Agricultural Research & Technology
Open Access Journal
ISSN: 2471-6774

Juniper Publishers
. . key to the Researchers

Research Article
Volume 2 Issue 3 - September 2016
DOI :10.19080/ARTOAJ.2016.01.555590

Agri Res & Tech: Open Access J

Spatial Distribution and Minimum Sample Size for Monitoring of Parlatoria Date Scale Insect, *Parlatoria blanchardi* (Targioni-Tozzetti) (Hemiptera: Diaspididae) on Date Palm Trees

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Submission: September, 2016; **Published:** September 27, 2016

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Abstract

The Parlatoria date scale insect, *Parlatoria blanchardi* (Targioni-Tozzetti) (Hemiptera: Diaspididae) is a serious pest on date palm trees in Egypt. The present work was carried out to study the spatial distribution and optimum sample size for monitoring of Parlatoria date scale insect, P. blanchardi on date palm trees through the two successive years of (2010/2011 and 2011/2012) at Esna district, Luxor governorate, Egypt. Data were analyzed using fourteen indices of distribution and used two methods of regression (Taylor's and Iwao's). All of the indices of distribution indicated aggregation distribution for all different stages and total population of *P. blanchardi* in both years and during the combined two years. Furthermore, that the regression methods of Taylor's power law (b) and Iwao's patchiness (β) were both significantly > 1, and indicating that the all alive stages of *P. blanchardi* had an aggregation distribution and follows a negative binomial distribution pattern in all years, except for first instar nymphs of *P. blanchardi* exhibited a random pattern during the first year (2010/2011). The optimal sample size for three fixed precision levels of 0.05, 0.10 and 0.15 at 0.05 probabilities were estimated with Iwao's regression coefficients. Required samples sizes decreased with increased levels of precision. Also, there are an inverse relationship was observed between the minimum number of samples required and the precision levels for sampling of different stages and total population of *P. blanchardi*. Results suggesting that the optimum sample size was flexible and depended upon the total population density and desired level of precision, it ranged from (1 to 3), (2 to 6) and (7 to 23) leaflets at the precision levels of 0.15, 0.10 and 0.05, through the combined two years respectively. Also, the results showed that the precision levels of 0.05 and 0.10 were suitable for ecological or insect behavioral studies where a higher level of precision is required, whereas for pest management programs, a 0.15 level would be acceptable.

Keywords: *Parlatoria blanchardi*; Parlatoria date scale; Population density; Spatial distribution; Minimum sample size

Introduction

The Parlatoria date scale insect, *Parlatoria blanchardi* is considered a serious pest in most areas producing dates. This species may infest all parts of the date palm with heaviest infestations at the base of the leaves and crown Khoualdia et al. [1]. The primary feeding site on the host is the succulent white tissue at the base of the leafstalk Boyden [2]. A discolored area of injured tissue develops where individuals settle and feed Al-Antary et al. [3]. Significant damage to the leaves results in the pinnae becoming withered and eventually dying. Heavy infestations weaken the tree by inhibiting transpiration and photosynthesis Moussa et al. Bakry, Idder-Ighili et al. [4-6]. Infestations of the fruit results in not only an unsightly appearance, but physical damage too. Smirnoff [7] reported fruit losses of 70-80 % resulting from direct feeding by the scale. In addition *P. blanchardi* secretes toxic saliva that causes malformed leaf and shoots growth, low photosynthesis and respiration rate, which leads to curling, yellowing and dropping of leaves, dwarfing of plant, decreasing or destroying chlorophyll. *P. blanchardi* affects photosynthetic pigments (chlorophyll-a, chlorophyll-b and carotenoids), leaflet area, moisture percentage, dry weight and wax contents of date palm leaflets [4,5].

Spatial distribution is one of the most characteristic properties of insect populations; in most cases it allows us to define them, and is a typical trait in insect populations and is an important characteristic of ecological communities Debouzie and

Thioulouse [8] and is a behavioral response of the individuals of a species to habitat Southwood and Young and Young [9,10]. It is important to find spatial and temporal structures in populations for applied and fundamental reasons. No field sampling can be efficient without understanding the underlying spatial distribution Taylor [11]. Knowledge of the spatial distribution provides useful information not only for theoretical population biology but for field monitoring programs Binns et al. [12]. Also, allows for the estimation of densities and in turn forms the basis for making decision in pest management programs Khaing et al. [13]. Methods that are commonly used to describe the distribution of insect populations have been summarized by Southwood [9].

Distribution patterns can change seasonally, in response to the availability of resources, and also depending on the scale at which they are viewed. Dispersion usually takes place at the time of reproduction. Spatial distributions of insect populations are not fixed but dynamic. Thus variations in space and in time of the pattern of individual occur not only at the scale of the species, but also at the population one Debouzie and Thioulouse [8]. On the other hand, detailed knowledge of insect distributions and the primary factors affecting how insect populations utilize their available resources are critical to the development of accurate sampling plans in agro ecosystems and integral to the study of population and community ecology of insects Trumble et al. [14]. The behavioral patterns and environment could be determinant the spatial distribution of population individuals in an ecosystem Moradi-Vajargah et al. [15]. The information of spatial distribution (i.e., regular, random or aggregated) can determine what sampling program must be carried out, especially sequential sampling Feng et al. [16]. The use of dispersion indices seem to be convenient decision making methods for man¬agement programs because of their easy calculation proce¬dure and simple results Darbemamieh et al. [17]. The models of Taylor and Iwao depend on the relationship between the sample mean and the variance of insect numbers per sampling unit through time, and can provide a stable relationship from one year to another, based only on the observed sampling mean Bisseleua et al. [18]. A reliable sampling program to estimate density should include a proper sampling time, sampling unit and sampling size in which the determination of spatial distribution is crucial Pedigo and Buntin & Southwood and Henderson [19,20]. Sampling plans based on these indicators can minimize variation of sam¬pling precision Kuno [21]. The minimum sample size is the smallest number of sample units that would satisfy the objectives of the sampling program and achieve the desired precision estimates. Determining the Taylor's power law and Iwao's regression coefficients eliminates experimental needs for a large sample size Ifoulis and Savopoulou-Soultani [22].

