Journal of Entomology

ISSN 1812-5670

Academic Journals Inc.

www.academicjournals.com

Journal of Entomology 8 (3): 280-287, 2011
ISSN 1812-5670 / DOI: 10.3923/je.2011.280.287

Spatial Distribution of *Thrips tabaci* and Development of a Fixed-Precision Sampling Plan for Greenhouse Cucumber

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ABSTRACT

The spatial distribution pattern of different life stages of *T. tabaci* Lindeman -a serious pest of ornamentals and vegetables worldwide and a fixed-precision sampling plan for this pest on cucumber was investigated in an experimental greenhouse. For decision-making in IPM information about spatial distribution pattern of this pest is needed as is sampling plans. Therefore, the second objective of this paper was to developing fixed- precision stop lines for decision making for onion thrips on cucumber. Population estimation was made with recording number of different life stages of onion thrips on each side of the cucumber leaves. Taylor's power law and Iwao's patchiness regression were used to analyze the data. The spatial distribution was aggregated for 1st instar larvae Taylor's coefficient (β 1.54) and random, for both 2nd instar larvae and adults (β 1.22 and 1.12, respectively). Based on the collected data, stop lines for decision making at a precision level of 0.1 or 0.25 was calculated to allow easy estimation of thrips population density.

Key words: Onion thrips, dispersion, taylor's power law, iwao's patchiness regression, sampling plan, integrated pest management, decision support

INTRODUCTION

Onion thrips (*Thrips atabaci* Lindemann (Thysanoptera: Thripidae)) is a serious cosmopolitan pest with a host range encompassing more than 300 plant species including onion, tomato, garlic, cucumber, leek, pea, bean, pepper, squash, wheat and some weeds (e.g., Butani and Verma, 1976; Milene and Walter, 1998; Theunissen and Legutowska, 1991). In addition, it is capable of causing severe injury to ornamentals hereby reducing their cosmetic value (Sauer, 1997). In addition to direct damage, *T. tabaci* may inflict indirect damage to several vegetable crops by transmission of viruses like Tomato Spotted Wilt Virus (TSWV) and sowbane mosaic virus (SoMV) (Hardy and Teakle, 1992). Infestations with *T. tabaci* are difficult to control chemically. But due to hidden lifestyle; this combined with a short life cycle and the sensitivity of some crops to thrips damage chemical control often needs to be repeated at a short intervals leading to fast development of resistance (Tommasini, 2003). Consequently, implementation of IPM for managing onion thrips is necessary.

Decision-making in IPM is based on information about pest density and the spatial distribution pattern of pest population (Pedigo and Buntin, 1994). Analysis of spatial distribution pattern is recognized as a necessary procedure for insect population studies and provides basic information for designing efficient and cost-effective sampling plans for population estimation and pest management (Kuno, 1991; Pedigo and Buntin, 1994; Southwood and Henderson, 2000; Esfandiari and Mossadegh, 2007). In addition, it allows better understanding of the relationships between an insect and its environment and provides basic information for interpreting spatial dynamics (Tsai *et al*., 2000).

Onion thrips are active insects which on cucumber are found mostly in the leaf pits (H. Madadi pers.obs.), making precise density estimations difficult. Development of a fixed-precision sampling plan (Dogramaci *et al*., 2006) will reduce the sampling efforts needed to obtain density estimates at a desired precision level.

The spatial distribution pattern of some thrips species in different crops have previously been studied (e.g. onion thrips on onion (Edelson *et al*., 1986) *T. palmi* Karny on fall potato (Cho *et al*., 2000) and sampling plans have been developed in some instances e.g. for western flower thrips (*Frankliniella occidentalis* (Pergande)) (Dogramaci *et al*., 2006), in nectarine orchards, (Pearsall and Myers, 2000), on greenhouse cucumber (Steiner, 1990; Higgins, 1992; Wang and Shipp, 2001) and on greenhouse impatiens (Todd *et al*., 2006). However, little is known about the spatial dispersion pattern of onion thrips on greenhouse cucumber and sampling plans for this particular pest-crop system have to our knowledge not been developed.

The objective of this study was to determine the spatial distribution pattern of different life stages of *T. tabaci* and to develop a fixed- precision sampling plan for this pest on cucumber.

MATERIALS AND METHODS

One hundred and fifty potted cucumber plants (*Cucumis sativa* L., cv. Negin), were grown from seeds in a 30×35 cm pots with 3:1 peat moss:sand under natural conditions in a greenhouse at the Horticulture Department, Bu-Ali Sina University from April 25 2008. The plants were allowed to become naturally infested with onion thrips - this infestation took place about three weeks after the cucumber plants had been sown in the greenhouse i.e. when the plants had attained the stage with 3-4 leaves.

