Frankliniella occidentalis (Thysanoptera: Thripidae) in spray-type carnations: spatial distribution analysis

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Frankliniella occidentalis (Thysanoptera: Thripidae) spatial distribution was studied in one variety of spray-type carnations, grown together with several other varieties, inside a greenhouse. Thrips were more abundant in flowers than in floral buds. In open floral buds thrips were more abundant than in closed ones. Significant differences were detected in the number of thrips present in adjacent flowers (in areas of 1m²), which were in close phenological stages. Analysing the spatial distribution pattern of the thrips (adult males, females, total and immatures) landed in the crop, in a homogenous small area (50 m²), the Taylor Power Law and the Iwao's Patchiness Regression Method indicated a random distribution pattern, and the individuals were the basic units of distribution. The spatial distribution pattern of thrips in flight, at the top of the crop (in an area of 150 m²), was studied with blue sticky traps. Both statistical methods indicated an aggregated distribution pattern, being the individuals the basic units of distribution. The location of thrips was studied with traps regularly distributed in the same area, in the winter, when population density was low, and in spring, with a higher density. Thrips location was different from one week to the next, being impossible to preview it.

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INTRODUCTION

The knowledge about pests spatial distribution, apart from the descriptive information about them, is essential in IPM, for: (1) the definition of monitoring procedures, used for risk assessment and evaluation of control measures efficacy; (2) a correct selection of natural enemies, which must have, at least, a partially overlapped spatial distribution in relation to pests; (3) the implementation of strategic target applications of control measures.

In this paper, the interplant distribution of *Frankliniella occidentalis* (Thysanoptera: Thripidae), an important pest in several crops in the Iberian Peninsula, is analysed in spray-type carnations grown inside greenhouses.

MATERIAL AND METHODS

Essays were conducted in a plastic greenhouse, 50 Km south Lisbon, where several varieties of spray-type carnations were being grown. Essays were developed in the variety Rossini, which occupied an area of 150 m².

All statistical tests were performed for a level of significance (α) equal to 0.05.

1. Presence of thrips in flowers and flower buds (Essay 1)

In two sampling dates, during summer, opened flowers, opened flower buds (with the petals' tip showing in the top of the sepals) and closed flower buds (no petals showing) were collected at random. Ten flowers (F), 10 opened buds (OB) and 10 closed buds (CB) were collected in sampling date 1 (S1), and 15 each were collected in sampling date 2 (S2). Flowers and buds were individually transported in alcohol 50%, inside plastic vials. Thrips were dislodged from these plant structures by a "washing method": each plant organ (flower or bud) was vigorously agitated vertically and horizontally, during some seconds, inside the transportation vial, in alcohol. After that process, they were transferred to a solution of water and some drops of detergent, and again were agitated during about 2 minutes. Floral buds were previously opened manually. The alcohol of transportation and the soapy solution were filtered, and thrips present in the filtration paper were registered.

The number of thrips (males, females, total of adults and immatures) inside F and OB, and inside OB and CB, was compared in sampling dates S1 and S2, using the t test, with the exception of females (S1:OB/CB), which were compared with the Mann-Whitney test. Transformation log (x+1) was used in some situations.

Sex ratios (males/ females) in F and OB were compared with Mann-Whitney test. Sex ratios inside CB were not considered owing to several mathematical indeterminations.

2. Distribution of thrips landed on the crop (Essays 2A and 2B)

In the central part (50 m²) of the area occupied by the variety under study, two essays were developed, in summer. Flowers were collected at random, at sun- set, 2-3 days after the last gathering of flowers, and with, at least, 5 days distance from the last pesticide spraying.

Essay 2A. Twenty flowers were collected at the top of the crop, in each of 7 sampling dates, and transported individually inside plastic vials with alcohol 50% into the laboratory, where they were submitted to the washing method described above. The number of adults (males, females, and total) and immatures found inside the flowers was registered, and two statistical methods, the "Taylor Power Law" (TAYLOR, 1961) and the "Iwao's Patchiness Regression Method" (BECHINSKY & PEDIGO, 1981), were used. The significance of F (of the respective ANOVA) and 4 null hypothesis (b=1; log a=0; α=0; and β=1) were tested, using the t test. Transformation SQRT (x+0.5) was used for the total number of adults and immatures.