Having information about density and changes in population of *P. blanchardi* during the year, identification of factors affecting population fluc¬tuations and determination of their effects will help date palm producers in management of this pest. Knowing the spa¬tial distribution of an insect pest is central to design of a management program Cho et al. and Wearing [23,24]. The study on the spatial distribution of the population assemblage organized around phloem feeding Parlatoria date scale seeks to improve the knowledge on the economic importance of them and on factors influencing the dynamics of their populations. In addition, the study aims at the estimate optimum sample size for Parlatoria date scale population densities with predefined levels of reliability Lozzia et al. [25].

Material and Methods

Population studies

The population fluctuations of Parlatoria date scale, *P. blanchardi* which infest date palm trees were carried out at half-monthly intervals at Esna district, Luxor governorate, Egypt, during the two successive years of study (i.e. from September 1, 2010 until August 15, 2012). An orchard about one feddan (4200 m^2) was selected for sampling, during the above-mentioned period. The selected date palm trees received the normal agricultural practices, without pruning the fronds or applying any chemical control measures, before and during the period of investigation. This experiment was extended two years for studying the population fluctuations of this insect.

Sampling: Four palms of nearly similar and uniform as possible in size, age (5 years), shape, height, vegetative growth and received the same horticultural practices, were chosen randomly for sampling which was practiced at bimonthly intervals were selected for carrying out this study. The sample size (12 leaflets) was taken from every palm at a rate of (3 leaflets) from each of the north, east, south and west directions. The samples are calculated as mean numbers of different stages of insect per leaflets.

Examination: Regular bimonthly samples were collected and immediately transferred to laboratory in polyethylene bags for more inspection by the aid of stereomicroscope. Number of live insects on leaflets of date palm trees was individually sorted into immature stages (first instar nymphs and second instar nymphs) and mature stages (adult females and gravid females) and then were counted and recorded together opposite to each inspected date.

General sampling method: We collected a total of 48 samples on 48 dates over a two-year period with each sample consisting of 12 sample units. All sampling was conducted from 2304 samples i.e. (12 leaflets x 4 palms x 48 dates). As before, we froze samples for later processing in the laboratory and recorded.

Analysis of spatial distribution

The spatial distribution among the sample units was determined by fourteen indices of distribution and used two methods of regression (Taylor's and Iwao's). Such indices were chosen in an attempt to get a consensus on dispersion because the use of a single index can lead to incorrect conclusions Myers

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[26]. Soemargono et al. [27] recommended that in evaluating distribution of an arthropod, one should use several different techniques before drawing conclusions about population distribution.

Distribution indices: Several estimates are based on sample means and variances (such as index of dispersion, clumping, crowding and Green's).

- Mean ($\bar{X}$): $\bar{X}$ is the mean of population.

- Range of means of population: between the maximum mean number of population and minimum for the year was calculated by applying the following equation:

- Range of Density = population maximum – population minimum

- Variance (S^2): $SD = \sqrt{S^2}$

- Standard deviation (SD) = $SE = \sqrt{\frac{S^2}{n}} = \frac{S}{\sqrt{n}}$

- Standard error (SE): $s^2 = \frac{\Sigma(x_i - \bar{X})^2}{n-1}$

- Coefficient of variance (C.V.): To assess the fidelity of sampling, the coefficient of variation values between sampling dates were compared.

$$C.V. = \frac{S}{\bar{X}} \times 100$$

- Relative Variation (R.V.) is employed to compare the efficiency of various sampling methods Hillhouse and Pitre [28]. The relative variation for the sampling data was calculated as follows:

$$R.V. = \frac{SE}{\bar{X}} * 100$$

Where, SE is the standard error of the mean and $\bar{X}$ is the mean of population.

- Index of dispersion (I_D):

The index of dispersion is also known as the **variance to- mean ratio.** Dispersion of a population can be classified through a calculation of the variance-to-mean ratio; namely: **$S^2/\bar{X}$ = 1** random distribution, **< 1** regular distribution, and **> 1** aggregated distribution (where S^2 = sample variance; $\bar{X}$ = mean of population). Departure from a random distribution can be tested by calculating the **index of dispersion (I_D)**, where, n: denotes the number of samples:

$$I_D = \frac{(n-1)s^2}{\bar{X}}$$

ID is approximately distributed as x2 with n-1 degrees of freedom. Values of I_D which fall outside a confidence in-terval bounded with n-1 degrees of freedom and selected probability levels of 0.95 and 0.05, for instance, would in¬dicate a significant departure from a random distribution.

This index can be tested by Z value as follows:

$$Z = \sqrt{2I_D} - \sqrt{(2\nu - 1)}$$

v = n - 1

If 1.96 ≥ Z ≥ -1.96, the spatial distribution would be random but if Z < - 1.96 or Z > 1.96, it would be uniform and aggregated, respectively Patil and Stiteler [29].