Sampling unit and number of samples: Onion thrips are mostly found on leaves (Capinera, 2001), and the middle leaves of the host plant were consequently selected as sampling unit. The number of necessary samples (N) was estimated from a preliminary experiment in which 30 leaves were sampled at random and scored for number of thrips larvae. Based on the following formula (Southwood and Henderson, 2000):

$$N = \frac{1}{\left(E^2 \cdot \bar{x}\right)} \quad (1)$$

where $\bar{x}$ average number of individuals in samples and E is the predetermined standard error as a decimal of the mean (here set to 0.05) the number of leaves to be sampled in the experiment was determined to 60. These leaves were selected at random and the number of thrips larvae and adults

were counted on both sides of each leaf. The first sampling was done two weeks after the first infestation with thrips to coincide with the first generation of thrips larvae (generation time of *T. tabaci* is nearly 14 days at 25°C (Madadi *et al.*, 2006). Afterwards, sampling was carried out every 5th days for a total of 5 samplings.

Data analyses

Variance-mean relationships: One method of determining spatial distribution is the relationship between the mean and the variance of the number of individuals per sample (Pedigo and Buntin, 1994). A commonly used models for describing this relationship is Taylor's power law (Taylor, 1961; Southwood and Henderson, 2000) which relates variance (s^2) to mean ($\bar{m}$) as:

$$s^2 = \alpha \cdot \bar{m}^{\beta} \quad (2)$$

Linear regression (SAS institute Inc., 1993) of Ln (s^2) = Ln(α) + (β)Ln($\bar{m}$) was used to estimate the values of α and β being the intercept and the slope, respectively. Regression slopes >1, 1 or <1 indicate an aggregated, random or uniform (regular) distribution pattern respectively (Taylor, 1961). T-test was conducted to determine if β differed significantly from Eq. 1.

The data was also analyzed with Iwao's patchiness regression, a regression-based method for determining insect distribution (Iwao, 1968). It is based on linear regression between Lloyd's mean crowding index (m*) (Lloyd, 1967) and mean density ($\bar{m}$) as:

$$m^* = \alpha + \beta \cdot \bar{m} \quad (3)$$

where:

$$m^* = \bar{m} + \left[\left(\frac{s^2}{\bar{m}}\right) - 1\right] \quad (4)$$

The slope in Iwao's patchiness regression (β) is a measure of spatial distribution; if it equals one, distribution is classified as random, if it greater or lesser than one means aggregated or regular distribution (Iwao, 1968). T-test was conducted to determine if β is differed significantly from Eq. 1

Fixed-precision sampling plan: After fitting of the data with Taylor's power law or and Iwao's model, stop lines were determined. Stop line is a criterion or critical line showing the relationship between sample size (n) and cumulative number of an insect pest and it helps to decide whether the sampling should be continued or stopped (Kuno, 1969). Stop lines can be determined either with Green's equation (Green, 1970) using parameters (α and β) estimated with Taylor's power law or with Kuno's model (Kuno, 1969).

Using parameters (α nad β) estimated with Iwao's patchiness regression model.

In the present study the best fit to the data was obtained with Taylor's power law and the stop lines were consequently determined with Green equation as:

$$\ln(T_n) = \frac{\ln(d^2/\alpha)}{\beta-2} + \frac{\beta-1}{\beta-2}\ln(n) \quad (5)$$

where, T_n is the cumulative number of the individuals per leaf on sample 1 to n, d is the predetermined precision as a decimal of the mean and α and β are the Taylor's power law coefficients. The value of d was set to 0.1 or 0.25, values commonly selected for research and IPM purposes respectively (Green, 1970; Cho *et al.*, 2000).

Once the stop line is exceeded, sampling will be stopped and the mean number of thrips per leaf is (m) calculated (Green, 1970) as:

$$m = \frac{T_n}{n} \quad (6)$$

RESULTS

Spatial distribution: The density of thrips larvae and adults differed significantly on the different sides of the sampled leaves (T-test; t = 4.10, p = 0.0084, df = 3; t = 7.33, p = 0.001, df = 3 ; t = 8.19, p = 0.0007; df = 3 for 1st instar larvae, 2nd instar larvae and adults, respectively).

In spite of this, the good fit to Taylor's power law (Table 1) obtained for all thrips stages resulted in similar coefficient estimates with the values of (β) being the same for either leaf sides for either of the life stages (T-test; t = 0, df = 6, p = 0.38 ; t = 0.086, df = 6, p = 0.38; t = -0.82, df = 6, p = 0.26 for 1st, 2nd instar larvae and adults, respectively) (Table 1).

