region of Moknine (Governorate of Monastir, Center-east of Tunisia) in 2009 using blue sticky traps and weekly flower samples. Critical periods of pest proliferation were correlated with greenhouse conditions of temperature, photoperiod and relative humidity. During the cold season and beginning of spring, populations showed limited variation, with the number of trapped thrips more or less constant. At this period, low temperatures, high relative humidity and shorter day-length prevent thrips development. Thrips populations increased during April, May and early June. This coincided with an increase in temperature, slight decrease in relative humidity, and longer days, and led to high population levels of *F. occidentalis*.

Keywords: *Frankliniella occidentalis*, pepper crop, photoperiod, population dynamics, relative humidity, temperature

INTRODUCTION

Frankliniella occidentalis Pergande (Thysanoptera, Thripidae) is a polyphagous species that attacks plants belonging to several botanical families (Lewis 1973; Yudin *et al.* 1986), including trees, vegetables such as cucumber, eggplant, melon, bean, pepper, tomato and strawberry (González-Zamora and García-Mari 2003; Papadaki *et al.* 2008), and ornamental crops like chrysanthemum, orchids, rose (*Rosa* L. spp.), *Gypsophila* spp., *Dendranthema grandiflora* (Yudin *et al.* 1986; Chau and Heinz 2006). Until the 1960's the distribution of this thrips was limited to the northwest of the United States, Canada and Mexico. Since 1970 it has been spread to many countries in different continents, including Europe, Africa, Asia and Oceania (Lacasa *et al.* 1996; Anonymous 2002; Kirk and Terry 2003). However, in Tunisia it is still considered a quarantine risk (Belharrath *et al.* 1994).

F. occidentalis may cause much damage to its host plants. On roses, damage to the flowers is particularly important, involving yellow spots and distortions (Brun *et al.* 2004). Feeding by larvae and adults results in scars on leaves and white spots on the petals, but these soon become brown, dry and perforate. Scarring on flower buds may prevent these from fully opening, and sepals become crimped and slightly discolored (Alford 1991; Brun *et al.* 2004).

F. occidentalis is usually controlled with insecticides, but these must be rotated to prevent the development of resistance (Fougeroux 1988; Guérineau 2003). Predatory bugs of the family Anthocoridae are sometimes used against Western Thrips populations and are regarded as promising biological control agents. Most Anthocoridae species used against this thrips belong to the genus *Orius*, including *O. laevigatus*, *O. insidiosus*, *O. majusculus*, *O. tristicolor.* These small species, not exceeding 5 mm in length, are used especially in greenhouses on crops like cucumber, pepper, sweet pepper and rose (Loomans and van Lenteren 1995; Parker *et al.* 1995; Frank and Slosser 1996). Some parasitoids of the genus *Ceranisus* have been used to control *F. occidentalis* populations, including *C. menes*, *C. americensis* and *C. lepidotus*, on several host plants (Loomans and van Lenteren 1995; Grasselly 1996; Lacasa *et al.* 1996; Loomans 2006). Predatory mites of the family Phytoseiidae, including *Neoseiulus cucumeris*, *Amblyseius cucumeris*, *A. swirskii*, *A. andersoni* and *Euseius ovalis* have been found to be promising biological control agents for thrips and proved successful against *F. occidentalis* (Gélinas 2000; Jones *et al.* 2005; Pijakker and Ramakers 2008).

Blue sticky traps with attractive kairomones can be used in greenhouses to help limit thrips populations, and these can also attract males and females of many thrips species. This control method can be employed regardless of the density of thrips in greenhouses (van Tol and de Kogel 2007; Broquier and Lacordaire 2008).

Climatic conditions can have a strong influence on the development of thrips populations, including temperature, photoperiod and relative humidity. High temperatures between 24 and 28°C, low relative humidity and longer photoperiod can cause populations of this pest to increase considerably (Bournier 1983; Loomans and van Lenteren 1995; Guérineau 2003; Whittaker and Kirk 2004; Chaisuekul and Riley 2005; Fraval 2006; Elimem and Chermiti 2009).

