Journal of Fundamental and Applied Sciences

ISSN 1112-9867

Available online at http://www.jfas.info

Research Article

MANAGEMENT OF A MAIN CITRUS PEST BLACK PARLATORIA SCALE *PARLATORIA ZIZIPHI* (LUCAS) (HEMIPTERA: DIASPIDIDAE) IN THE MEDITERRANEAN BASIN

N. Haddad[1*], D. Sadoudi[1], F. Garcia-Mari[2]

[1]PSEMRVC laboratory, Faculty of Biological and Agricultural Sciences, University Mouloud Mammeri of Tizi-Ouzou, 15000, Tizi Ouzou, Algeria

[2]Instituto Agroforestal Mediterráneo, Universitat Politècnica de València, Cami de Vera s/n, 46022 València, Spain

Received: 04 November 2018 / Accepted: 10 December 2018 / Published online: 01 January 2019

ABSTRACT

The scale of black parlatoria, Parlatoria ziziphi (Lucas) (Hemiptera: Diaspididae), causes considerable damage to citrus fruits in the Mediterranean basin. For well managed this pest, we carried out a thorough ecological and behavioral study on the preference of localization and fixation of this pest on the citrus tree throughout the year for two years in six different citrus orchards to know: the lemon, the clementinier and the orange variety Thomson and washington in Tizi Ouzou, sub-humid region of the Mediterranean, in the North of Algeria. This new information on the biology and behavior of *P. ziziphi* could be applied to the definition of a better pest management strategy and to improvement of sampling methodology for monitoring this devastating pest by the good recognition of its place of infestations.

Keywords: Citrus; *Parlatoria ziziphi*; leaves; fruits; twigs; tree canopy.

*Author Correspondence, e-mail: haddad.nora8190@mail.com

doi: http://dx.doi.org/10.4314/jfas.v11i1.13

1. INTRODUCTION

The black parlatoria scale, *Parlatoria ziziphi* (Lucas) (Hemiptera: Diaspididae), is an armored scale insect considered a major pest of citrus all around the world [1-3]. It is common in the Mediterranean countries [4] and is of economic importance in Egypt [5], France [6], Algeria, Tunisia, Morocco, Italy and Greece [7]. Its populations are particularly significant in the Maghreb countries, mainly in Algeria and Tunisia [8], where it has been considered one of the main citrus pests for many years [9,10,7]. In Algeria, the black parlatoria scale is present in citrus since at least the beginning of the XXth century [11,12].

The damage caused by *P. ziziphi* consists in the weakening and drying of aerial parts of the tree, discoloration of the leaves and fruits, and, most importantly, a reduction of the commercial value of fruit due to the scales fixed on it [13,14]. This cosmetic damage is aggravated by its specific resistance to fruit cleaning [10]. Further, it is one of the most difficult armored scales to control with insecticides [15].

Studies on the bio-ecology of *P. ziziphi* in citrus orchards have been carried out in several countries, such as Spain [16], Sicily [17], Tunisia [18], China [19], Taiwan [2], Greece [20] and Egypt [21]. *Parlatoria ziziphi* attacks all aerial parts of the tree: leaves, twigs, branches and fruits [13-15,22]. Its fixation behavior on the plant is typical of all armored scales, but there are differences between species in spatial distribution on different organs within the host plant. For example, *Aonidiella aurantii* (Maskell) prefers fruits [23], while *Parlatoria pergandii* Comstock prefers the branches inside the tree canopy [24,25].

Work has been published on the black parlatoria scale on the behavior and location of attachment to different tree organs and within host-plant spatial distribution [10,21,26], but such studies generally include only short-term or qualitative observations. Because it is known that the spatial distribution of the armored scales is influenced by factors such as orchard structure or season of the year [27]. The objective of this work is to improve our knowledge of the spatial distribution of *P. ziziphi* on the tree as well as its location on various organs of the plant, determining if the overall preferences change throughout the year and in different orchards. This knowledge is important from a practical point of view for the development of appropriate sampling methods and for improving integrated pest management strategies.

