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# Use of a Synthetic Kairomone to Control *Frankliniella occidentalis* Pergande (Thysanoptera; Thripidae) in Protected Pepper Crops in Tunisia

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## ABSTRACT

*Frankliniella occidentalis* Pergande (1895) (Thysanoptera; Thripidae) is a harmful thrips species that may cause serious damage in pepper crop greenhouses. The aim of this study was to monitor and control this pest using blue sticky traps with and without kairomone capsules. Traps with kairomone capsules caught much more than twice as many thrips as those without, with highly significant differences throughout the study period proving thus the effectiveness of these substances to attract this pest. Monitoring thrips populations in the control greenhouse showed a continuous population increase, with high average values of adults and larvae of about 23.89 and 16.27 individuals/flower, respectively. However, in the greenhouse with traps without kairomone capsules the thrips population was the lowest. In the greenhouse where traps with kairomone capsules where installed, the thrips population was marked by variations throughout the study period; increasing to a very high value (20.41 adults and 10.77 larvae/flower) compared with the other greenhouses. Kairomone capsules attracted thrips from the outside, because when the greenhouse entries were closed, *F. occidentalis* populations began to decrease rapidly, on blue sticky traps and in flowers, to 3.43 adults/flower and 1865.8 adults/trap on June 25$^{th}$. These results demonstrate that kairomone capsules have the potential to improve trap capture of *F. occidentalis* in covered pepper crop.

**Keywords:** attraction, effectiveness, growth rate, kairomone capsules, pepper crop, thrips

## INTRODUCTION

The Western Flower Thrips (WFT), *Frankliniella occidentalis* Pergande (Thysanoptera, Thripidae), is a polyphagous thrips species that may attack plant species that belong to many botanical families (Yudin *et al.* 1986; Brødsgaard 1989; Lewis 1973; Alford 1991) such as tree species (Papadaki *et al.* 2008), vegetables (González-Zamora and Garcia-Mari 2003), ornamental crops (Yudin *et al.* 1986; Chau and Heinz 2006) and even weeds (Reddy and Wightman 1988). Originally from the western United States, this species had a limited distribution until the 1960's in western United States, Canada and Mexico. Since 1970 it has spread to many countries in different continents around the world (Anonymous 2002; Kirk and Terry 2003). Introduction of this species to Tunisia dates from the early 1990's but it is still considered a quarantine pest due to its ability to transmit viruses (Belharrath *et al.* 1994; Kirk and Terry 2003).

Control of *F. occidentalis* may be assured through different ways. Biological management, using predators or parasitoids is a very promising method on many crops Most parasitoids species used to control WFT belong to the genus *Ceranisus*, including *C. menes*, *C. americensis* and *C. lepidotus* (Lacasa *et al.* 1996; Loomans and van Lenteren 1995; Loomans 2006; Bosco *et al.* 2008). On the other hand, most employed predators employed for controlling WFT on different crops such as cucumber, pepper, sweet pepper and rose, belong to the *Anthocorridae* family and especially species of the genus *Orius* such as *O. laevigatus*, *O. insidiosus*, *O. majusculus*, and *O. tristicolor* (Loomans and van Lenteren 1995; Parker *et al.* 1995). Moreover, predatory mites seem to be effective in controlling WFT also. Those mites belong to the *Phytoseiidae* family. Most employed mite species are *Neoseiulus cucumeris*, *Amblysseius cucumeris*, *A. swirskii*, *A. andersoni* and *Euseius ovalis* (Jones *et al.* 2005; Pijakker and Ramakers 2008). Chemical control has not changed greatly since the pest arrived from the New World, due to various difficulties (Grasselly 1996; Kirk and Terry 2003). Among these difficulties, the thrips has the ability to acquire a kind of resistance towards several families of insecticides, thus making chemical treatments ineffective. This resistance is developed especially toward the most commonly applied insecticides against thrips pest. Thus, it is strongly recommended to alternate use of insecticides from different families every two to three weeks depending on the biology of the pest, the season of the year, environmental factors and number of generations of thrips (Fougeroux 1988; Grasselly 1996; Shelton *et al.* 2003; Shelton *et al.* 2006).