The aim of this study was to monitor *F. occidentalis* populations in a greenhouse pepper crop in relation to temperature, photoperiod and relative humidity, and to determine critical periods of population growth throughout the year.

MATERIALS AND METHODS

Experimental site

The study was carried out in a 520 m² greenhouse of pepper crop in the region of Moknine (Governorate of Monastir, center-east of Tunisia) during 2009. The greenhouse contained four rows each with two lines of the pepper variety 'Chargui'. The inter-row dis-

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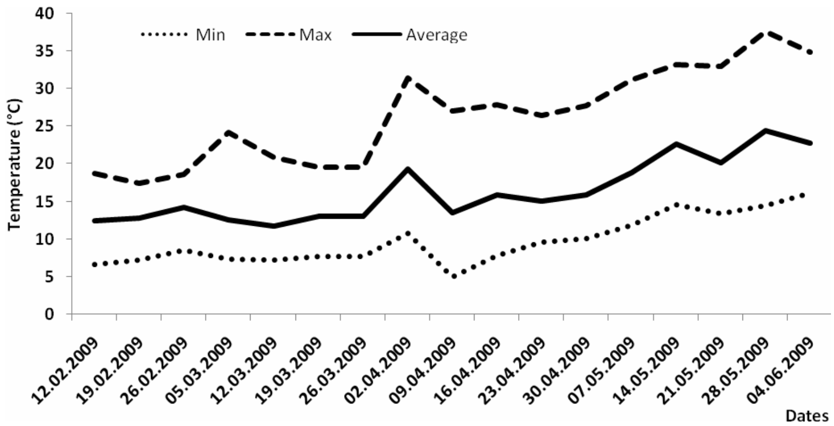

Fig. 1 Temperature (Min, Max and average) in a greenhouse pepper crop in the region of Moknie (Monastir, Tunisia) in 2009.

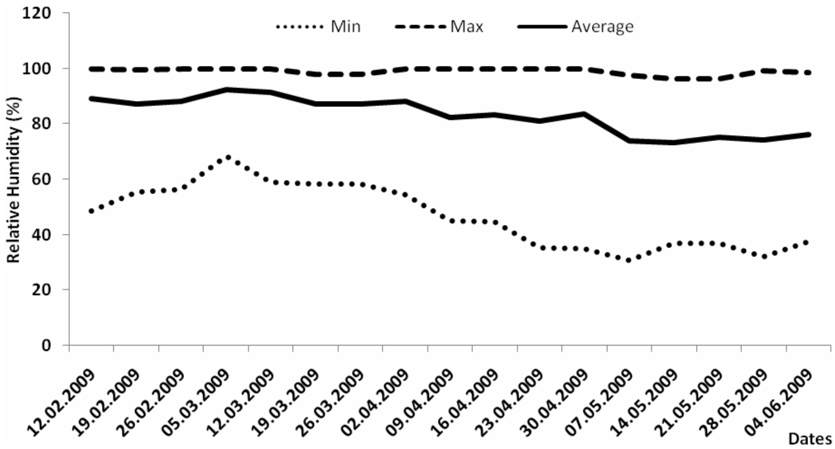

Fig. 2 Relative humidity (Min, Max and average) in a greenhouse pepper crop in the region of Moknie (Monastir, Tunisia) in 2009.

tance was about 1 m. The study was conducted without pesticides throughout the study period, in order to evaluate the growth and development of thrips populations.

Environmental parameter monitoring

Climatic factors (temperature and relative humidity (R.H.)) were monitored weekly with a thermohygrograph.