- Index of mean clumping (I_{DM}) David and Moore [30]:

$(I_{DM}) = (S^2/\bar{X}) - 1$

David and Moore index of clumping values increase with increasing aggregation. If the index value = 0, the distribution is random, positive value for negative binomial (aggregated) and negative value for positive binomial (regular).

- Lloyd's mean crowding ($\dot{X}$):

Mean crowding ($\dot{X}$) was proposed by Lloyd to indicate the possible effect of mutual interference or competition among individuals. Theoretically mean crowding is the mean number of other individuals per individual in the same quadrate:

$$\dot{X} = \bar{X} + \left(\frac{s^2}{\bar{X}}\right) - 1$$

As an index, mean crowding is highly dependent upon both the degree of clumping and population density. To remove the effect of changes in density, Lloyd introduced the index of patchiness, expressed as the ratio of mean crowding to the mean. As with the variance-to-mean ratio, the index of patchiness is dependent upon quadrate size Lloyd [31].

Index of patchiness (IP):

$$IP = \frac{\dot{X}}{\bar{X}}$$

If IP = 1 random, < 1 regular and > 1 aggregated

- Green's index (GI) Green [32]:

$$GI = \left[\left(\frac{s^2}{\bar{X}}\right) - 1\right] / n - 1$$

This index is a modification of the index of cluster size that is independent of n.

If **GI > 0** or positive values are indicative of aggregation dispersion, **GI < 0** or negative values indicative of uniformity or regular dispersion, and **GI = 0** or negative values closer to 0 indicate randomness.

Regression methods

Taylor's power law: We modeled the sampling distributions for immature stages (nymphs), mature stages (adults) or both combined using both Taylor's power law [33]. A power law function can be used to model the relationship between mean and variance as:

$$S^2 = a\bar{X}^b$$

where, S2 is the variance; m is the sample mean; and a is the scaling factor related to sample size and b measuring the species aggregation. When, **b = 1, b < 1 and b > 1**, the distribution is random, regular and aggregated, respectively. Through the use of a log transformation, one can estimate the coefficients with linear regression as:

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$$\log(s^2) = \log(a) + b\log(\bar{X})$$

Where a and b are the parameters of the model, estimated by linearizing the equation after a log–log transformation [11].

Iwao's patchiness regression: Iwao's regression method was used to quantify the relationship between mean density ($\bar{X}$) and mean crowding index ($\overset{*}{x}$) Lloyd's [31] and using the following equation:

$$\overset{*}{X} = \alpha + \beta \bar{X}$$

Where α indicates the tendency to crowding (positive) or repulsion (negative), if **(a = 0)** indicates whether single individuals, a colony **(a >0)** or a negative association of individuals and **(0>0>-1)** is the basic component of the distribution. The slop (β) reflects the distribution of population in space and is interpreted in the same manner as b of Taylor's power law Iwao and Kuno [34]. Goodness- of-fit for each model was evaluated by coefficients of determination (R2) and multiple correlations (MR).

A t-test: A t-test: was used to determine whether the

$$t = \frac{slope - 1}{SE_{slope}}$$

Colony is composed of single individuals, and to determine. If colonies are dispersed randomly Feng and Nowierski [35].

Test b = 1, $t = (b-1)/SE_b$ a and Test β = 1, $t = (\beta - 1)/SE_\beta$

Where, SE_b and SE_β are the standard errors of the slope for the Taylor's power law and Iwao's model, respectively. Calculated values are compared with tabulated (t) values with n-2 degrees of freedom. If the calculated t (t_c) < t-table (t_t), the null hypothesis (b= 1) would be accepted and spatial distribution would be random. If t_c > t_t, the null hypothesis would be rejected and if b > 1 and b < 1, the spatial distribution would be aggregated and uniform, respectively Naeimamini et al. [36]. The annual data was pooled between years and overall distribution coefficients were used.

Minimum number of sample units (sample size)

The coefficient from Iwao's patchiness regression model was used to determine sample size requirements necessary for estimating population means for each year with fixed levels of precision. Precision (D) was defined as follows: D= Sm/m, where Sm is the standard error of the mean. D is a fixed proportion of the absolute mean of the population involved. It is also known as the allowable error, or fixed precision level, with which the mean is measured Lindblade et al. [37]. Estimators with standard errors of 5, 10 and 15% at 0.05 probabilities were chosen for this study.

The number of samples necessary to estimate the mean with fixed precision was determined by solving for the following:

$$n = \left[(\alpha + 1)/\bar{X} + (\beta - 1)\right]/C^2$$

Where a and b are coefficients obtained from Iwao's patchiness regression Kuno [38].

The obtained data were subjected to analyzed and calculated and shown graphically by Excel sheets.