The second complexity of chemical treatments is related to the biology and behavior of thrips. Species such as *F. occidentalis* insert their eggs into the plant epidermis, and this prevents insecticides reaching them. It is thus necessary to repeat treatments every ten days to kill newly hatched larvae (Bournier 1983; Freuler and Benz 1988). Larvae usually hide in the bottom of the host plant flowers, buds or in very young leaves. Pupae are generally in the ground, consequently they are unaffected by treatments. All these elements make this thrips a hard target for insecticides (Grasselly *et al.* 1991; Fraval 2006). Thus, strategies must be developed to preserve or restore the effectiveness of currently applied insecticides. To develop strategies, it is important to monitor resistance and understand underlying resistance mechanisms (Jensen 2000). On the other hand, plant extracts and herbal insecticides seam to have an impact on many thrips species on many crops and showed high efficacy with no phytotoxicity (Venkateshalu et *al.* 2009; Wohlenberg and Lopes Da Silva 2009). In fact,

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Elimem and Chermiti (2011) mentioned in their works that use of plant based insecticides against *F. ociidentalis* may have an efficiency rate that ranks up to 70 and 80% on total population. Sticky traps seem to be an effective way to control and monitor WFT population. Use of yellow sticky traps for exemple in cucumber crop greenhouses attracted a large number of WFT adults and could be used directly in the control or monitoring of this pest population (Zepa-Coradini *et al.* 2010). However, Sampson *et al.* (2012) mentioned that thrips in general, as for WFT, use scent and color to find flowers of its host. For that reason, trap color is an important factor to catch WFT. Blue sticky traps caught the highest WFT number with high significant differences with yellow, clear and black traps. On the other hand, traps and especially blue sticky traps may be associated with semiochemical substances to improve their effectiveness such as kairomones or pheromones (Gomez *et al.* 2006; van Tol and de Kogel 2007). Blue sticky traps with attractive kairomones can be used in greenhouses to control this pest, or to prevent proliferation of populations. Kairomones can attract males and females of many thrips pests, such as *F. occidentalis* and *Thrips tabaci*. This control method can be employed regardless of the density of thrips in greenhouses (van Tol and de Kogel 2007; Broquier and Lacordaire 2008). According to Uchida *et al.* (2008), a pheromone is a chemical substance that triggers a variety of behavioral responses in another member of the same species, while a kairomone is a chemical substance released by an organism that affects other organisms in a food chain series and belonging to other species.

The aim of this work was to test the effeciency of the kairomone capsules that are based on aromatic substances (van Tol and de Kogel 2007) against the Western Flower Thrips *Frankliniella occidentalis*.

## MATERIALS AND METHODS

### Experimental sites

The present study was carried out in three pepper crop greenhouses situated in the region of Bekalta (35°36′02.24″N, 11°00′20.38″E, elevation 10m) that belongs to the Governorate of Monastir in the Eastern Central Coast of Tunisia. This work started from April 2nd till June 25th 2009. Each greenhouse has an area of about 520 m². Greenhouses were formed by four rows that each of which is formed by two lines of the Tunisian pepper variety named "*Chargui*". The inter-row distance is about 1 m. On May 7th 2009, all the greenhouses were closed using an insect-proof to prevent the entry of thrips from the outside.

### Adults' trapping

Adults' trapping started on April 9th in the greenhouses using blue sticky traps (Koppert®; Holland) that have 25cm long and 10cm wide. First greenhouse served as control where no trap was installed. In the second one, five blue sticky traps (Koppert®; Netherlands) associated with kairomone capsules (Lurem TR®; Koppert®; Netherland). Other five blue sticky traps were installed too through the third greenhouse but without kairomone capsules. Traps were suspended above pepper plants at a height of about 30 cm. Distance between traps is about 10 m. During this study, blue sticky traps were weekly renewed and the kairomone capsules monthly. In fact, kairomone capsules were changed on April 9th, May 07th and June 04th 2009. On the other hand, greenhouses' entries were closed on May 07th with insect-proof to prevent the entry of thrips from the outside.