Adult thrips trapping

Thrips population monitoring was carried out using ten blue sticky traps (Koppert®, the Netherlands), renewed weekly, installed between the pepper rows and suspended at a height of 30 cm above the plants. The distance between traps was about 10 m. The blue sticky traps were 25 cm long and 10 cm wide, and they were installed from February 12th 2009 till June 4th 2009.

Flower sampling

A weekly sampling of flowers started on February 12th 2009 till June 4th 2009 (just before the plants were uprooted). Rows were divided into five blocks each, with a total number of 20 sampling units. From each sampling unit, a pepper plant was selected randomly and three flowers were collected from the different plant parts (apical, middle and basal). Every pepper plant used for sampling was marked so it was not used next week. Sampling units located on the greenhouse borders were not used. Each sampled flower was kept in a plastic bag labeled with number of sampling unit and stratum.

RESULTS AND DISCUSSION

Monitoring of climatic conditions in the experimental site

Conditions in the greenhouse varied throughout the study period; until March 26th 2009, the highest average temperature was about 14.17°C, while the lowest average (11.70°C) was on March 12th 2009. Subsequently, the temperature increased gradually over the next months to reach average values approaching 25°C on May 28th 2009 (**Fig. 1**).

Relative humidity (R.H.) mean values were high from the start of observations till April 2nd 2009, after which date R.H. tended to decrease with the lowest average recorded on May 14th 2009 with 73.13% (**Fig. 2**).

Photoperiod data taken from the National Institute of Meteorology of Tunisia showed that day length increased throughout the study period (**Table 1**).

F. occidentalis numbers on blue sticky traps

The number of adult *F. occidentalis* captured on blue sticky traps varied throughout the study period (**Fig. 3**). Population development and biological characteristics of this pest are strongly associated to climatic conditions such as temperature, relative humidity and photoperiod (Bournier 1983;

Table 1 Variation in photoperiod (in hours) during the different months of the study period (from February 2009 till June 2009) in the governorate of Monastir (NIMT* 2009)

Month	February	March	April	May	June
Photoperiod (Hours/month)	179	208	228	276	303

*NIMT: National Institute of Meteorology of Tunisia

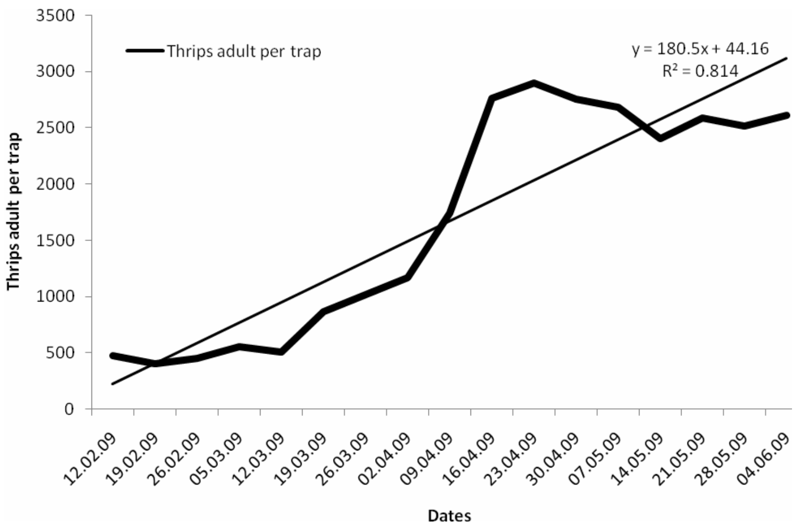

Fig. 3 Mean number of *F. occidentalis* adults per trap in a greenhouse pepper crop in the region of Moknine (Monastir, Tunisia) in 2009.

Loomans and van Lenteren 1995; Guérineau 2003; Whittaker and Kirk 2004; Chaisuekul and Riley 2005; Fraval 2006; Elimem and Chermiti 2009).

