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Spatial Distribution of *Frankliniella occidentalis* (Thysanoptera: Thripidae) in Greenhouse Crops: Location of Infestation Foci and Distribution Patterns

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The spatial distribution of *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) was analysed in ornamental crops (roses and spray-type carnations) and horticultural crops (pepper and strawberries), inside greenhouses, using sticky traps. In ornamental crops, at low population densities, during the winter, there was not a constant location of the isolated foci of infestation, from one week to the next, or a specific pattern of variation in that location. In spray-type carnations, pepper and strawberries, at higher population densities, in spring and summer, the basic units of distribution were the individuals, and they were aggregated. For roses, at those population levels, a random distribution was observed, with a tendency for aggregation. The number of traps needed to estimate population densities, in each crop, was evaluated for two fixed levels of precision (0.10 and 0.25) and results are indicated and discussed.

Keywords: Thysanoptera, *Frankliniella occidentalis,* spatial distribution.

Frankliniella occidentalis (Pergande) (Thysanoptera: Thripidae) is known as an agricultural pest in several crops, especially in Europe and North America. Portugal is no exception. Losses are caused by the feeding and oviposition activities. Apart from direct damages, this species is a vector of Tomato Spotted Wilt Virus.

Being impossible to identify and quantify accurately this species by direct observation in crops, other monitoring procedures have been developed. A practical and economical procedure is the use of coloured sticky traps, placed at the top of the crops (Mateus, 1998).

In this paper, essays conducted for the analysis of *F. occidentalis* spatial distribution in ornamental crops (roses and spray-type carnations) and horticultural crops (pepper and strawberries), inside greenhouses, are described, and the results are discussed.

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Materials and Methods

Field sampling and laboratory procedures

Essays were performed by using blue sticky traps (see Mateus and Mexia, 1995). Traps were 15 × 10 cm blue acrylic plates (Plexiglas no. 326), 3 mm thick, with each face covered by a transparent polyacetate sheet (stuck to the plate with sticky tape on the top and bottom edges), which was covered afterwards by a thin layer of Napvis glue. Traps were hung vertically, inside the greenhouses, at the top of the crops.

Essays were performed in four greenhouses, located 40 km south Lisbon: one greenhouse with several varieties of spray-type carnations; another with several varieties of roses; another with some varieties of pepper plants; and, finally, one greenhouse with one variety of strawberries. Essays were concentrated just in one variety of each crop: Rossini (spray-type carnations), Sonia (roses), Cadete (pepper) and unknown variety (strawberries).

The area occupied by the spray-type carnations variety (150 m^2), was divided in 25 rectangles and, in the centre of each, a trap was placed. Traps were changed weekly, during two periods: the first (P1), of 7 weeks, in the winter, when population density was low, and the other one (P2), of 5 weeks, in spring, when population density was higher.

In the area occupied by the roses variety (224 m^2), 28 traps were also regularly distributed (as described above) and changed weekly, in two periods: P3, of 4 weeks, in the winter, when population density was low, and P4, of 5 weeks, in the summer, when population density was higher.

In the area occupied by the pepper variety (500 m^2), 8 traps were randomly distributed and changed periodically, constituting 25 sampling dates, at the end of spring.

In the area occupied by the strawberries variety (800 m^2), 10 traps were randomly distributed and changed periodically, in 7 sampling dates, in the beginning of spring.

Mean population densities in winter essays (P1 and P3) were 0.4 and 0.2 thrips/trap, respectively. The range of population densities in spring/summer essays is indicated in *Table 1*.

Traps collected periodically were taken to the laboratory and handled according to the methodology described in Mateus et al. (2002).

Inside each greenhouse, over the varieties in the vicinity of the one under study, traps were also placed and changed with the same periodicity as in that variety, but the insects caught in those traps were not counted.

Statistical analysis

Statistical analysis was performed only for *F. occidentalis*.

In relation to adults (males, females and total) captured in the traps, in spray-type carnations (P2), roses (P4), pepper and strawberries, the "Taylor power law" (Taylor, 1961; Tanner, 1978) and the "Iwao's patchiness regression" (Bechinski and Pedigo, 1981; Boivin and Stewart, 1983; Wipfli et al., 1992) were used. The following null hypotheses were tested, for each crop, by the *t* test: $b=1$, $b\leq1$, $\log a=0$, $\alpha=0$, $ß=1$, $ß\leq1$). Females captured in strawberries were not submitted to this analysis, owing to very low densities, in each sampling date.