2. EQUIPMENT AND METHODS

2.1. Region studies

The present study was carried out in the wilaya (province) of Tizi Ouzou, located in the north of Algeria (X= 3°42’ 56 ‘’ E - 4°39’ 19’’E and Y= 36°27’6’’ N - 36°54’42’’ N), characterized by a temperate climate with a mild winter and is in a sub-humid bioclimatic stage. Mean annual of daily maximum and minimum temperatures are 24.0°C and 13.6°C respectively, with average annual rainfall of 867 mm.

2.2. Sampling

We selected six commercial citrus orchards in full production in different localities in Tizi Ouzou, one lemon orchard (Citrus limon (L.) Burm.) and one orange orchard (Citrus sinensis (L.) Osbeck) and one clementine orchard (Citrus reticulata Blanco) in the locality of Irdjen, one clementine orchard in Chamlal, one lemon orchard and one orange orchard in Chabane locality. Every orchard was sampled at ten-day intervals through a twelve-month period, from January 2014 to December 2015. The sampling methodology consisted of dividing each orchard into nine square-shaped plots with 25 trees each. On each sampling date, we selected randomly two trees per plot. On each tree, we sampled randomly five 20-cm long twigs containing two leaves each, one from each of the four compass points on the external part of the tree canopy and from the interior of the canopy. One mature fruit was also sampled on each orientation when present.

2.3. Statistical Analysis

The differences in population density between organs (leaves and twigs, leaves and fruits, upper and lower side of the leaf, twigs of interior and exterior of the tree canopy, and twigs from the four compass points), were analyzed by two-way ANOVAs for each one of the six orchards and for the total. A two-way ANOVA per season was also carried out the compare the four compass points within each of the four seasons. Data of percentage were [arcsin] transformed to meet normality assumptions. Means were compared using Fisher’s least significant difference (LSD) test with the significance level set at α=0.05. All statistical analyses were performed using Statgraphics Centurion XVI [28].

3. RESULTS AND DISCUSSION

3.1. On leaves, twigs and fruits

We compared the abundance of living females of *P. ziziphi* among the three organs of the citrus tree we sampled, leaves, twigs and fruits. The comparison of the overall abundance between leaf and twig showed a strong dominance of *P. ziziphi* individuals on the leaves. The average number of *P. ziziphi* per leaf was 2.44 ± 0.04, while in a twig this average was 0.233 ± 0.004 ($F = 83.8$; $df = 1, 213$; $P < 0.0001$). This represents that on a leaf there is approximately 10 times more population than on a twig. This strong tendency of individuals of *P. ziziphi* to fix on leaves appears in all six citrus orchards studied: the population abundance on leaves oscillates between 7.8 and 11.7 times higher on leaves than on twigs (Table 1). In any case, the average surface area of a leaf (15-25 cm^2) is 3-5 times larger than that of the twig (5-10 cm^2).

Table 1. Mean (± SEM[1]) population density of *P. ziziphi* on leaves and twigs, expressed as number of live females per leaf or twig

orchard	Leaves		Twigs		Factor	
	Mean	SEM[1]	Mean	SEM[1]	(leaf/twig)	P
Lemon-Chabane	2.582	0.064	0.333	0.012	7.8	< 0.0001
Lemon-Irdjen	3.204	0.137	0.274	0.012	11.7	< 0.0001
Clementine-Chamlal	0.850	0.023	0.094	0.006	9.0	< 0.0001
Clementine-Irdjen	3.272	0.129	0.283	0.013	11.6	< 0.0001
Orange-Irdjen	3.327	0.159	0.291	0.014	11.4	< 0.0001
Orange-Chabane	1.548	0.043	0.136	0.006	11.4	< 0.0001
Total	2.44	0.04	0.233	0.004	10.5	< 0.0001

[1]*Standard Error of Mean*

The population trend of abundance of living females per leaf and twig through the year showed that the differential factor remains during all the months of the year in favor of the leaf. The ratio leaf / twig oscillate through the year with two maxima of up to 15 for the months on April and September (Fig. 1).