The value of β was not significantly different between thrips 1st and 2nd instar larvae (T-test; t = 0.96, df = 6, p = 0.23 ; t = 0.73, df = 6, p = 0.28 for upper and lower leaf sides respectively) nor was it significantly different between for 2nd instar larvae and adults (T-test; t = 0.49, df = 6, p = 0.33; t = -0.46, df = 6, p = 0.34 for upper and lower leaf sides, respectively. The values of ln (α) also was not significantly different both over leaf sides or life stages of onion thrips (T-test; t = -0.37; p = 0.35; t = 0.15, p = 0.38; t = 0.23, df = 6, p =0.37 for 1st, 2nd instar larvae and adults, respectively) (Table 1).

When the counts of thrips from each leaf side were pooled and subsequently fitted to Taylor's power law the estimates shown in Table 2 were obtained. The estimated values of β were not significantly different from 1 for second instar larvae and adults (T-test, t = 0.6, p = 0.33, df =3 and t = 0.52, p = 0.35, df =3 for 2nd larvae and adults, respectively) but was significantly larger than 1 for first instars (T-test, t = 3.93, p = 0.0002, df =3) indicating a random distribution for the 2 aforementioned stages but an aggregated distribution for first instars larva).

Table 1: Parameter estimates (±SE) for α and β of Taylor's power law obtained from counts of instars and adults of *Thrips tabaci* on separate leaf sides of cucumber leaves, as well as the p-values and R^2-values for the fit to the data. Means in a row followed by different letters are significantly different ($p<0.05$)

	1st instar larvae		2nd instar larvae		Adults	
	Underside	Upperside	Underside	Upperside	Underside	Upperside
Ln α	1.26±0.14 A	1.32±0.23 A	2.42±1.05 AB	2.31±1.14 AB	0.76±0.39 B	0.62±0.27 B
β	1.51±0.15 a	1.51±0.18 a	1.14±0.39 ab	1.09±0.62 ab	0.77±0.37 b	1.54±0.55 b
p-value	0.0021	0.0036	0.064	0.178	0.125	0.066
R^2	0.97	0.96	0.73	0.51	0.6	0.73

The fit of the data of thrips counts on each leaf side to Iwao's patchiness regression model is shown in Table 3. This model indicated an aggregated distribution pattern for 1st instar larvae on lower leaf sides and for adults on upper leaf sides but a random distribution for the remaining stages and leaf sides (T-test, 1st instar larvae (lower and upper leaf side respectively): t = 2.91, df = 3, p-value = 0.025; t = 1.01, df =3, p-value = 0.205; 2nd instar larvae (lower and upper leaf side, respectively): t = 0.1, df = 3, p = 0.365, t = 0.133, df =3, p-value = 0.363; adults (lower and upper leaf side, respectively): t = -0.59, df = 3, p = 0.29, t = 3.06, df = 3, p-value = 0.022). Generally, this model gave a lesser fit to the data compared to Taylor's power law.

Fixed-precision sampling plan: Due to better fit of Taylor's power law compared with Iwao's model, the parameters obtained from pooled data (Table 2) with former method were used for developing a fixed precision sampling plan. The stop line for decision making for different thrips life stages at a precision 0.1 and 0.25 as calculated from (5) is shown in Fig. 1. It is evident from

Table 2: Parameter estimates (±SE) for α and β of Taylor's power law obtained from counts of instars and adults of *Thrips tabaci* on cucumber leaves with data for both leaf sides pooled, as well as the p-values and R^2-values for the fit to the data

	1st instar larvae	2nd instar larvae	Adults
Ln α	1.19±0.179	2.41±1.15	0.67±0.17
β	1.54±0.138	1.22±0.38	1.12±0.23
p-value	0.0015	0.05	0.016
R^2	0.97	0.77	0.88

Table 3: Parameter estimates (±SE) for α and β of Iwao's patchiness regression model obtained from counts of instars and adults of *Thrips tabaci* on separate leaf sides of cucumber leaves, as well as the p-values and R^2-values for the fit to the data

	1st instar larvae		2nd instar larvae		Adults	
	Underside	Upperside	Underside	Upperside	Underside	Upperside
α	1.97±1.03	1.25±2.22	15.37±9.6	11.58±11.28	1.46±0.75	-0.18±0.16
β	1.94±0.32	2.46±1.44	1.06±0.58	1.21±1.58	0.69±0.53	1.67±0.22
p-value	0.0092	0.19	0.16	0.50	0.28	0.0047
R^2	0.92	0.49	0.53	0.16	0.6	0.95