Essay 2B. Squares of 1 m² were selected, at random, in different sampling dates, 12 squares in total. In each one, 5 flowers were collected, transported and manipulated, as described above. Thrips found inside the flowers were registered. In each group of 5 flowers, the flower with the highest number of males and the one with the lowest were compared in relation to males abundance, using the paired-sample t test (a total of 12 pairs were compared). This analysis was repeated for females, total number of adults, and for immatures. Data were previously transformed by the SQRT (x+0.5).

3. Distribution pattern of thrips in flight over the crop (Essays 3A and 3B)

In the area occupied by the variety under study (150m²), 25 blue sticky traps, hung at the top of the crop, were regularly distributed, 5 traps in each crop line, constituting a quadrate net, organized in lines and sectors, with one trap in the centre of each quadrate (Fig. 1). Some traps were also placed in the varieties in the vicinity.

Traps were changed weekly during two periods: P1, of 7 weeks, in the winter (Essay 3A), and P2, of 5 weeks, in spring (Essay 3B). In the laboratory, traps were handled according to the methodology described in MATEUS et al. (2002), and thrips caught in

each trap were counted, except those trapped in the vicinity varieties.

The number of males, females, and total of adults trapped in essay 3B was statistically analysed: (1) The Taylor Power Law and the Iwao's Patchiness Regression Method were used, and 6 null hypothesis were tested using t test (log a=0; b=1; b≤ 1; α=0; β=1; and β≤ 1); (2) In each sampling date, captures in the lines were compared, as well as those in the transversal sectors, by using ANOVA, followed by the Tukey test- in some cases, data were transformed with log (x) or log (x+1).
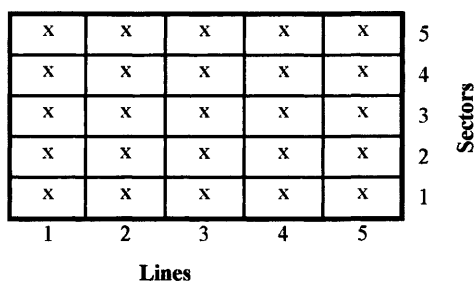

Figure 1- Area occupied by the spray-type carnations variety Rossini, regularly divided into quadrates, with one sticky trap (x) in the centre of each quadrate. [Lines are the crop ones and sectors are transversal areas].

RESULTS

All results about adults indicated in this work are referred to the species *F. occidentalis*. Thysanoptera immatures were not identified to the specific level.

1. Presence of thrips in flowers and flower buds

In relation to the adults detected, 98.8% were *F. occidentalis*.

Results of the comparison of thrips presence in flowers (F), in opened floral buds (OB) and in closed floral buds (CB) are presented in table 1: (1) for the total of adults and males, the number of thrips in F was significantly higher than in OB, and in OB it was significantly higher than in CB; (2) for females and immatures, the number of thrips in OB was significantly higher than in CB, but between F and OB results were not statistically consistent in the two samples, with the mean number of individuals always higher in F; the high standard deviation observed in F, in S2, has affected negatively the performance of the t test; (3) adults' sex ratio (males/females) was significantly higher in F than in OB; in CB it was not analysed.

It was also observed that, in relation to the 12 adults and 28 larvae found associated to closed buds, 8 and 17, respectively, were detected inside these buds.

Table 1- **Mean number of adults *Frankliniella occidentalis* and immature Thysanoptera detected in three floral development stages**

Sample	Floral stage	Females	Males	Total adults	Sex ratio	Immatures
	Flower	11.6 a	5.8	17.4	0.62	10.2
1	Opened bud	8.0 a	0.7	8.7	0.12	3.5
	Closed bud	0.1	0.0	0.1	-	0.1
	Flower	20.1	5.5	25.7	0.36	20.1 b
2	Opened bud	10.5	1.3	11.7	0.11	5.7 b
	Closed bud	0.7	0.0	0.7	0.00	1.8

Values followed by the same letter are not statistically different (α = 0.05); standard deviations (by column):
females- 5.4; 4.0; 0.3; 8.0; 5.7; 0.9;
males- 3.4; 0.9; 0.0; 2.7; 1.4; 0.0;
total- 6.7; 4.2; 0.3; 7.9; 6.9; 0.9;
sex ratio- 0.53; 0.17; 0.30; 0.11;0.0;
immatures- 11.1; 3.4; 0.3; 23.4: 5.0; 2.5.