According to the results (**Fig. 3**), three phases could be detected in the development of the thrips population on peppers in the greenhouse. During the first phase between February 12th 2009 and March 12th 2009, number of trapped adults was relatively constant, with an average maximum of about 552.4 adults per trap recorded on March 5th 2009. This could be due to climatic conditions in the greenhouse during this phase, with the average recorded temperature being between 11 and 14°C, and the maximum and minimum recorded being 24.14°C on March 5th 2009 and 6.71°C on February 2009. Such conditions are not favorable to the population development of this pest. According to authors such as Bournier (1983), Loomans and van Lenteren (1995), Guérineau (2003) and Trdan *et al.* (2003), this thrips develops best at temperatures between 20 and 25°C, and low temperatures reduce the development rate (Stacey and Fellowes 2002). Minimum temperatures recorded during the same period ranged between 6.71°C for February 12th 2009 and 8.51°C in February 26th 2009, and such low temperatures can cause larval death (Bournier 1983; Fraval 2006) which could be the cause of the low pest population during that period.

The low temperatures were coupled to relatively high humidity from February 12th till March 12th 2009, with averages above 80% RH. This is able to limit pest population increase by causing pupal mortality (Bournier 1983), while the best pest development is promoted in low relative humidity, even below 50% (Guérineau 2003).

The third factor influencing *F. occidentalis* population growth in the greenhouse pepper crop was the photoperiod which can affect the breeding rate of the insect (Whittaker and Kirk 2004; Chaisuekul and Riley 2005). During the first phase, and especially during February, day length was reduced. This probably inhibited thrips development, which is stimulated by prolonged daylight hours (Whittaker and Kirk 2004), with fewer eggs being laid during shorter daylight hours (Chaisuekul and Riley 2005).

The second phase of population growth took place from March 12th till April 4th 2009, with the average number of thrips per trap increasing from 502.5 adults on March 12th 2009 to 868.3 one week later. This increase continued gradually (with $R^2 = 0.8142$) to reach a mean of about 1164.3 adults per trap on April 2nd 2009. This population increase correlated with the beginning of the improvement in climatic conditions in the greenhouse, with photoperiod increased to 208 hours during March and temperature reaching an average of 19.30°C on March 2nd 2009. This was probably the cause of the beginning of the increase in the development rate and the biological potential of this pest

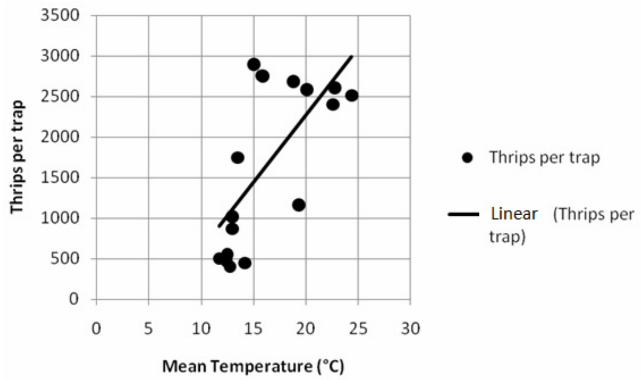

Fig. 4 Correlation between mean temperature values and mean number of thrips per trap.

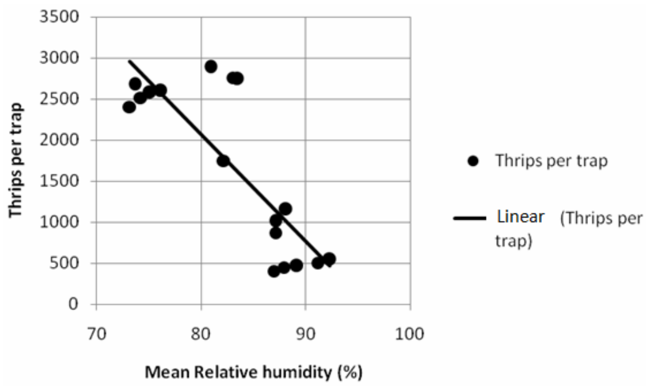

Fig. 5 Correlation between mean relative humidity values and mean number of thrips per trap.