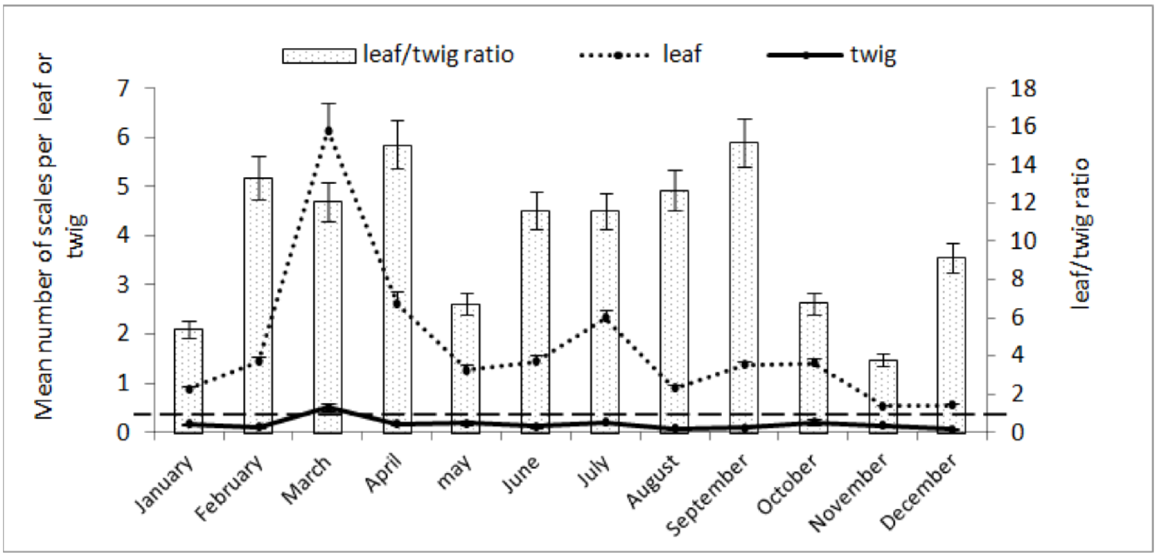

Fig.1. Seasonal change through the year in the mean number (± SE) of *P. ziziphi* live female scales on leaves and twigs, the horizontal line represents ratio number 1. Vertical lines represent standard error of the mean

During the three months, October to December, when the mature fruits were present on the trees, we compared the level of infestation per fruit and per leaf. The results show that the population of living females of *P. ziziphi* is always higher on leaves, reaching on average 0.78 ± 0.11 scales per leaf, while fruits harbor only 0.45 ± 0.05 scales per fruit (F = 93.79; df = 1, 34; P = <0.0001) (Fig. 2). This ratio leaf/fruit in *P. ziziphi* population changes with the orchard, but always remains in favor of the leaves (Table 2).

Table 2. Mean (± SEM[1]) population density of *P. ziziphi* on leaves and fruits, expressed as number of live females per leaf or fruit

orchard	Leaves		Fruits		Factor (leaf/fruit)	P
	Mean	SEM[1]	Mean	SEM[1]		
Lemon-Chabane	1.256	0.274	0.273	0.103	4.6	< 0.0005
Lemon-Irdjen	1.607	0.463	0.359	0.104	4.5	< 0.0247
Clementine-Chamlal	0.810	0.300	0.284	0.118	2.9	< 0.1618
Clementine-Irdjen	0.954	0.284	0.352	0.110	2.7	< 0.1374
Orange-Irdjen	0.517	0.119	0.264	0.110	2.0	< 0.2269
Orange-Chabane	1.107	0.185	0.173	0.093	6.4	< 0.0028
Total	0.78	0.11	0.45	0.05	1.7	< 0.0001