Table 2- Results of the Taylor Power Law and of the Iwao's Patchiness Regression Method for Frankliniella occidentalis adults and Thysanoptera immatures, detected in flowers in a restricted area of a spray-type carnations variety; thrips mean densities.

Thrips	Taylor Power Law				Iwao's Patchiness Regression				Mean number/flower
	F [1]	r^2	log a [2]	b [3]	F [1]	r^2	α [2]	β [3]	
Total adults	9.18	0.65	0.11	1.46	189.75	0.97	-0.68	1.00	7.4- 37.4
Females	11.14	0.69	-0.12	1.65	63.35	0.92	0.91	1.18	5.8- 24.8
Males	26.36	0.84	0.15	1.27	234.30	0.98	0.34	1.18	1.6- 12.7
Immatures	15.92	0.80	0.48	1.60	58.71	0.92	-0.76	1.26	0.8- 20.7 [4]

Tests were performed for α= 0.05; (1) all F values are significant; (2) H_o: log a = 0 and H_o: α = 0 are not rejected; (3) Ho: b = 1 and H_o: β = 1 are not rejected; (4) for the Taylor Power Law, the minimum mean density considered was 3.2.

Table 3- Mean number of adults *Frankliniella occidentalis* and immature Thysanoptera detected in the flower with the highest number of thrips (+) and in the flower with the lowest number of thrips (-), in twelve groups of five flowers, each occupying an area of 1 m²

Flowers	Females	Males	Total adults	Immatures
Flower (+)	23.3	3.8	26.0	40.4
Flower (-)	7.7	0.7	9.1	5.2

Table 4- Results of the Taylor Power Law and of the Iwao's Patchiness Regression Method for Frankliniella occidentalis adults captured in blue sticky traps, hung at the top of a spray-type carnations variety; thrips mean densities.

Thrips	Taylor Power Law				Iwao's Patchiness Regression				Mean number/trap
	F [1]	r^2	Log a [2]	b [3]	F [1]	r^2	α [4]	β [5]	
Total adults	683.64	0.99	-0.58	2.10	1229.41	1.00	-0.56	1.35	7.4-52.7
Females	419.07	0.99	0.11	1.61	288.80	0.99	0.29	1.40	1.7-14.1
Males	174.68	0.98	-0.38	1.96	1361.94	1.00	-0.45	1.34	3.7-39.1