Results and Discussion

Population density and fluctuation of *P. blanchardi*

The first year (2010/2011)

Immature stages of *P. blanchardi*: The obtained results are illustrated in (Figure 1) also, showed that in the first year (2010/2011), the peaks of 1st instar nymphs were recorded in the beginning of October, mid-November, mid-April and mid-June. While, the second instar nymphs, four peaks were recorded in mid- October, beginning of December, beginning of May and beginning of July

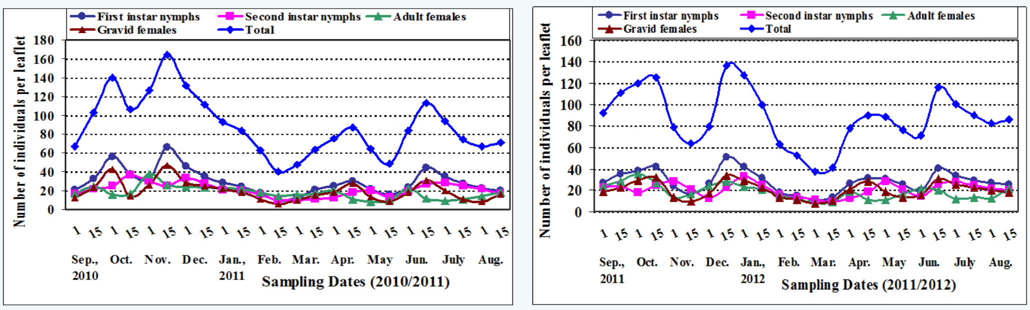

Figure 1: Seasonal abundance of different stages of the white date palm scale, *P. blanchardi* on the date palm leaflets at Esna district, Luxor governorate during the two successive years of (2010/2011 and 2011/2012).

Mature stages of *P. blanchardi*: Differently, adult females had four peaks that were recorded in mid-September, beginning of November, beginning of April and beginning of June. Similarly, however with different values the gravid females had four peaks that were recorded in the beginning of October, mid-November, mid-April and mid-June as in illustrated in (Figure 1).

Total population of *P. blanchardi*: The results showed are illustrated in (Figure 1) also the occurrence of four peaks of seasonal activity per year, which was recorded in the mid-October, mid-November, mid-April and mid-June. Also, the least total population density of *P. blanchardi* was recorded in the mid of February, which may due to the influence of cold weather

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under 10ºC and high relative humidity.

The second year (2011/2012):

Immature stages of *P. blanchardi*: The 1st instar nymphs had four peaks were recorded in the mid of October, mid-December, mid-April and mid-June. While, the 2nd instar nymphs, four peaks were recorded in beginning of November, beginning of January, beginning of May and beginning of July as in illustrated in (Figure 1).

Mature stages of *P. blanchardi*: The adult females had four peaks that were recorded in beginning of October, mid-December, beginning of April and beginning of June.

Similarly, however with different values the gravid females had four peaks that were recorded in the mid of October, mid-December, mid-April and mid-June as in illustrated in (Figure 1).

Total population of *P. blanchardi*: The results showed are illustrated in (Figure 1) also the total population of *P. blanchardi* had four peaks that were recorded in the mid of October, mid-December, mid-April and mid-June. Also, the total population of pest in the second year was smaller in comparison to the first year of investigation, which may due to the influence of favorable factors (such as environmental conditions and the abundance of the natural enemies, …etc.).

These results were coincided with those obtained by Eraki [39] found that the population had four generations of *P. blanchardi* in the 1st year and three generations in the 2nd year. El-Said and El-Sherif et al. [40,41] in North Sinai, Egypt, recorded that the white date palm scale, *P. blanchardi* had four annual peaks corresponding to the four annual generations. Peaks were recorded in mid-May, mid-July, mid-September and mid-November in the first season and early May, mid-July, mid-September and early December in the two seasons. Elwan and El-Said [42] in Egypt indicated that *P. blanchardi* had four annual overlapping generations per year.

Sampling program

The obtained values in (Table 1) showed that the relative variation for the primary sampling data of different stages and total population of *P. blanchardi* ranging from (3.59 to 5.63 %), (3.08 to 4.26%) and (2.36 to 3.51%) and was very appropriate for a sampling program through the years of first, second and during the combined two years. It is clear from the results that the lowest values for the relative variation (R.V.) were recorded on total population of *P. blanchardi* (Table 1). Naeimamini et al. [36] however with different insect species and different host, also stated that the relative variation for the primary sampling data of different stages of Pulvinaria floccifera (Hemiptera: Coccidae) were less than 25% and were acceptable.

Spatial distribution

Distribution indices: The obtained results in (Table 1) showed that the spatial distribution among the sample units was determined by fourteen indices of distribution. The results of distribution with using the variance to- mean ($S^2/\bar{x}$) was >1, by using Index of mean clumping (I_{DM}) was positive value for negative binomial, using Z test > 1.96, by using index of patchiness ($x^*/\bar{x}$) was >1 and with using green's index (GI) was > 0 and positive values. All these indices are indicative of aggregation distribution for all different stages and total population of *P. blanchardi* in both years and during the combined two years. Nestel et al. [43] however with the same genus of insect and different host, they suggested that the spatial distribution of *P. oleae* was discerned aggregate.

Also, the highest values for the index of mean clumping (IDM) were recorded on total population of pest (9.88, 7.00 and 8.39) during the years of the first, second and during the combined two years, respectively. Similarly, however with different values the total population of pest was exposed the highest values of the variance to- mean ($S^2/\bar{x}$) (10.88, 8.00 and 9.39) during the both years and through the combined two years (Table 1). These results agree with that obtained by Southwood [44] stated that the higher the variance to mean ratio, the greater the extent of aggregation. Naisheng et al. [45] reported that the spatial distribution of *Parlatoria pergandei* with using the means of Lloyd's mean crowding and index of patchiness, Iwao's patchiness and Taylor's law were indicated aggregated distribution on the apple trees. Siswanto et al. [46] however with different insect species and different host, also suggested that when the population of *Helopeltis antonii* (Signoret.) (Hemiptera: Miridae) was high, the insects tend to aggregation. Chellappan et al. [47] stated that the value of mean crowding increased with the increase in mean population density of *Paracoccus marginatus* (Hemiptera: Pseudococcidae).