[1]*Standard Error of Mean*

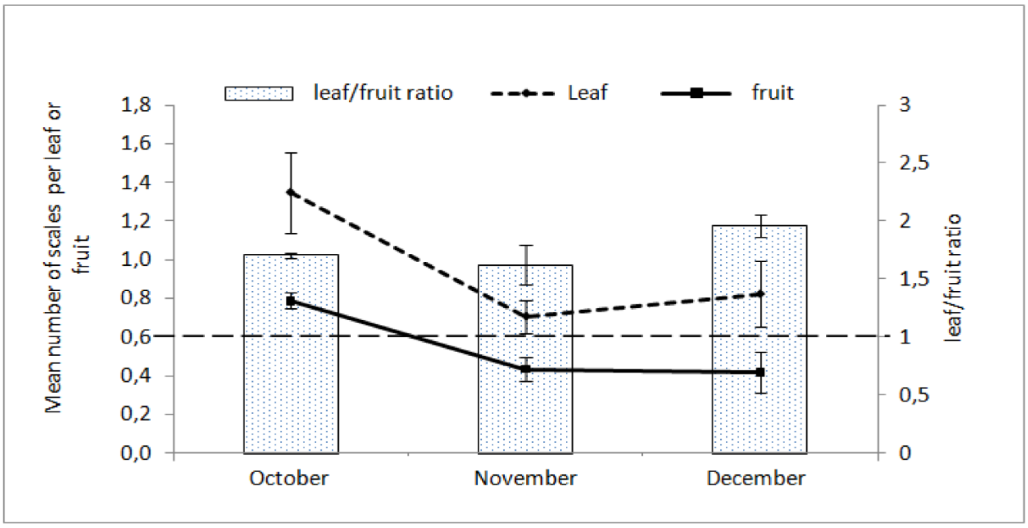

Fig.2. Seasonal change through the year in the mean number (± SE) of *P. ziziphi* live female scales on leaves and fruits, horizontal line represents ratio number 1, vertical lines represent standard error of the mean

On the upper side of leaves we found an average number of 1.59 ± 0.18 *P. ziziphi* living females, while on the lower side it was only 0.85 ± 0.09 ($F = 86.53$; $df = 1, 213$; $P < 0.0001$). This represents that 65.3% of individuals of *P. ziziphi* are located on the upper face against 34.7% on the underside, or approximately twice as much population of living females on the upper side than on the lower side (Fig. 3). Significantly higher scale population on the upper face of the leaf was also found in five of the six orchards studied (Table 3).

Table 3. Mean (± SEM[1]) population density of *P. ziziphi* on upper and lower side of the leaf, expressed as number of living females per leaf side

Orchard	Lower side		Upper side		Factor	P
	Mean	SEM[1]	Mean	SEM[1]	(upper/lower)	
Lemon-Chabane	1.804	0.286	0.778	0.110	2.3	< 0.0001
Lemon-Irdjen	1.725	0.511	1.479	0.325	1.2	< 0.1131
Clementine-Chamlal	0.532	0.078	0.318	0.070	1.7	< 0.0004
Clementine-Irdjen	2.197	0.526	1.074	0.267	2.0	< 0.0001
Orange-Irdjen	2.397	0.742	0.930	0.231	2.6	< 0.0001
Orange-Chabane	1.019	0.187	0.529	0.076	1.9	< 0.0002
Total	1.59	0.18	0.85	0.09	2	< 0.0001

[1]*Standard Error of Mean*

The monthly evolution through the year in the average number of living individuals per leaf side showed that the preference for the upper side is not constant but oscillates reaching its maximum in March and the lowest value in September, when the abundance of living females of *P. ziziphi* is similar in both sides of the leaf (Fig. 3).