### Sampling of flowers

Monitoring of *F. occidentalis* population on the host plant flowers was done through a weekly sampling that took place on April 2nd till June 25th 2009. Each greenhouse had been divided into four blocks and each one into five experimental units making thus a total number of repetitions of 20. From each sampling unit, a pepper plant was selected randomly and from which three flowers were collected. Every single pepper plant that was used for sampling was marked in order to not to serve for the next week. Each sampled flower was placed in a plastic bag on which the number of sampling unit and the strata has been marked.

### Calculating *F. occidentalis* growth rate population

*F. occidentalis* total population's growth rate was calculated according to the formula cited by Ramade (2003):

$$G_r = (P^n - P^{n-1})/P^{n-1} \times 100$$

where $G_r$ = Growth rate; $P^n$ = Total population (Larvae and adults) at the sampling date n; $P^{(n-1)}$ = total population (larvae and adults) at the sampling date (n-1).

### Statistical analysis

The statistical analyses were done by the statistical software program SPSS 17 (Statistical Package for the Social Sciences version 17) (SPSS 2008). This program was used for analysis of variance (ANOVA) and Duncan's multiple range test to determine differences between number of thrips encountered on traps with and without kairomone capsules at $P \leq 0.05$.

## RESULTS

Obtained results showed that during first sampling date, adults' thrips number per flower in the three greenhouses are almost the same and they were respectively 2.7, 1.6 and 1.33 adults per flower in greenhouse control, greenhouse without kairomones capsules and greenhouse with kairomone capsules (**Fig. 1**). *F. occidentalis* adults in the greenhouse control increased continually all through the study period reaching thus average values of about 6.93, 17.68 and 23.89 adults per flower respectively on May 07th, June 04th and June 25th 2009. Concerning greenhouse without kairomone capsules it showed the lowest number of thrips per flower. In fact, increase of *F. occidentalis* adults' number was lower than in the greenhouse control without showing important variations with average values of about 5.33, 7.41 and 7.75 adults per flower respectively on May 07th, June 04th and June 25th 2009. However, greenhouse with traps associated with kairomone capsules showed a different evolution. In fact, during the two first weeks of this work, adults' number per flower was very close to those observed in greenhouse control and greenhouse without kairomone capsules. However, after the first date of installation of traps with kairomone capsules, adults' population began to increase reaching thus average numbers higher than in the other greenhouses especially during April 30th, May 07th and May 14th where adults' number was respectively 9.39, 12.91 and 20.41 adults per flower. On the other hand, it should be noted that one week after closing the greenhouses entries with insect proof on May 07th adults' number in greenhouse with kairomone capsules began to decrease continuously from 20.41 to 11.64 and 8.16 adults per flower respectively on May 14th, May 21st and May 28th. Moreover, this decrease has continued till the end of the study period to reach very low values comparing with those observed in the other greenhouses and they were of about 4.68 and 3.43 adults per flower respectively on June 18th and June 25th.

Concerning larvae they showed almost the same evolution in the three greenhouses (**Fig. 2**). In fact, in greenhouse control, larvae's population was marked by a continuous increase from 3.2 larvae per flower on April 2nd and April 9th to 13.31 and 16.27 respectively on June 4th and June 18th. In greenhouse without kairomone capsules, larvae's population was lower than control with a maximum average value around 10.12 larvae per flower on June 04th. Beyond that date, average larvae's number began to decrease reaching values around 8.64, 8.12 and 8.31 respectively on June 11th, June 18th and June 25th. Concerning greenhouse with kairomone capsules, larvae showed almost the same evolution