While, the lowest values for the mean of population, the variance (S2), the standard deviation (SD) and the standard error (SE) were recorded on adult females of *P. blanchardi* as compared with the other different stages during the combined two years (2010 to 2012). On the contrary, the first instar nymphs of *P. blanchardi* were exhibiting the highest one (Table 1). The values of coefficient of variance (C.V.) for different stages and total population of *P. blanchardi* were ranging from (35.15 to 55.12 %), (30.22 to 41.78%) and (32.71 to 48.65%) and was very appropriate for a sampling program through the first, second years and during the combined two years, respectively in (Table 1).

Table 1: Estimated parameters for spatial distribution of different stages of P. blanchardi on date palm trees during the two successive years from 2010 to 2012 years.

Years	Stages		Parameters estimations												
		Mean	Range	S^2	Sd	Se	S^2/m	RV	C.V.	ID	I dm	Z value	X*	X*/m	GI

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2010/2011	First instar nymphs	29.2	56.65	194.79	13.96	1.42	6.67	4.88	47.8	633.77	5.67	21.85	34.87	1.19	0.06
	Second instar nymphs	21.19	27.08	66.06	8.13	0.83	3.12	3.91	38.35	296.13	2.12	10.59	23.31	1.1	0.02
	Adult females	17.91	29.47	53.11	7.29	0.74	2.97	4.15	40.69	281.71	1.97	9.99	19.88	1.11	0.02
	Gravid females	19.75	40.66	118.46	10.88	1.11	6	5.63	55.12	569.91	5	20.01	24.75	1.25	0.05
	Total	88.05	123.71	957.96	30.95	3.16	10.88	3.59	35.15	1033.59	9.88	31.72	97.93	1.11	0.1
2011/2012	First instar nymphs	28.32	40.68	112.94	10.63	1.08	3.99	3.83	37.53	378.94	2.99	13.78	31.3	1.11	0.03
	Second instar nymphs	20.65	23.53	50.46	7.1	0.72	2.44	3.51	34.39	232.08	1.44	7.8	22.1	1.07	0.02
	Adult females	18.42	26.52	59.05	7.68	0.78	3.21	4.26	41.71	304.52	2.21	10.93	20.63	1.12	0.02
	Gravid females	20.19	26.47	71.13	8.43	0.86	3.52	4.26	41.78	334.73	2.52	12.13	22.71	1.13	0.03
	Total	87.58	98.33	700.29	26.46	2.7	8	3.08	30.22	759.64	7	25.23	94.57	1.08	0.07
Two years (2010 to 2012)	First instar nymphs	28.76	56.65	153.26	12.38	0.89	5.33	3.11	43.05	1017.93	4.33	25.6	33.09	1.15	0.02
	Second instar nymphs	20.92	28.16	58.03	7.62	0.55	2.77	2.63	36.41	529.69	1.77	13.03	22.7	1.08	0.01
	Adult females	18.17	29.47	55.85	7.47	0.54	3.07	2.97	41.14	587.24	2.07	14.75	20.24	1.11	0.01
	Gravid females	19.97	40.66	94.35	9.71	0.7	4.73	3.51	48.65	902.52	3.73	22.97	23.69	1.19	0.02
	Total	87.81	126.1	824.84	28.72	2.07	9.39	2.36	32.71	1794.09	8.39	40.38	96.21	1.1	0.04

In general, the differences in our values may be due to the differences are at least partly caused by the population density of pest and environmental conditions such as weather and ventilation. Other studies have used these indexes to determine the distribution pattern of insect pest population in different crops Chellappan et al. and Arbab [47,48].

Regression methods: Taylor's power law regression showed highly significant positive relationships between the log (mean of population) and log (variance) for different stages of *P. blanchardii* during the years of first and second and through the combined two years is represented in (Table 2) and graphically illustrated in (Figure 2). The values of regression coefficient (b) from Taylor's power law were significantly and it being > 1, ranged from (1.30 to 2.04), (1.52 to 2.20) and (1.40 to 2.11) for all different stages and total population of pest through the years of first, second and during the combined two years, respectively, thus indicating an aggregated distribution. Also, the calculated regression coefficient for Taylor's method indicated that increase of one degree in the log (mean of population), increased the log of variance of population about (1.30 to 2.04), (1.52 to 2.20) and (1.40 to 2.11) for alive stages of pest during the years of first, second and through the combined two years, respectively (Table 2).

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Table 2: Parameters estimation for spatial distribution of different stages P. blanchardi on date palm trees derived from different regression methods during the two successive years from 2010 to 2012 years.