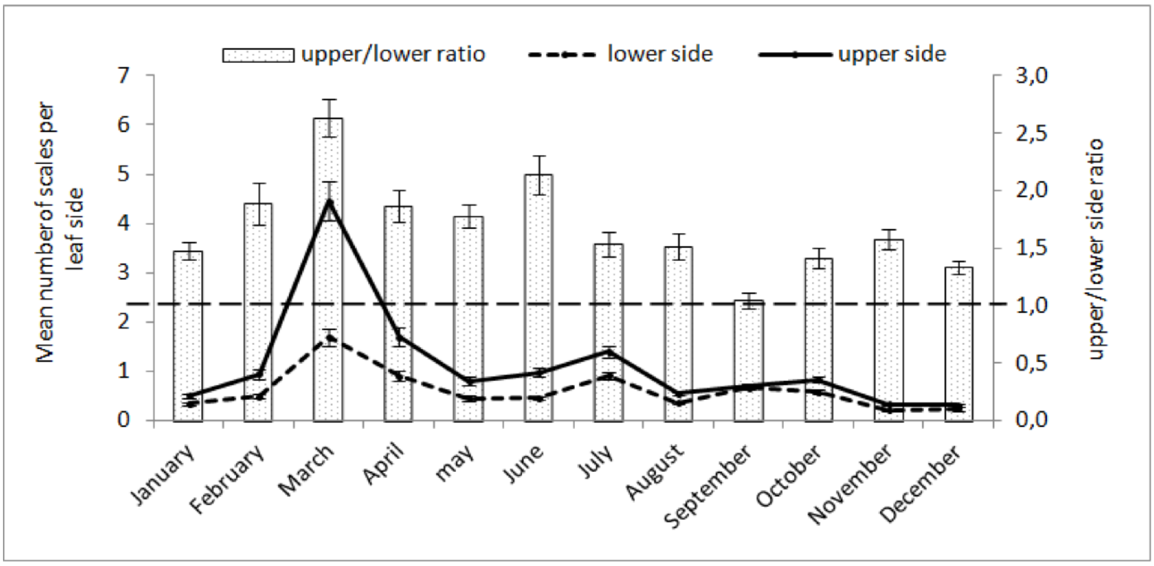

Fig.3. Seasonal change through the year in the mean number (± SE) of *P. ziziphi* live female scales on upper and lower side of leaves. The horizontal line represents ratio number 1. Vertical lines represent standard error of the mean

3.2. Inside and outside of the tree

Concerning the abundance of living females of *P. ziziphi* on the interior (center) and exterior (the outer crowns of East, South , North and West orientation) of the tree canopy, the results showed that populations were significantly more abundant at the interior of the tree, averaging 138.0 ± 18.4 individuals per sample unit (one sample unit includes all organs from a particular orientation observed on each sampling date, that is to say, 18 twigs and 36 leaves), whereas in the exterior of the tree we found 80.5 ± 5.0 individuals per sample unit ($F = 86.53$; df = 1, 210; $P < 0.0001$). This represents that there is 1.7 times more population in the interior of the tree canopy than at the outside (Fig. 4). This higher density of *P. ziziphi* populations in the interior of citrus trees is not homogeneous in all orchards. In the three orchards of the Chabane and Chamlal regions (which showed the lowest tree density according to shaded surface area of the orchards, see Material and Methods section) the population density of living females of *P. ziziphi* was distributed in a similar way inside and out of the tree canopy, while in the three orchards of the Irdjen region (with the most dense vegetation) the abundance of *P. ziziphi* was twice as high inside the tree canopy compared with outside (Table 4).

Table 4. Mean (± SEM[1]) population density of *P. ziziphi* inside and outside the citrus tree canopy

Orchard	Interior		Exterior		Factor (interior/exterior)	P
	Mean	SEM[1]	Mean	SEM[1]		
Lemon-Chabane	95.2	16.7	99.9	14.6	0.95	< 0.4782
Lemon-Irdjen	200.6	56.1	100.2	24.8	2.00	< 0.0311
Clementine-Chamlal	32.0	5.4	32.3	5.5	0.99	< 0.3593
Clementine-Irdjen	189.0	40.5	101.5	24.9	1.86	< 0.0001
Orange-Irdjen	255.8	76.2	88.6	26.1	2.89	< 0.0004
Orange-Chabane	55.4	12.0	58.9	10.1	0.94	< 0.9048
Total	138	18.4	80.5	5	1.7	< 0.0001

[1]*Standard Error of Mean*

When we represented the monthly evolution through the year in the average number of living females of *P. ziziphi* inside and outside of the tree canopy, the density in the interior of the tree changes periodically reaching two maxima, in April and September, while there is a minimum in June when populations are rather similar inside and outside (Fig. 4).