Tests were performed for α= 0.05; (1) all F values are significant; (2) H_o: log a = 0 is not rejected; (3) H_o: b = 1 and H_o: β ≤ 1 are rejected; (4) H_o: α = 0 is not rejected; (5) H_o: β = 1 and H_o: β≤ 1 are rejected.
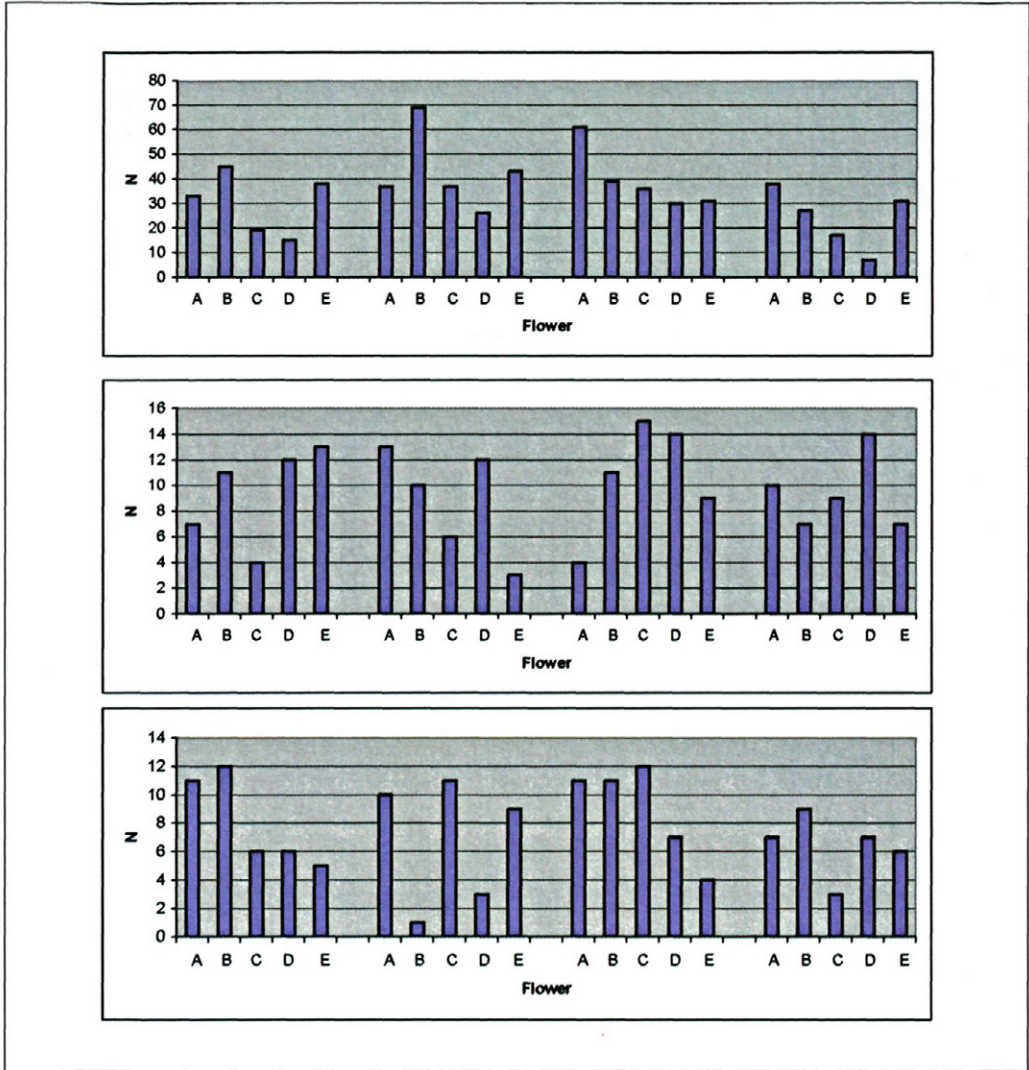
Figure 2- Number of *Frankliniella occidentalis* adults captured in each group of 5 flowers (from A to E), which occupied an area of 1m² [the 12 groups were organized in 3 series according to the magnitude of captures].

Of the 554 immatures observed, only one was a pre-pupae; all the others (99.8%) were larvae.

2. Distribution of thrips landed on the crop

The mean percentage of *F. occidentalis* adults collected in flowers was 89.3%, in essay 2A, and 98.7%, in essay 2B.