Years	Stages	Taylor's power law									Iwao's patchiness regression								
		a	Se_a	b	Se_b	MR	R^2 x 100	p	t_c	t_t	α	SE_α	β	SE_β	MR	R^2 x 100	p	t_c	t_t
2010/2011	First instar nymphs	-0.45	0.16	1.3	0.11	0.92	85.44	<0.000	2.63	2.07	-0.19	0.12	1.001	0.004	0.99983	99.967	<0.000	1.52	2.07
	Second instar nymphs	-1.48	0.12	2.04	0.16	0.94	87.68	<0.000	6.39	2.07	-1.03	0.1	1.04	0.004	0.9998	99.96	<0.000	9.05	2.07
	Adult females	-1.2	0.09	1.83	0.07	0.98	96.87	<0.000	11.83	2.07	-0.78	0.07	1.026	0.004	0.99985	99.97	<0.000	6.92	2.07
	Gravid females	-1.45	0.07	2.04	0.06	0.99	98.24	<0.000	17.83	2.07	-1.03	0.02	1.041	0.001	0.99998	99.998	<0.000	38.52	2.07
	Total	-1.91	0.22	1.77	0.11	0.96	99.99	<0.000	5.59	2.07	-0.89	0.05	1.003	0.001	0.99999	99.999	<0.000	5.59	2.07
2011/2012	First instar nymphs	-0.92	0.15	1.52	0.11	0.95	90.32	<0.000	4.92	2.07	-0.72	0.08	1.015	0.003	0.99992	99.985	<0.000	5.51	2.07
	Second instar nymphs	-1.68	0.23	2.2	0.17	0.94	87.77	<0.000	6.85	2.07	-1.08	0.09	1.043	0.004	0.99981	99.964	<0.000	10.15	2.07
	Adult females	-1.11	0.11	1.75	0.09	0.97	94.45	<0.000	8.32	2.07	-0.77	0.08	1.025	0.004	0.99982	99.965	<0.000	6.14	2.07
	Gravid females	-1.51	0.11	2.09	0.09	0.98	96.16	<0.000	12.22	2.07	-1.17	0.1	1.05	0.005	0.99978	99.957	<0.000	10.73	2.07
	Total	-2.47	28	2.11	0.14	0.95	90.77	<0.000	7.72	2.07	-1.13	0.1	1.007	0.001	0.99998	99.997	<0.000	6.59	2.07
Two years (2010 to 2012)	First instar nymphs	-0.66	0.14	1.4	0.1	0.9	80.92	<0.000	3.96	2.02	-0.43	0.1	1.01	0.003	0.9998	99.958	<0.000	3.1	2.02
	Second instar nymphs	-1.57	0.15	2.11	0.12	0.94	87.61	<0.000	9.5	2.02	-1.05	0.07	1.041	0.003	0.9998	99.962	<0.000	13.69	2.02
	Adult females	-1.15	0.07	1.79	0.06	0.98	95.57	<0.000	13.89	2.02	-0.77	0.05	1.026	0.003	0.9998	99.967	<0.000	9.37	2.02
	Gravid females	-1.47	0.06	2.06	0.05	0.99	97.38	<0.000	21.26	2.02	-1.07	0.05	1.044	0.002	0.9999	99.981	<0.000	21	2.02
	Total	-2.17	0.2	1.93	0.1	0.94	88.75	<0.000	9.18	2.02	-0.98	0.05	1.005	0.001	0.99999	99.998	<0.000	6.95	2.02

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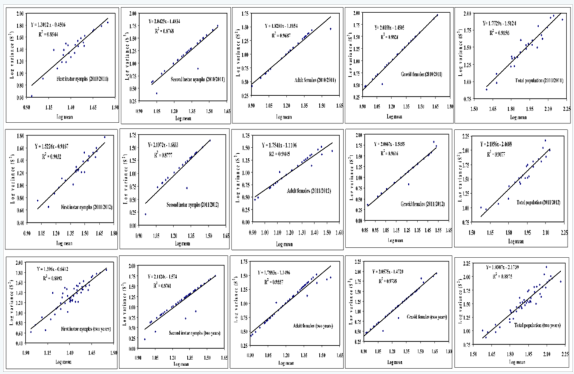

Figure 2: Regression analysis of Taylor's power law for different stages of P. blanchardi on date palm trees during years of 2010/2011 and 2011/2012 and for combined two years.

The relationship between them i.e. (log variance and log mean of population) has given a good fit for Taylor's model and the coefficients of determination (R^2x100) were ranged from (85.44 to 99.99%), (87.77 to 96.16%) and (80.92 to 97.38%) for all different stages of pest and total population of pest through the years of first, second and during the combined two years, respectively. R^2 values showed that the increase in values of variance of population occurred due to the increase in mean of population density. In this model, Also, the values of t-calculated (t_c) > t-table (t_t) in all tested stages and total population in both years and through the combined two years, thus confirming an aggregation distribution for individuals.

Regarding, the regression method of Iwao's patchiness was described the relationship between mean of population ($\bar{x}$) and mean crowding index ($\overset{*}{x}$) for different stages of *P. blanchardi* during the years of first and second and through the combined two years are represented in (Table 2) and illustrated in (Figure 3). The values of regression coefficient (β) were significantly > 1, ranged from (1.003 to 1.041), (1.015 to 1.050) and (1.005 to 1.044) for all different stages and total population of pest through the years of first, second and during the combined two years, respectively, thus implying an aggregated distribution.

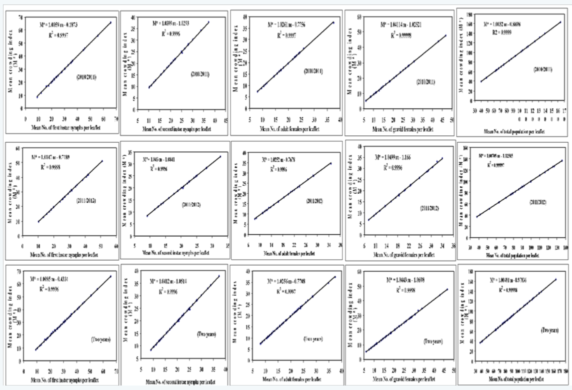

Figure 3: Regression analysis of Iwao's means crowding for different stages of P. blanchardi on date palm trees during years of 2010/2011 and 2011/2012 and for combined two years.