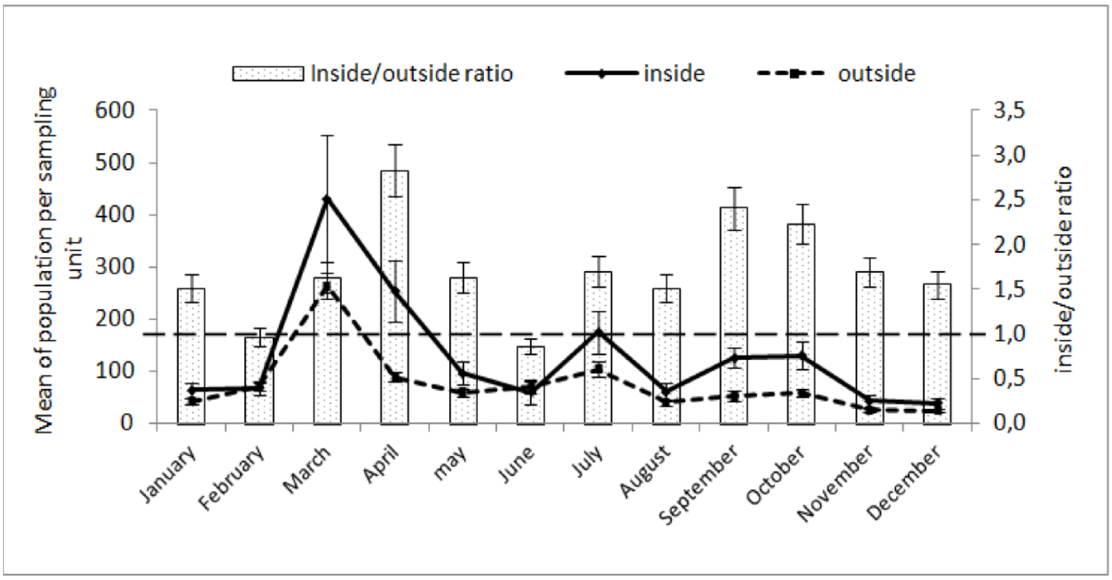

Fig.4. Seasonal change through the year in the mean number (± SE) of *P. ziziphi* live female scales at the inside and outside of the tree canopy. The horizontal line represents ratio number 1. Vertical lines represent standard error of the mean

3.3. Cardinal points differences in abundance

The average number of living female per sample unit on the four compass orientations showed a mean value of 89.1 ± 11.1 scales in the East, 85.3 ± 9.8 in the South, 81.2 ± 8.6 in the North, and 66.3 ± 8.2 in the West. Thus, the East orientation has the highest abundance of living females of *P. ziziphi* with a percentage of 27.7%, South and North are close by with 26.5% and 25.2% respectively, while the West contains the lowest population with 20.6% ($F = 14.30$; $df = 1, 166$; $P < 0.0001$). However, the distribution on the four cardinal directions of the tree canopy varies according to the orchard. In four of the six orchards sampled there were no significant differences among the orientations (Table 5).

Table 5. Mean (± SEM[1]) population density of *P. ziziphi* on the four cardinal directions of the tree

Orchard	East		North		West		South		P
	Mean	SEM[1]	Mean	SEM[1]	Mean	SEM[1]	Mean	SEM[1]	
Lemon-Chabane	96.6	15.6	98.9	15.7	63.4	10.2	140.6	24.1	< 0.1216
Lemon-Irdjen	137.4	46.3	121.9	30.1	82.7	24.3	58.7	15.9	< 0.0021
Clementine-Chamlal	38.1	8.0	37.4	9.4	25.3	5.0	28.5	6.6	< 0.2572
Clementine-Irdjen	106.8	31.8	108.2	29.3	80.4	24.1	110.6	27.0	< 0.0450
Orange-Irdjen	95.1	27.1	64.9	17.9	93.1	30.5	101.1	35.8	< 0.1742
Orange-Chabane	59.5	10.3	54.4	11.1	51.1	9.9	70.6	18.0	< 0.0871
Total	89.1	11.1	81.2	8.6	66.3	8.2	85.3	9.8	< 0.0001

[1]*Standard Error of Mean*

The distribution on the four compass points in the population density of living females of *P. ziziphi* changes with the season of the year (Fig. 5). We found that the South direction is the most favorable during the autumn and winter seasons (autumn: $F = 4.74$; $df = 3, 53$; $P = 0.0034$, winter: $F = 1.17$; $df = 3, 53$; $P = 0.0123$), while East, North and South are preferred during the summer ($F = 5.76$; $df = 3, 53$; $P = 0.0009$), with no differences in the spring ($F = 0.86$; $df = 3, 75$; $P = 0.4620$). The West orientation remains the least preferred throughout the four seasons of the year.