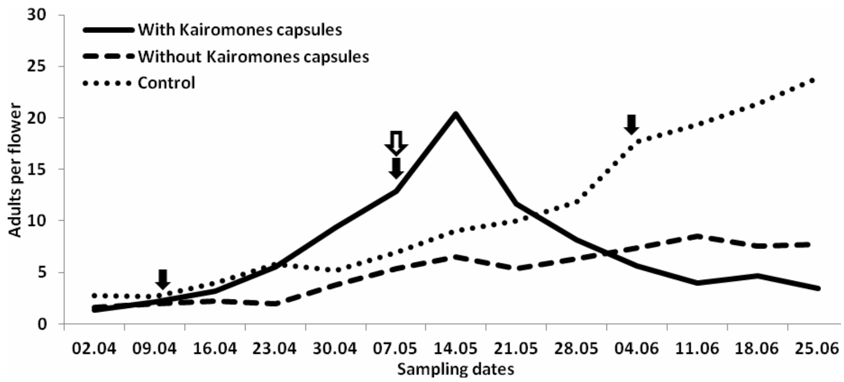


**Fig. 1 Evolution of *Frankliniella occidentalis* adults per flower in three pepper crop greenhouses in the region of Bekalta (Monastir, Tunisia) in 2009.** Closed arrow: installation of kairomone capsules; open arrow: closing entries to greenhouses.

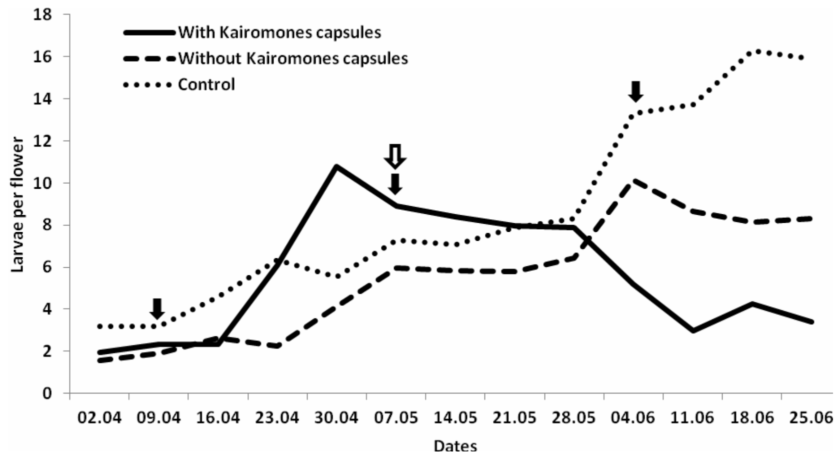


**Fig. 2 Evolution of *Frankliniella occidentalis* larvae per flower in three pepper crop greenhouses in the region of Bekalta (Monastir, Tunisia) in 2009.** Closed arrow: installation of kairomone capsules; open arrow: closing entries to greenhouses.

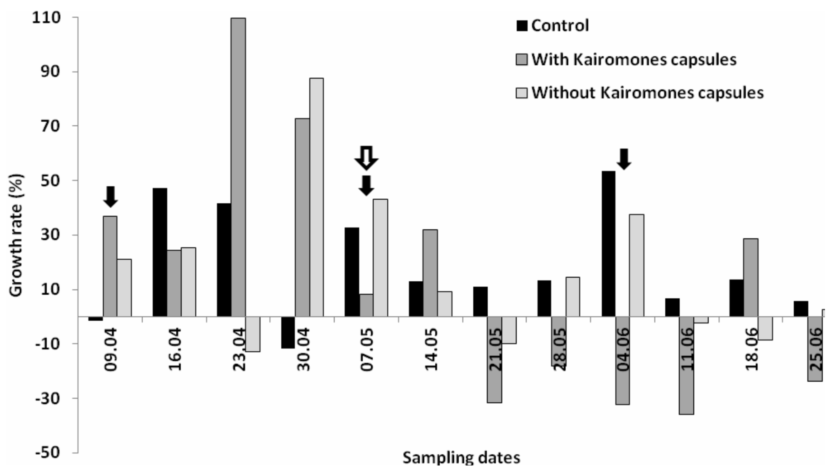


**Fig. 3 *Frankliniella occidentalis* total population's growth rate in three pepper crop greenhouses in the region of Bekalta (Monastir, Tunisia) in 2009.** Closed arrow: installation of kairomone capsules; open arrow: closing entries to greenhouses.