As well as, the calculated regression coefficient of Iwao's method indicated that an increase of one degree in the mean of population (m), increased the mean crowding index about 1.003 to 1.041), (1.015 to 1.050) and (1.005 to 1.044) for alive stages of pest during the years of first, second and through the combined two years, respectively (Table 2).

Also, the intercept values (α) or the index of basic contagion were negatively and < zero and > -1, the value of α ranged from (-0.19 to -1.03), (-0.72 to -1.17) and (-0.43 to -1.07) for all stages of pest during the years of first, second and through the combined two years (Table 2). The negative values indicated that aggregation was from individuals rather than colonies and smaller than zero indicating that for all live stages of *P. blanchardi* the basic component of the population tends to be a single individual.

The relationship between mean of population and mean crowding index had a better fit; the coefficients of determination (R^2x100) were ranged from (99.960 to 99.999%), (99.964 to 99.997%) and (99.958 to 99.998%) for all different stages of pest and total population of pest during the years of first, second and through the combined two years, respectively. R^2 values showed that the increase in the mean crowding index occurred due to the increase in mean of population (Table 2) and (Figure 3).

In this model, Also, the values of t-calculated (tc) > t-table (tt) in all tested stages and total population in both years and through the combined two years, thus confirming an aggregation distribution for individuals, except the first instar nymphs in the first year, the value of t-calculated (tc) < t-table (tt), although the slope of Iwao model (b) was greater than unity, it is insignificantly different, indi¬cating that first instar nymphs of *P. blanchardi* are randomly distributed in the sampling area (Table 2). The present results are generally in agreement with those of Moradi-Vajargah et al. [15] however with different insect species and different host, they mentioned that the regression of Taylor's model showed an aggregated distribution pattern for all life stages of the alfalfa weevil, *Hypera postica* (Coleoptera: Curculionidae). Iwao's patchiness regression indicated that larvae, adult and total life cycle had aggregated spatial distribution (t_c < t_t), while pupae of alfalfa weevil exhibited a random pattern.

The varied conclusions for dispersion pattern of different stages of insect from two regression methods suggest that different statistical methods accuracy in calcu¬lating the spatial distribution could be different. Based on Southwood [44], when a population in an area becomes sparse, the chance of an individual occurring in any sample unit is so low that the distribution is in effect random. Tonhasca et al. [49] they recoded that the patchiness regression is not subject to the stabilizing effect of a log transformation. Also, Lee et al. [50] however with the different insect species and different host, reported an aggregated distribution pattern for leaf miner in tomato greenhouses, because all b values from Taylor's power law regressions were significantly greater than one.

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Furthermore, aggregated distribution of other different pests using the aggregation indices have been reported in previous studies Naseri et al. Payandeh et al. Wang and Shipp, Beltra et al. Nematollahi et al. Arbab and McNeill [51-56].

Optimum Number of Sample Size

The optimal sample size was calculated using Iwao's regression coefficient, and the relationship between op-timum number of sample unit and mean numbers of different stages of *P. blanchardi* with levels of precision for 5, 10 and 15% was calculated are represented in (Table 3) and graphically illustrated in (Figure 4). The optimum sample size fluctuated throughout the year and depended upon the density of *P. blanchardi* and desired level of precision. With the precision level of 15 %, the number of samples required for estimating the total population density of P. blanchardi varied between one to three leaflets for each of the two years, when the mean total population density per leaflet was ranged from (40.01 to 163.72 individuals) for the first year and (37.62 to 135.95 individuals) through the second year. However, these values for population ecology studies, which need a precision of 10 %, increased the sample size, it ranged from (2 to 5) and (2 to 6) leaflets during the two years, respectively under the same densities of total population of pest (Figure 1).

But for a more accurate estimate (D= %5). The required sample size of date palm leaflets was increasing, it ranging from (6 to 20) and (9 to 25) leaflets for the first and second years, respectively under the same densities of total population of pest (Table 3)and illustrated in (Figure 4). Required samples sizes decreased with increased levels of precision. Also, there are an inverse relationship was observed between the minimum number of samples required and the precision levels for sampling of different stages and total population of *P. blanchardi* (Figure 3). These results agree with that obtained by Arbab [48] however with different insect species and different host also, mentioned that there are an inverse relationship was observed between the minimum number of samples required and the precision level for sampling of the rice stem borer, *Chilo suppressalis* (Walker) in paddy fields.

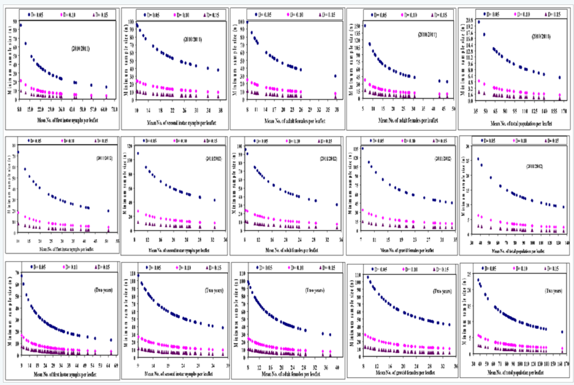

Figure 4: Relationship between population density for different stages of *P. blanchardi* and optimum sample size (n) for achieving a fixed precision levels of (D = 0.05, 0.10 and 0.15) using enumerative sampling procedures during years of 2010/2011 and 2011/2012 and for combined two years.