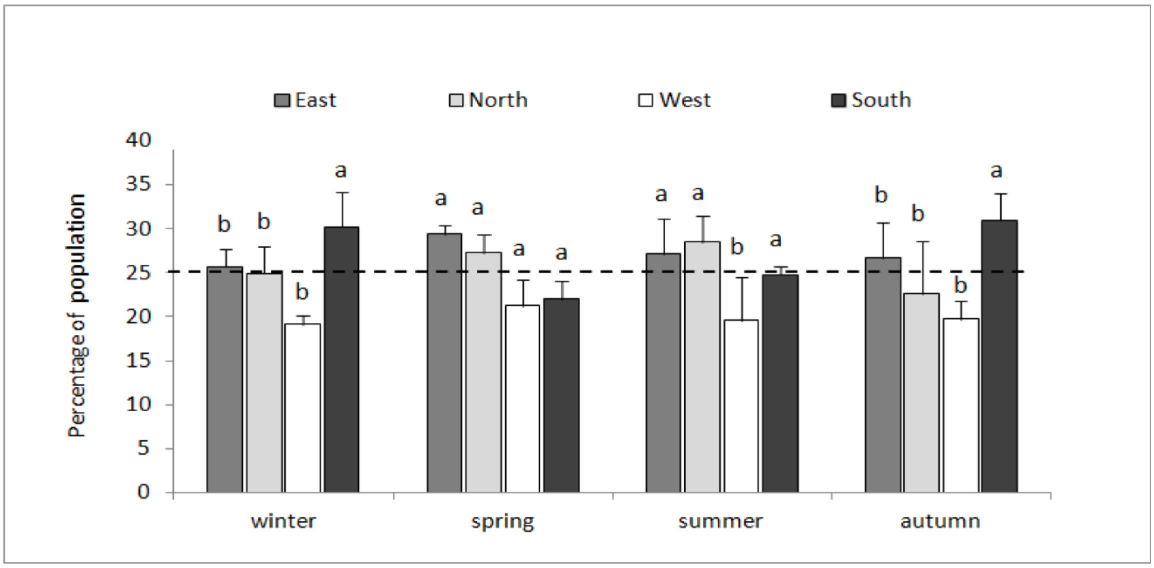

Fig.5. Seasonal distribution of the population of live females of *P. ziziphi* on the four cardinal directions of the citrus tree canopy, for each season, values with the same letter do not differ ($P > 0.05$). The horizontal line represents 25% of the population. Vertical lines represent standard error of the mean

In our results, populations of *P. ziziphi* showed a strong dominance on the leaf with a high density on the upper face of the leaf at a rate of 65%. Also, 16,13,29,22 and 30 spoke about the preference of *P. ziziphi* for the leaf, but without giving a precise quantification. Our results are consistent with those of [26] and [30] who point out that most of the *P. ziziphi* population appears on the upper surface of the citrus leaf.

This work also demonstrated that population density of *P. ziziphi* is higher at the interior of the tree canopy compared with the exterior. [16], [10] and [21] also reported a tendency on *P. ziziphi* to fix on the central and shaded branches of trees, with *P. ziziphi* outbreaks being more important in tight and poorly ventilated orchards. Our results revealed that the density of *P. ziziphi* in the center of the tree is not fixed and homogeneous but changes according to the orchard, because several parameters such as orchard layout, tree age and size, pruning system, distance between trees and climatic factors, in particular the high humidity in the center due to poor aeration and the absence of light, may influence the distribution of *P. ziziphi* populations on the tree canopy [10]. Reports that direct exposure to the leaves of the outer crown of the tree can cause significant mortality of first instar larvae of *P. ziziphi*.

The cardinal distribution of *P. ziziphi* populations underlined a great variability depending on the season of the year and the orchard, being the most heterogeneous parameter in our study. Overall, we found that the East quadrant had the highest population and West quadrant the lowest. Our results agree with those of [21] who found 24-28% of *P. ziziphi* females in the East quadrant versus 21-22% in the West.