than adults; after the first date of kairomone capsules installation, number of larvae increased from 1.91 and 2.64 larvae per flower respectively on April 04th and April 16th to 6.08 on April 23rd and a maximum of about 10.77 larvae per flower on April 30th was recorded. The differences between larvae and adults' evolutions are in the dates where they began to drop off; adults' population declined one week after closing the greenhouse entries; however it was one week before for larvae making thus an interval of two weeks between larvae and adults' population decrease. It should be noted also that at the end of the study period, mean number of larvae in this greenhouse dropped to very low values, comparing with the other greenhouses, with 2.95, 4.27 and 3.39 larvae per flower respectively during June 11th, 18th and 25th.

On the other hand, obtained results (**Fig. 3**) showed that in the control greenhouse, the growth rate ($G_r$) was almost always positive and varied between a maximum value of about 53.56% on June 4th and a minimum of 5.81% recorded on June 25th except on April 09th and April 30th where the growth rate was -1.4 and -11.66%, respectively. Concerning greenhouse without kairomone capsules, this parameter showed big variations between positive and negative values during all the study period with a maximum of about 87.62% on April 30th and a minimum of -12.93% on April 23rd. In the greenhouse with kairomone capsules growth rate showed positive values during the first period of observations with a maximum of 109.73% on April 23rd. How-

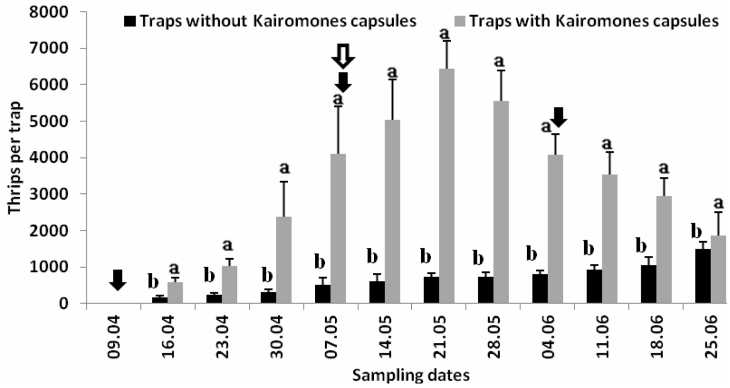


**Fig. 4 Evolution of *Frankliniella occidentalis* adults (males and females) on blue sticky traps in greenhouses with and without kairomone capsules in the region of Bekalta (Monastir, Tunisia) in 2009.** Closed arrow: installation of kairomone capsules; open arrow: closing entries to greenhouses. Means followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test..

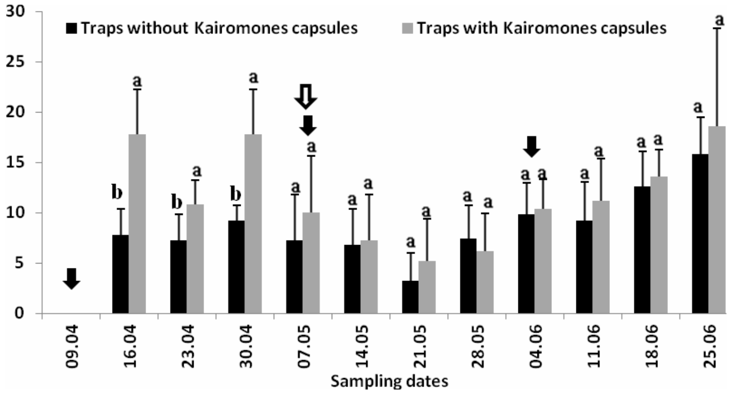


**Fig. 5 Evolution of *Aeolothrips tenuicornis* adults (males and females) on blue sticky traps in greenhouses with and without kairomones capsules in the region of Bekalta (Monastir, Tunisia) in 2009.** Closed arrow: installation of kairomone capsules; open arrow: closing entries to greenhouses. Means followed by the same letter are not significantly different at $P \leq 0.05$ according to Duncan's multiple range test.

ever, it was obvious that two weeks after closing the greenhouses entries the growth rate became negative with values ranging between -18.15 and -35.89% respectively on May 28$^{th}$ and June 11$^{th}$.