Table 3: Maximum and minimum population density for different stages of *P. blanchardi* and optimum sample size (n) for achieving a fixed precision levels of (D = 0.05, 0.10 and 0.15) using enumerative sampling procedures during years of 2010/2011 and 2011/2012 and for both two years.

Years	Stages	Population density		Optimum sample size (n) for achieving a fixed precision levels (D)					
				5%		10%		15%	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
2010/2011	First instar nymphs	65.76	9.11	84.65	13.75	21.16	3.44	9.40	1.53
	Second instar nymphs	37.26	10.18	95.69	37.74	23.92	9.44	10.63	4.19
	Adult females	37.52	8.06	98.79	29.37	24.70	7.34	10.98	3.26
	Gravid females	46.75	6.09	149.42	33.73	37.36	8.43	16.60	3.75
	Total	163.72	40.01	20.17	5.90	5.04	1.47	2.24	0.66
2011/2012	First instar nymphs	50.92	10.23	73.20	19.50	18.30	4.88	8.13	2.17
	Second instar nymphs	32.63	9.10	108.78	42.72	27.20	10.68	12.09	4.75
	Adult females	34.82	8.30	95.29	30.40	23.82	7.60	10.59	3.38
	Gravid females	34.01	7.54	134.84	45.47	33.71	11.37	14.98	5.05
	Total	135.95	37.62	25.40	9.05	6.35	2.26	2.82	1.01
Two years 2010/2011 and 2011/2012	First instar nymphs	65.76	9.11	66.76	12.52	16.69	3.13	7.42	1.39
	Second instar nymphs	37.26	9.10	106.64	38.49	26.66	9.62	11.85	4.28
	Adult females	37.52	8.06	98.18	29.12	24.55	7.28	10.91	3.24
	Gravid females	46.75	6.09	153.66	35.41	38.42	8.85	17.07	3.93
	Total	163.72	37.62	22.96	6.76	5.74	1.69	2.55	0.75

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The sample size required to achieve a desired level of precision was found different for each year. This difference in the number of leaflets of date palm required to be sampled could be explained by the fact that as the *P. blanchardi* population increases within a sample season, the minimum number of leaflets to be sampled declines. This study showed that precision levels of 5 and 10% were suitable for ecological or insect behavioral studies where a higher level of precision is required, whereas for pest management programs, a 15% level would be acceptable.

These different precision lev¬els (three lines) adopted in this study, could be chosen for ecological or insect behavioral studies. In order to acquire a higher level of precision the 5% or 10% level could be adopted, whereas in IPM programs 15% level would be ac¬ceptable. Although such sample sizes could be acceptable for research purposes, they are not practicable for agronomic or pest management. One attribute of *P. blanchardi* is that, at a given density, the required sample size increases as the target population becomes more aggregated Wipfli et al. [57].

Generally, the regression models of Taylor's power law and Iwao's patchiness to estimate the spatial distribution of pest, exhibited an aggregated distribution and follows a negative binomial distribution pattern for all live different stages of *P. blanchardi*, except for first instar nymphs of *P. blanchardi* exhibited a random pattern. The differences in values of results of spatial distribution of pest were a summation of many factors including the level of infestation, environmental condition, or some particular behavioral characteristics of the insect. Also, these two methods differ from other analysis methods which used in this study and were more accurate and produce different results than the other distribution indices are based on sample means and variances of population. Also, Iwao's patchiness regression parameters were used to compute minimum sample size needed to estimate populations at three fixed precision levels, 5, 10 and 15% at 0.05 probabilities. Results suggesting that the optimum sample size was flexible and depended upon the total population density of *P. blanchardi* and desired level of precision, it ranged from (1 to 3), (2 to 6) and (7 to 23) leaflets at the precision levels of 0.15, 0.10 and 0.05, through the combined two years respectively. With respect to the optimum sample size were suitable for IPM purposes of *P. blanchardi* at a precision level of D= 0.15.

Taylor [11] contends that the slope (b) is an index of the spatial distribution characteristic of the species, but some studies have shown that b is not species specific and varies among environments and development stages Downing [58]. Scale insects differ from other insect taxa because their distribution pattern in subsequent stages is shaped by mobile first instars (the crawler stage). The adult females are sessile or move very short distances. The typical thigmotactic behavior of the crawler Bodenheimer [59], as the major factor, as well as other intrinsic behavior of the scales (e.g. tendency to settle closely to the parent female, photo taxis during crawlers dispersal) determine the distribution of the scale population Nestel et al. [43].

Therefore, understanding the distribution pattern of the insect is very essential in the management of *P. blanchardi*. The next steps are to develop an efficient scouting program and establish threshold densities for action that will inform growers on when the pest is active and when interventions (e.g. insecticides) can be applied. The results from this study show that it is indicative of populations present in the field as well as provides information on the relative change over time. So, the spatial distribution parameters of this species can be employed to estimate the population density of *P. blanchardi*. Therefore, it can be concluded that for the monitoring, sampling and population density estimation of *P. blanchardi*, the spatial distribution pattern should be considered because minimal sample size is dependent on the spatial pattern of the sampled population.

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How to cite this article: Arbab A, MMS B. Spatial Distribution and Minimum Sample Size for Monitoring of Parlatoria Date Scale Insect, *Parlatoria blanchardi* (Targioni-Tozzetti) (Hemiptera: Diaspididae) on Date Palm Trees. Agri Res & Tech: Open Access J. 2016; 2(3): 555590. DOI: 10.19080/ARTOAJ.2016.01.555590

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