Essay 2A. Results of the Taylor Power Law and of the Iwao's Patchiness Regression Method, for adults (males, females and total) and immatures, and the range of mean densities, are presented in table 2. Regressions were significant. Both regression methods provided a good fit to the data but, in the
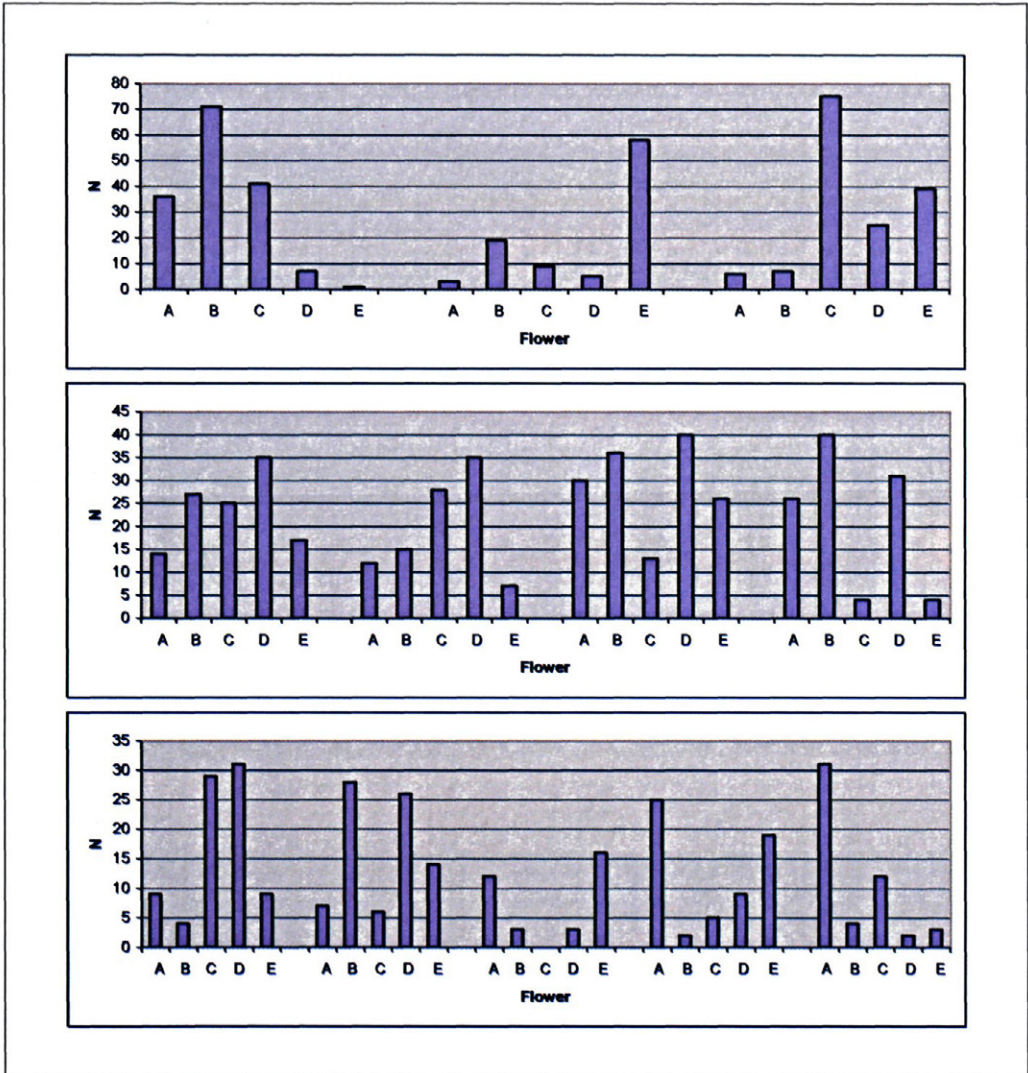
Figure 3- Number of Thysanoptera immatures captured in each group of 5 flowers (from A to E), which occupied an area of 1m^2 [the 12 groups were organized in 3 series according to the magnitude of captures].

second one, r^2 values were higher for all thrips categories analysed.

Null hypothesis H_o: log a=0 and H_o: b=1 (Taylor Power Law) were not rejected in all thrips categories, indicating a random spatial distribution pattern. Null hypothesis H_o: α=0 and H_o: β=1 (Iwao's Patchiness Regression Method) were not rejected, indicating that

the basic units of distribution were the individuals, and that they were distributed at random.

Essay 2B. The number of adults (total) and immatures detected in the 5 flowers of each one of the 12 groups analysed is presented in figures 2 and 3. For each thrips category (males, females, total adults, and immatures), there was a significant differen-

ce between the number of thrips in the flower with the highest number of individuals in one group and the number of thrips in the flower with the lowest number of individuals in the same group (Table 3).