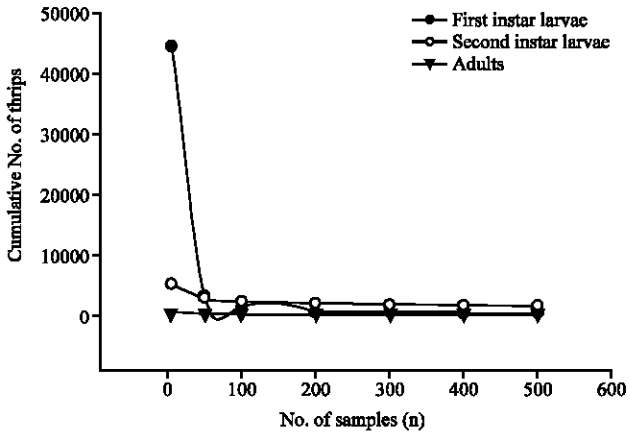

Fig. 1: Fixed precision sampling plan for estimating the density of *Thrips tabaci* in greenhouse cucumber density at 0.1 precision levels

the figure that reliable estimates of adult thrips density require fewer samples than reliable estimates of the density of thrips larvae. In addition, the figure illustrates that less samples will be needed for population density estimates when the thrips population is high.

DISCUSSION

Spatial distribution: The results showed that leaf side did not have any effect on spatial distribution pattern of *T. tabaci* on cucumber. In other words, despite different thrips densities on two leaf sides second instar larvae and adults thrips randomly distributed. This results is contrary to those obtained in most of the spatial distribution pattern studies of thrips done so far where aggregated distribution pattern have revealed (e.g., Edelson *et al*., 1986) for *T.tabaci* on onion; (Steiner, 1990) for western flower thrips on cucumber (Wang and Shipp, 2001) for same pest on cucumber flowers).

Contrary to 2nd instar larvae and adult, the first instar larvae of *T. tabaci* showed aggregated distribution. It may be a reflection of an aggregated egg-laying followed by the newly hatched larvae feeding nearby.

Fixed-precision sampling plan: From the calculated stop lines (Fig. 1, 2) the mean number of thrips per leaf can be easily estimated at the desired level of precision. It is evident from the figures that estimates of population densities at a precision level of 0.1 require a considerably larger samples size than for estimates at a precision level of 0.25, a sample size that would not be applicable for growers. Practically, these stop lines could be useful for thrips management. When the cumulative number of thrips counted during a sampling procedure exceed the critical cumulative number of thrips (T_n) determined as stop line, sampling should be terminated and the thrips mean density subsequently calculated according to Eq. 6 (Green, 1970). Based on comparison between the calculated density and the Economic Injury Level (EIL) for *T. tabaci* infesting cucumber, decisions on corrective measure can be made to assist growers with timely insecticide application, hereby helping to reduce the use of pesticides

Although a few studies have examined the EIL for onion thrips (Fournier *et al*., 1995; Goncalves, 1988) no information on EIL for onion thrips in cucumber is available. For the related *T. palmi*, (Kawai, 1990) proposed a value of 4.4 adults per leaf as EIL on cucumber

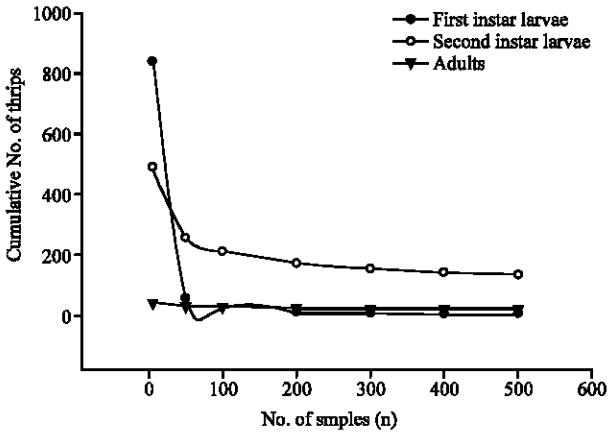

Fig. 2: Fixed precision sampling plan for estimating the density of *Thrips tabaci* in greenhouse cucumber at 0.25 precision level

but further studies will be needed to establish if this value could be extrapolated to onion thrips in this crops.

ACKNOWLEDGMENTS

The first author gives thanks to Dr. A.Ershadi former head of the Horticulture Department, Bu-Ali Sina University who helped conducting this study in the Department greenhouse. This project was supported financially by Bu-Ali Sina University, Hamedan, Islamic Republic of Iran (Project No. 370611.86).

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