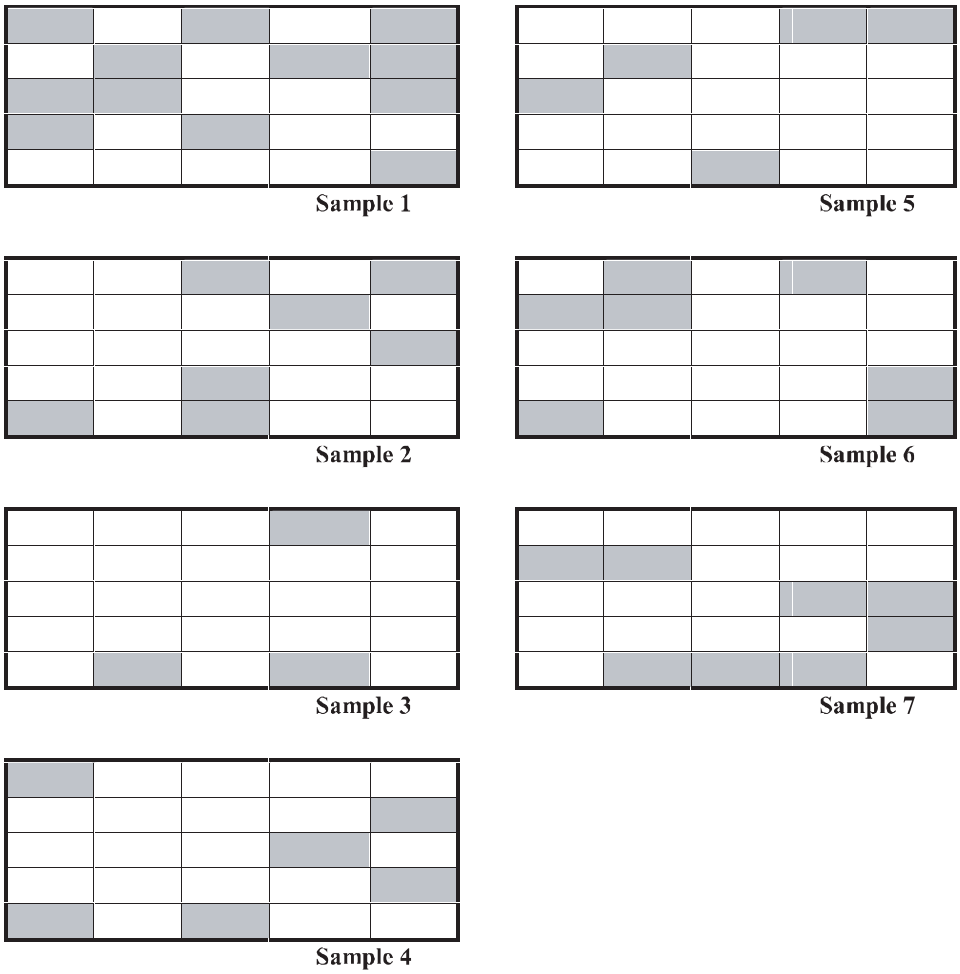

Fig. 1. Distribution of *Frankliniella occidentalis* in spray-type carnations, during the period P1 (low population density). In each sample, the grid corresponds to the area of the variety studied, and in the middle of each small rectangle, a trap was placed; the grey coloration indicates that one or more insects were captured in the correspondent trap

The number of traps needed to estimate the population density registered in each sampling date was estimated for two fixed levels of precision (standard error of the mean equal to 0.10 and equal to 0.25). The equation used was: $n = (s/Em)^2$, where, n= number of traps to be estimated, s=standard deviation, E= predetermined standard error of the mean, and m = mean density (Southwood, 1978).

Inversely, using the same equation, the standard error of the mean (i.e. the level of precision) associated to the estimates of population densities made during the essays, in each sampling date, was also calculated.