3. Distribution pattern of thrips in flight over the crop

Essay 3A. The location of adult thrips in the selected area of the crop, during P1 (7 weekly samples), is indicated in figure 4.
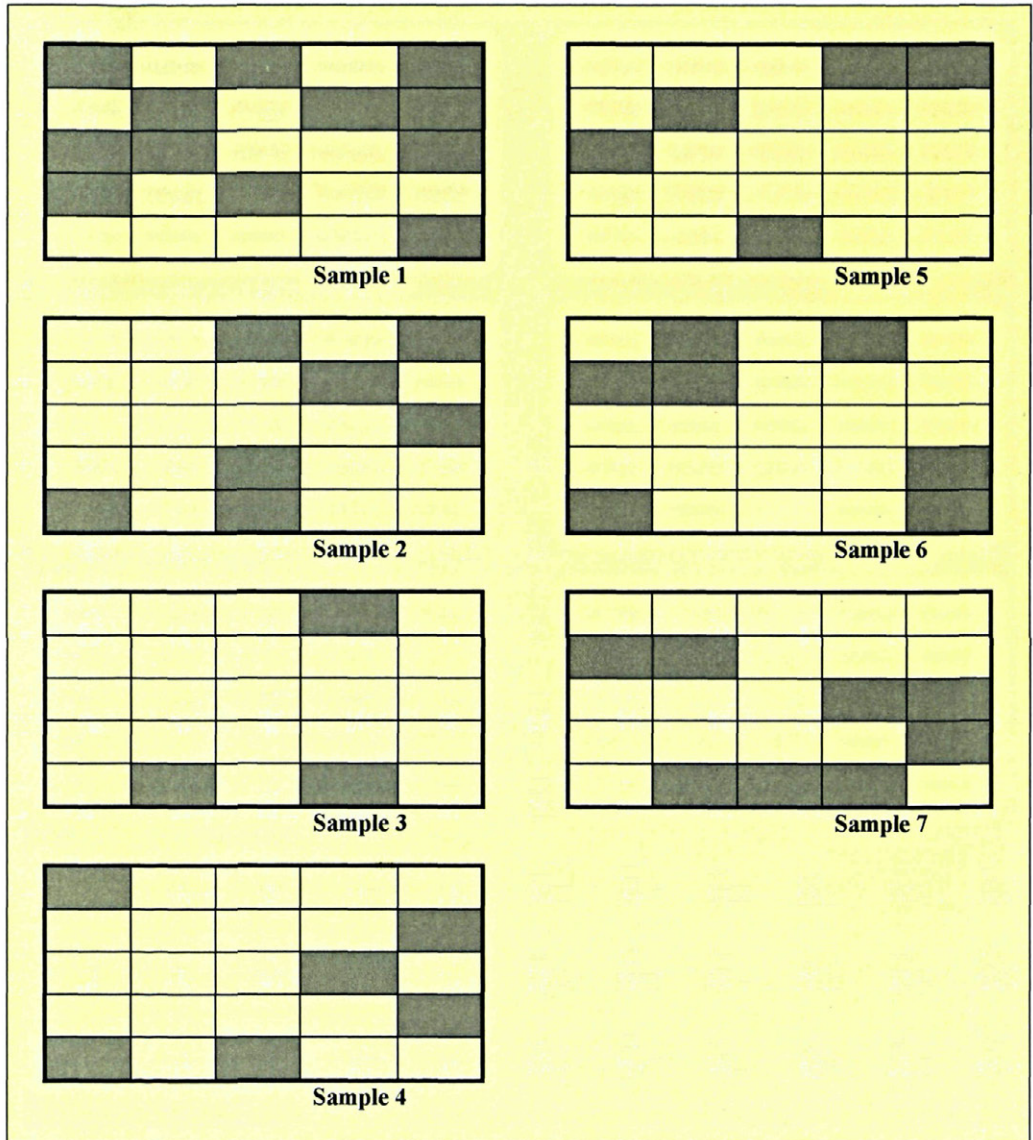

Figure 4- Distribution of *Frankliniella occidentalis* in spray- type carnations, during the period P1. [For each sample, the area occupied by the variety studied is represented as shown in fig.1; the grey coloration of a quadrate indicates that one or more insects were captured in the trap placed in the centre of that quadrate].

During this period, there were quadrates where none thrips was captured along the week, and quadrates where few (a mean of 1.3 thrips) were detected, constituting isolated foci. From one week to the next, there was not a fixed location of those foci, or a pattern of variation in their location. Females caught during this period (winter) belonged to the dark form.

Essay 3B. Results of the Taylor Power Law and of the Iwao's Patchiness Regression, for males, females and total number of adults, are presented in table 4, as well as the range of mean densities. Regressions were significant. Both regression methods provided a good fit to the data but, in the second one, r^2 was higher for all thrips categories analysed. Null hypothesis H_o: log a=0 was not rejected, and H_o: b=1 and H_o: b≤ 1 were rejected for all categories, indicating an aggregated spatial distribution pattern. Null hypothesis H_o: α=0 was not rejected, and H_o: β=1 and H_o: β≤ 1 were rejected, indicating that the basic units of distribution were the individuals, which were aggregated.