(Stacey and Fellowes 2002; Fraval 2006). The only parameter that did not show significant change during this phase was the relative humidity that averaged between 91.15% on March 12th 2009 and 88.04% on April 2nd 2009.

The third phase began on April 2nd 2009 when the number of captured adults per trap increased to average values of 1744.2 on April 9th 2009 and then to 2898.3 on April 23rd 2009. Subsequently, populations remained more or less high and constant during the rest of the study period. During this last phase several parameters interacted together to contribute to such an increase. Temperature increased steadily to reach values between 18.83 and 22.57°C, respectively on May 7th and May 14th 2009, until an average maximum of about 24.38°C was recorded on May 28th 2009. These tem-

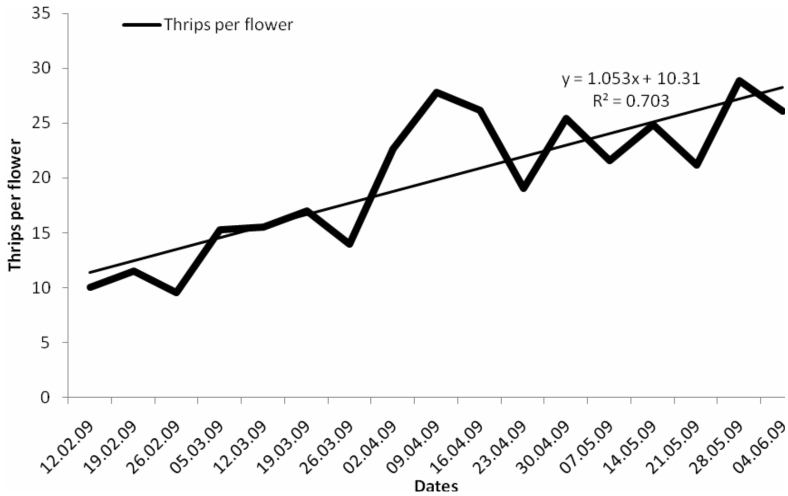

Fig. 6 Mean number of *F. occidentalis* mobile forms per flower in a greenhouse pepper crop in the region of Moknine (Monastir, Tunisia) in 2009.

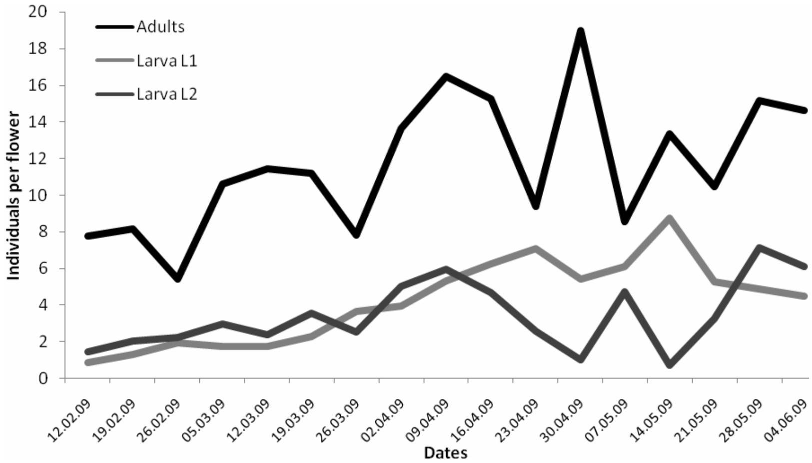

Fig. 7 Mean number of *F. occidentalis* adults and larvae (L1 and L2) per flower in a greenhouse pepper crop in the region of Moknine (Monastir, Tunisia) in 2009.

peratures allow this thrips to develop more rapidly, and improve the population development rate and the biological potential of this pest (Loomans and van Lenteren 1995; Stacey and Fellowes 2002; Chaisuekul and Riley 2005; Fraval 2006; Elimem and Chermiti 2009). This may explain the rapid population increase and its maintenance at high values.