Monitoring *F. occidentalis* adults (males and females) on blue sticky traps in both greenhouses (**Fig. 4**) showed that number of thrips captured on traps with kairomone capsules is higher than in traps without kairomone capsules with high significant differences according to the Duncan test at $P \leq 0.05$. In fact, number of thrips recorded on traps with kairomone capsules reached a maximum of about 6442 adults per trap on May 05$^{th}$ while it was 1492 adults per trap on June 25$^{th}$ on traps without kairomone capsules. Despite that thrips population was almost the same on flowers in the three greenhouses at the beginning of the study, thrips number increased faster on traps with kairomone capsules; from 582.4 to 6442 adults per trap respectively on April 16$^{th}$ and May 05$^{th}$, than on traps without where adults' number increased slowly without showing any significant variations. Moreover, obtained results demonstrated that thrips number encountered on traps with kairomone capsules tends to decrease three weeks after closing the greenhouses entries with insect-proof, one week after population decrease observed on pepper flowers in the same greenhouse. Thrips number on traps with kairomone capsules continued to decrease reaching an average value of about 1865.8 adults per trap at the end of study period which is close to those observed on traps without kairomone capsules.

On blue sticky traps, *F. occidentalis* was not the only thrips species that was found, another specimen was encountered on traps with and without kairomone capsules. In fact, and according to the identification keys of Lacasa and Lloréns (1996), Lacasa and Lloréns (1998) and Mound and Kibby (1998), the thrips species was *Aeolothrips tenuicornis* Bagnall (1934) which is a predatory thrips that feeds on other thrips species such as *F. occidentalis* and *Thrips tabaci* Lindemann (1888). In fact, *A. tenuicornis'* number on both traps was almost the same with no significant differences according to the Duncan test at $P = 0.05$ (**Fig. 5**) except during the three first weeks of this study where thrips number on traps with kairomone capsules was higher than on traps without kairomone capsules. On the other hand, *A. tenuicornis* values were lower compared to those registered for *F. occidentalis*. Indeed, maximum values recorded on the blue sticky traps for the predatory thrips.

## DISCUSSION

The obtained results showed that thrips populations in three greenhouses were almost the same during the first period of observation. However, thrips numbers on traps associated with kairomone capsules were significantly higher than on traps without kairomone capsules during all the study period. This proves the effect of these molecules, that are based on aromatic substances (van Tol and de Kogel 2007), on thrips adults' attraction. The number of thrips caught on traps with kairomone capsules was 1.24 to 8.64 times higher than on traps without kairomone capsules (**Table 1**).

In fact, these results concord with those cited by Moerman (2008) and van Tol and de Kogel (2007) who mentioned that traps with kairomone capsules caught more than twice as many thrips as the ones without. Brødsgaard (1990), Frey *et al.* (1994), and Teulon *et al.* (1993), reported that colored traps with host plant odors caught 1.3 to 5.6 more *F. occidentalis* than traps without odors. Davidson *et al.* (2007) demonstrated also that *F. occidentalis* were attracted 14 times more to traps with some compounds such as methyl isonicotinate or ethyl isonicotninate than to control ones. Moreover, van Tol *et al.* (2007) mentioned that these kairomone capsules are able to attract males and

**Table 1** Number of times more of thrips number caught on traps with kairomones capsules versus traps without kairomones capsules.

| Dates | Number of times more |
|---|---|
| 16.04.09 | 3.48 |
| 23.04.09 | 4.16 |
| 30.04.09 | 7.61 |
| 07.05.09 | 7.94 |
| 14.05.09 | 8.33 |
| 21.05.09 | 8.64 |
| 28.05.09 | 7.64 |
| 04.06.09 | 5.06 |
| 11.06.09 | 3.84 |
| 18.06.09 | 2.79 |
| 25.06.09 | 1.24 |

females of thrips which was observed in this study case too. De Kogel *et al.* (1999) who tested the attractiveness of plant volatile substances to *F. occidentalis*, showed also that this species is much more attracted to plant volatiles (such as kairomone) than control or other substances with significant differences often.