Comparing thrips captures in the 5 lines (which correspond to the crop lines), in each sample of P2 (5 weekly samples), significant differences were detected, except in sample 1 (Table 5). For the 5 sectors, there were no significant differences. Additionally, considering the area studied, there was a change from one sample to the other (i.e. from one week to the other) in the location of the highest and lowest captures.

DISCUSSION AND CONCLUSIONS

In this work, thrips identification to the specific level was conducted exclusively in adults. However, it is suggested that most larvae detected in flowers belonged to *F. occidentalis*, owing to the almost absence of larvae in other parts of the plants of this crop (data not published), together with the high percentage of *F. occidentalis* adults, in relation to other Thysanoptera species, in the samples collected, and also owing to the high reproduction rate known for this species (ARZONE *et al.*, 1989; GINDIN *et al.*, 1996).

The large majority (99.8%) of immatures detected in flowers and floral buds were larvae (Essay 1), indicating that pre-pupa and pupa stages did not develop there.

When comparing the presence of thrips in flowers and in floral buds (Essay 1), there was a higher number of adults and larvae in

Table 5- **Mean number of *Frankliniella occidentalis* adults captured in blue sticky traps distributed in the area occupied by the spray-type carnations variety, during P2; results of the ANOVA and Tukey test.**

		Sample				
		1	2	3	4	5
Line	1	10.6	20.2 a	31.0 ab	15.0 bc	31.2 a
	2	6.4	18.8 a	14.0 a	8.6 ab	31.2 a
	3	4.6	20.6 a	16.8 a	6.2 a	32.8 a
	4	7.8	48.6 b	40.6 b	18.2 c	72.2 b
	5	7.6	60.0 b	54.0 b	25.4 c	96.0 b
Sector	1	9.4	46.0	35.8	11.0	68.8
	2	7.6	29.2	25.6	12.8	53.0
	3	5.6	29.2	27.8	12.6	39.6
	4	5.0	26.2	23.2	15.6	45.2
	5	9.4	37.6	44.0	21.4	57.0

ANOVA did not advise the use of the Tukey test in the shadowed samples; in each column, values followed by the same letter are not significantly different (α= 0.05); mean square errors (of transformed data) for non shadowed samples (from 2 to 5): 0.02; 0.04; 0.05; 0.02.

flowers in relation to opened buds, and in these buds there were more thrips than in closed ones. This is probably owing to the difference in the pollen maturation and in the intensity of visual and odoriferous stimuli, between these three floral development stages.

The detection of individuals inside closed buds indicates an early colonization of the floral structures, as also found by CARRIZO & KLASMAN (2001). The presence of thrips in the floral buds guarantees the permanency of the pest in the crop after each gathering of flowers, and a protection in relation to pesticide spraying and to arthropod enemies with big body sizes.

In relation to thrips spatial distribution pattern in the selected variety of the crop, in an area of 50 m² (Essay 2A), data were better fitted to the Iwao's Patchiness Regression Method, in relation to the Taylor Power Law. Parameters "a" and "b" indicated that the total number of adults, males, females and immatures were distributed at random in that area. Parameters "α" and "β" suggest that the basic units of their distribution were the individuals themselves, which were randomly distributed. In this essay, several factors of heterogeneity were intentionally eliminated: sampled flowers belonged to the same variety, and were in close phenological stages and located at the same high level in the crop; the sampling area was small; and sampling occurred always at the same period of the day.

The negative values of "α" obtained for the total number of adults and immatures may indicate a certain degree of repellence between the individuals, which may correspond to a competition for space in each flower: means of 37.4 adults/ flower and 20.7 immatures/ flower were detected. Parameters "b" and "α" indicate that there was a higher tendency for aggregation in females, which may correspond to a lower tendency of females for flight activity in relation to males, when sufficient feeding and oviposition resources are available.