The photoperiod increased significantly during April, May and June, with the number of daylight hours rising from 228, to 276 and 303 h (**Table 1**). Longer day length increases thrips development and also egg laying activity (Bournier 1983; Loomans and van Lenteren 1995; Whittaker and Kirk 2004; Chaisuekul and Riley 2005). Relative humidity tended to decrease slightly to around 75%, and both Bournier (1983) and Guérineau (2003) mentioned that Western Flower Thrips development is favored by dry environments. This is not consistent with results found during this study, proving that this pest may tolerate more or less high relative humidity values when the other environmental parameters such as photoperiod and temperature are favorable.

Correlation between number of thrips per trap and environmental conditions (temperature and relative humidity) (**Figs. 4, 5**), shows that the highest numbers of thrips per trap occurred when mean temperature ranged between 15 and 25°C. This is consistent with results found by (Stacey and Fellowes 2002; Whittaker and Kirk 2004; Chaisuekul and Riley 2005), who mentioned that *F. occidentalis* development begins to increase from 15°C and that the optimal thermal conditions are between 20 and 25°C. Similarly, correlation between number of thrips per trap and mean relative humidity confirms the information mentioned by Bournier (1983) that high relative humidity prevents thrips to develop and increase, and that pest population increases when this parameter begins to decrease.

F. occidentalis numbers in host plant flowers

Weekly monitoring of *F. occidentalis* population in pepper flowers (**Fig. 6**) started on February 2nd 2009, the same date that blue sticky traps were installed in the greenhouse pepper crop. The population in flowers increased progressively throughout the study period ($R^2 = 0.7032$) despite some slight variations, and the number of thrips in the flowers was consistent with the numbers found on blue sticky traps. Moreover, the number in flowers was highly correlated to climatic conditions in the greenhouse. The number of individuals per flower increased steadily with rising temperature and photoperiod till March 26th 2009, where number of thrips per flower was about 14 mobile forms per flower. The damage threshold of thrips in pepper crop is of about 10 mobile forms per flower.

The thrips population continued to increase, reaching about 27.75 mobile forms per flower on April 9th 2009. During the rest of the study period, thrips population varied between 19.05 and 28.85, respectively on April 4th 2009 and May 5th 2009. This relatively high number of individuals per flower may be explained by the increased temperature which reached average values between 15 and 24°C. Relative humidity was reduced to averages around 75%, and the photoperiod increased during the last two months of the study.

The number of adults per flower was higher than that of the two larval instars (**Fig. 7**). The results indicate that the adult population continued to rise from the beginning till the end of the observations. The number adults increased from 7.75 adults per flower on February 12th 2009 to 19 on April 30th 2009 with four peaks of 8.15, 11.43, 16.5 and 19 adults per flower recorded respectively on February 19th, March 3rd, April 9th and April 30th 2009. These peaks possibly correspond to four successive generations of the pest.

Numbers of first instar larvae (L1) showed a continuous increase, peaking on April 23rd at an average value of about 7.08 larvae per flower to decline the following week with a mean number of 5.4 L1 per flower. The resumption of growth of L1 numbers was not maintained thereafter, but after reaching a value of 8.73 L1 per flower recorded on May 15th 2009 it fell again till the end of the observations.

Unlike first stage larvae, the numbers of second instar larvae was variable throughout the study period. The number increased gradually till April 9th 2009 with a mean number of about 5.95 L2 per flower. During the next month, development of second stage larvae decreased, reaching values lower than 1.01 larvae per flower on April 30th 2009. However, during the rest of the observations the numbers of second stage larvae in flowers increased to 7.13 L2 per flower on May 28th 2009.

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