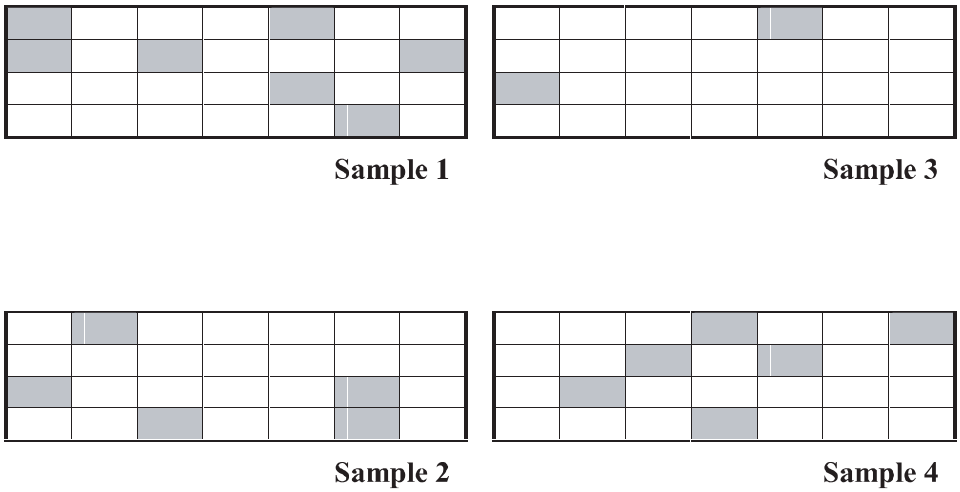

Fig. 2. Distribution of *Frankliniella occidentalis* in roses, during the period P3 (low population density). See explanation in Fig. 1

Results

In relation to the location of thrips, in spray-type carnations and roses, during periods of low population density (P1 and P3), results are indicated in *Figs 1* and *2*. During those sampling periods, there were areas where no specimen was captured along the week, and areas where few were detected, constituting isolated foci. There was not a fixed location of those foci, from one week to the next, or a specific pattern of variation in their location.

Results of the "Taylor power law" and of the "Iwao's patchiness regression" are presented in *Tables 1* and *2*. In *Table 1,* the range of mean population densities (mean number of adults/ trap) registered during the sampling periods is also indicated.

Regressions were significant, with two exceptions in roses (males and total adults). The values r^2 were higher in Iwao's method for all specimen categories analysed (males, females and total adults). In strawberries, the number of females was very low and so, statistical tests were not performed.

In relation to the parameter "b" (from "Taylor power law"), the null hypotheses (H_o: b=1 and H_o: b≤1) were rejected in all the cases studied (crops/ specimen categories), except in roses. This indicates an aggregated spatial distribution of thrips; for roses, in spite of, statistically, H_o: log a=0 and H_o: b=1 were not rejected, indicating a random distribution, the "b" value was high, indicating a tendency for aggregation.

In relation to the "Iwao's patchiness regression", in all crops, except for roses, H_o: α=0 was not rejected, and H_o: ß=1 and H_o: ß≤1 were rejected. These results indicate that, in those crops, the basic units of distribution were the individuals, and that they were

Table 1

Results of the "Taylor power law" for *Frankliniella occidentalis* (total adults, females and males) caught in sticky traps in one variety of spray-type (ST) carnations, roses, pepper and strawberries. Range of mean thrips density

Crop	Thrips	F	r^2	log a	b	Thrips/trap
ST Carnations	Total	683.64	0.99	–0.58	2.10	7.4–52.7
	Females	419.07	0.99	0.11	1.61	1.7–14.1
	Males	174.68	0.98	–0.38	1.96	3.7–39.1
Roses	Total	–	–	–	–	25.6–43.3
	Females	18.09	0.86	–0.07	1.72*	9.7–19.4
	Males	–	–	–	–	15.9–27.8
Pepper	Total	91.81	0.80	–0.20	1.69	2.1–22.1
	Females	59.57	0.72	–0.07	1.46	0.9–16.3
	Males	122.50	0.84	0.04	1.67	0.6–5.7
Strawberries	Total	161.97	0.97	–0.08	1.50	8.2–116.6
	Males	159.52	0.97	–0.14	1.52	7.5–111.1

Tests were performed for $\alpha = 0.05$. F values presented are significant. H_o: log a=0 was not rejected; H_o: b=1 and H_o: b≤1 were rejected, except for the value signalled with an asterisk.

Table 2

Results of the "Iwao's patchiness regression" for *Frankliniella occidentalis* (total adults, females and males) caught in sticky traps in one variety of spray-type (SP) carnations, roses, pepper and strawberries

Crop	Thrips	F	r^2	α	β
SP Carnations	Total	1229.41	1.00	-0.56	1.35
	Females	288.80	0.99	0.29	1.40
	Males	1361.94	1.00	-0.45	1.34
Roses	Total	52.92	0.95	-1.16	1.25*
	Females	51.07	0.94	1.39	1.24*
	Males	31.68	0.91	-3.56	1.37*
Pepper	Total	406.89	0.95	-0.63	1.32
	Females	383.30	0.94	-0.58	1.30
	Males	124.50	0.84	-0.17	1.54
Strawberries	Total	20099.26	1.00	0.86	1.08
	Males	24506.61	1.00	0.53	1.08

Tests were performed for $\alpha = 0.05$. F values are significant. H_o: α=0 was not rejected (test not performed for roses); H_o: ß =1 and H_o: ß≤1 were rejected, except for the values signalled with an asterisk. The range of thrips density is indicated in Table 1.

aggregated. In relation to roses, the parameter α was not tested, because the associated standard deviations were quite high (reducing *t* test precision); in relation to the parameter ß, the hypothesis H_o: ß=1 was not rejected, indicating a random distribution, in spite of the values being similar to those of the other crops.