Significant differences were detected in the number of thrips present in flowers close to each other in space, in areas of 1 m² (Essay 2B), which must be taken into attention when population dynamic studies are being conducted. Flowers had been gathered 2-3 days before the sampling dates, and so those analysed in this essay were in close phenological stages.

Sampling of flowers occurred, at least, 5 days after the last pesticide spraying, to avoid pesticides application effect in insects' behaviour (AYYAPPATH et al., 1995), and in their distribution, when mortality rates are high (TAYLOR, 1987; TRUMBLE, 1985).

The spatial distribution pattern of thrips in flight, at the top of the crop, was also studied with blue sticky traps, in the area of the selected variety (Essay 3B). Data were better fitted to the Iwao's Patchiness Regression Method, and according to it, the basic units of distribution of adults (males, females and total) were the individuals themselves, which were aggregated. Taylor Power Law also indicated an aggregated distribution pattern. An aggregated distribution of F. occidentalis was also detected, by other authors, in several crops (e.g. ROBB, 1989; STEINER, 1990; SHIPP & ZARIFFA, 1991; NAVAS et al., 1994; CHO et al., 1995; SÁNCHEZ et al., 1997; CHO et al., 2001; DELIGEORGIDIS et al., 2002). This pattern may be due to the "swarming behaviour" reported for this species (MATTESON & TERRY, 1992), but also to the influence of the colour of the background under each trap in the ability of traps to capture thrips (BERLINGER et al., 1993; VERNON & GILLESPIE, 1995), and so an heterogeneous distribution of plants or flowers in the crop influences differently each trap, which cause an heterogeneity in trap catches.

According to the results obtained, indicating an aggregation pattern, whenever thrips in flight are being studied, and two or more factors are under consideration, blocks should be used in the experimental design.

The knowledge about the spatial distribution pattern of a population does not indicate individuals exact location in a crop, which is of particular interest for a pest like F. occidentalis, which is a virus vector. This infor-

mation was obtained by thrips captures in a "quadrate net" established over the area under study (Essays 3A and 3B).

During the winter (Essay 3A), when population density was still low, isolated infestation foci were detected in the crop and there was not a pattern of permanency or variation on thrips location, from one week to the next, being impossible to preview the location of the infestation foci. So, during this season, the weekly monitoring of thrips, or of infected plants, must be conducted all over the area of the crop.

In spring (Essay 3B), when population density was higher, differences were detected bet-

ween lines and between sectors, but also there was a change from one week to the next in the location of the highest and lowest captures, indicating the need for a regular monitoring in space and time, when the location of individuals is of interest.

ACKNOWLEDGEMENTS

RESUMEN

C. MATEUS, J. ARAÚJO, A. MEXIA. 2005. Distribución espacial de *Frankliniella occidentalis* (Thysanoptera: Thripidae) en clavel miniatura. *Bol. San. Veg. Plagas*, **31**: 47-57.

Se estudió la distribución espacial de *Frankliniella occidentalis* (Thysanoptera: Thripidae) en una variedad de clavel miniatura cultivada en invernadero conjuntamente con otras variedades. Los trips fueron más abundantes en las flores que en los botones florales. En los botones florales abiertos los trips fueron más abundantes que en los botones florales cerrados. Se encontraron diferencias significativas en el número de trips presentes en flores adyacentes (en áreas de 1m^2) que estaban en una fase fenológica similar. Analizando el patrón de distribución espacial de los trips (adultos machos y hembras, total y inmaduros) posados en el cultivo, en una pequeña área homogénea (50m^2), la ley de la potencia de Taylor y el análisis del coeficiente de agregación de Iwao indicaban un patrón de distribución al azar, y los individuos como unidad básica de distribución. Se estudió con trampas pegajosas azules el patrón de distribución espacial de los trips en vuelo en la parte superior del cultivo (en un área de 150m^2). Ambos métodos estadísticos indicaban un patrón de distribución agregado, siendo los individuos la unidad básica de distribución. La localización de los trips se estudió con trampas regularmente distribuidas en la misma área, en invierno, cuando la densidad de población era baja, y en primavera, con densidades más altas. La localización de los trips fue diferente de una semana a otra, siendo imposible de prever.

Palabras clave: Thysanoptera, *Frankliniella occidentalis*, clavel miniatura, distribución espacial.

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