The kairomone capsules used are able to attract only phytophagous thrips species such as *F. occidentalis* and *T. tabaci* (van Tol and de Kogel 2007). However, the predatory thrips *A. tenuicornis* was found trapped. The inexistence of significant differences between numbers of *A. tenuicornis* on traps with kairomone capsules and ones without confirms the results found by van Tol *et al.* (2007) proving thus that the predatory thrips was not attracted by kairomone capsules but was accidentally trapped. Besides, predators and parasitoids are also attracted by some kairomone such as those produced by their prey, like the glandular and cuticular secretions and the excrements of pests, and not those emitted by plants (Leroy *et al.* 2009; Battaglia *et al.* 1993). In fact, this can be the same case for this present work where *A. tenuicornis* was present in all greenhouses without differences and independently of the kairomone capsules' presence.

Concerning dynamic population's evolution in pepper's flower on the greenhouses and especially in greenhouse control, it must be noted that, and according to Elimem and Chermiti (2009) and Elimem *et al.* (2011), thrips populations tend to increase continuously approaching the hot season depending on climatic conditions' amelioration. In fact, high temperatures, low relative humidity and prolonged day light improve *F. occidentalis* biotical potential and consequently affect pest populations' level that increases relatively. This was observed in the case of this study. Consequently, growth rate ($G_r$) was almost positive during all the study period due to the continuous evolution of thrips populations till the end of observations.

However, adults and larvae's numbers, in greenhouse where traps without kairomone capsules were installed, were lower than the other greenhouses. In fact, ten blue sticky traps served not only to survey and to monitor thrips populations but also to prevent them to increase normally such as in control greenhouse by adults' trapping and even to hold up their development.

Concerning thrips evolution in the greenhouse where traps with kairomone capsules were installed, population increased continuously and much more than in the other greenhouses for adults and larvae till May 14$^{th}$; date from which adults' number began to decrease continuously. Consequently, growth rate ($G_r$) became negative from May 21$^{st}$ (two weeks after closing the entries) till the end of the study except for June 18$^{th}$. On the other hand, adults' population on traps with kairomone capsules showed the same evolution. In fact, this proves not only the effectiveness of kairomone capsules, but also that they were attracting adults from the outside of the greenhouse because since the closing of the entries adults began to decrease relatively to reach low values at the end of the study period only in greenhouse with kairomone capsules while thrips populations continued their evolutions normally in the other greenhouses. These results do not concord with those mentioned by Moerman (2007) who indicated that kairomone capsule do not attract thrips from the outside of the greenhouse because traps near the openings did not attract more thrips than following traps more inward. Indeed, to make sure that control of *F. occidentalis* has high effectiveness greenhouses entries must be closed to prevent the entry of thrips.

Besides, Anonymous (2002) indicates that *F. occidentalis* prefers to feed and live in flowers than other parts of the plants. In addition, thrips adults are first in flowers of their host which constitute the ecological site for the pest, and then they migrate by flight activity to other regions such as other host plants (Bournier 1983) or sticky traps when these ones are installed in the greenhouses (Elimem and Chermiti 2009; Elimem *et al.* 2011). In fact, these results concord with those observed during this study where populations' decrease on pepper flowers was observed two weeks after closing the greenhouses entries on May 07$^{th}$, while on traps it was recorded on May 28$^{th}$; three weeks after that.

As a conclusion of this study, thrips population may be controlled effectively and to reach very low values of adults and larvae using blue sticky traps associated to kairomone capsules when pepper crop greenhouses entries are closed to prevent the entry of adult thrips from the outside.

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