Table 3

Mean population density, standard deviation, mean number of traps estimated for two levels of precision (0.10 and 0.25) and mean standard error of the mean associated to the density estimates made during the essays

		SP carnations	Roses	Pepper	Strawberries
Population density		27.94	33.47	8.79	35.79
Standard deviation		16.95	16.29	5.08	12.54
Traps number	0.10	36.11	24.14	39.77	20.54
	0.25	5.78	3.86	6.32	3.30
Standard error		0.12	0.09	0.21	0.13

Results of the evaluation of the mean number of traps needed to estimate population densities (for a standard error of the mean equal to 0.10 and 0.25) are indicated in *Table 3,* as well as the mean value of the standard errors of the mean associated to the density estimates made, in each crop, during the essays.

Discussion and Conclusions

The success of *F. occidentalis* control, and of the virus it transmits, depends on the early detection and monitoring of the first winter foci of infestation, and so, captures in traps regularly placed over spray-type carnations and roses were analysed during the winter, when population density was low, a few weeks before a significant increase of population density. During the period analysed, in each crop variety tested, there was not a pattern of permanency or variation on thrips location, from one week to the next, making it impossible to preview the location of the infestation foci. So, during the winter, the weekly monitoring of thrips (or of virus infected plants) must be conducted all over the area of the crop varieties. One can put the hypothesis that the variability of thrips location registered in this study, in two ornamental crops, is due to the high frequency of the cutting of flowers, which causes a high level of disturbance in the ecosystem, forcing thrips to move, even with the low temperature and radiation values, characteristic of winter conditions. In the future, it would be interesting to extend this study to horticultural crops, which are not manipulated so often, in order to compare results.

Data were better fitted to the "Iwao's patchiness regression". Statistical analysis indicated that, in spray-type carnations, pepper and strawberries, adults (total, males and females) spatial pattern was aggregated, and that the basic units of spatial distribution were the individuals. Roses were an exception: both methods (Taylor's and Iwao's) indicated random distribution, but the parameters values indicate a tendency for aggregation.

The comparison of the spatial patterns of males and females in different crops was not conclusive: there were contradictions (see, for example, the parameter "ß" in spray-type carnations and in pepper).

The aggregation detected in this study corresponds to the spatial pattern in flight, since the individuals were caught in traps, during the flying activity. Matteson and Terry (1992) reported a "swarming behaviour" in this species, which corresponds to aggregations of individuals in flight. However, another factor must be considered: according to Berlinger et al. (1993) and Vernon and Gillespie (1995), trap captures are influenced by the colour of the background under each trap, which in this case is the colour of the crop. A heterogeneity in the distribution of flowers (or of their degree of opening) or in the distribution of plants in the crop will effect differently each trap, causing a heterogeneity in trap catches. Anyway, results obtained here are supported by other authors, who, studying *F. occidentalis* spatial distribution in several crops also detected an aggregated distribution (e.g. Robb, 1989; Steiner, 1990; Shipp and Zariffa, 1991; Navas et al., 1994; Cho et al., 1995; Sánchez et al., 1997; Cho et al., 2001 and Deligeorgidis et al., 2002).

According to the results obtained, whenever thrips in flight are being studied, and two or more factors (treatments, in the statistical sense) are under consideration, blocks should be selected for the experimental design.

In relation to the number of traps needed to estimate *F. occidentalis* population densities, the evaluation was done at two fixed degrees of precision: a standard error of the mean equal to 0.10, which is generally used for population dynamics studies, and equal to 0.25, generally used for losses evaluation and decision making in agriculture. Results indicate that the number of sampling units calculated for 0.10 can be used only in studies of population dynamics, because they are too high for routine monitoring. For 0.25, the number of traps estimated may be used in horticultural crops; in relation to floriculture, generally, there are several varieties in the same greenhouse (i.e. a high crop heterogeneity), which means that the number of traps that will be needed to estimate population density is higher than the one that was calculated here (only for one variety).

Results indicate that the estimates of population density made during the essays had an adequate level of precision, except in pepper, where the standard error of the mean was too high for a population dynamics study, which is the case presented here.

Monitoring is essential in any IPM program and studies about the spatial distribution of pests are valuable contributions for the development of monitoring techniques that reduce the number of sampling units and/or reduce the time involved in their performance.

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