It was clear in our study that the highest population density on leaves compared with branches or fruit is the most constant or stable parameter of the four aspects studied, because it was maintained during the 12 months of the year and in the six the citrus orchards studied. The distribution inside or outside of the tree canopy and on the cardinal orientations was more variable depending on the month of the year and the orchard considered. The higher abundance of *P. ziziphi* on some organs or parts of the tree canopy can be explained on one side by to the choice of a place of fixation by neonate larvae that avoid extreme and unfavorable climatic conditions and on the other to differential mortality that occurs along the period of development of the insect. The mobile larvae (crawlers) of armored scales are known for the very limited duration, a few hours, before they settle permanently on the substrate for the rest of their life [31]. The larva relies on a combination of stimuli to locate the fixation site. This stimuli are initially visual and olfactory [32, 33]. The visual stimulus may be influenced by color perception, shape of the host plant and spectral intensity or reflectivity [34]. Positive phototaxis defines an orientation towards a light source [32]. Light appears to be a major factor influencing the direction of wandering in armored scales. Settling by crawlers may be induced largely by thigmotaxis, or response to a contact or mechanical stimulus from crevices, other surface irregularities or contact surfaces, producing in some cases closely packed aggregations of scales [31]. By tasting, the chemical content of the plant is verified by the insect for continuation of feeding [35-37]. All these stimuli can be strongly conditioned by climatic factors such as humidity, temperature and direct sunlight which negatively influence neonate larvae, and which are responsible for decreasing or increasing the population of *P. ziziphi* on an organ or part of the tree [38] reports that the population density of *P. ziziphi* is negatively influenced by relative humidity and precipitation and positively by temperature. This last climatic factor has a strong influence on the physiological mechanisms of ectothermic insects [39], and consequently conditions many behavioral strategies [40].

4. CONCLUSION

The information reported by most authors on the distribution of *P. ziziphi* populations on the citrus tree was often based on non-quantified or short-term observations. With this work, we provide new information on the biology and behavior of the black parlatoria scale by determining the changes in its distribution depending on the month of the year and the diversity of citrus orchards. From an applied point of view, the information provided may be applicable to the improvement of the sampling methodology of the black parlatoria scale *P. ziziphi* populations and to define a better strategy of chemical spraying or mechanical pruning for pest management.

5. ACKNOWLEDGEMENTS

My sincere acknowledgments to Pr. Ferran Garcia-Mari (Polytechnic University of Valencia, Spain) for his help in writing the document and for statistical analyzes, to Pr D. Sadoudi who reviewed the manuscript.

6. REFERENCES

[1] Miller D R., Davidson J A. A list of the armored scale insect pests, 1990, 299-306. In D. Rosen (Ed). Armored scale insects: their biology, natural enemies and control. Word Crop Pests, vol. 4B. Elsevier, Amsterdam The Netherlands.

[2] Miller D R., Davidson J A. Armored Scale Insect Pests of Trees and Shrubs. Cornell Univ Press Ithaca New York, U.S.A, 2005, pp. 312-350.

[3] Podsiadlo E, Bugila A. Morphology of the second-instar males of *Parlatoria ziziphi* (Lucas) (Hemiptera: Diaspididae). Proceedings of the XI international symposium on scale studies, 2007, 51- 53.

[4] Ebeling W. Subtropical fruit pest. Univ. California Div Agric Sciences. California, U.S.A, 1959, pp.317-338.

[5] Coll M, Abd-Rabou S. Effect of oil emulsion sprays on parasitoids of the black parlatoria scale, *Parlatoria ziziphi*, in grapefruit. BioControl, 1998, 43 : 29-37.

[6] Foldi I. Liste des cochenilles de France (Hemiptera, Coccoidea). Bull Soc entomol de France, 2001, 303-308.

[7] Tena A, Garcia-Marí F. Current situation of citrus pests and diseases in the Mediterranean basin. IOBC/wprs Bull, 2011, 62: 365-378.

[8] Talhouk A M S. Citrus pests throughout the world. Technical Monograph 4, 1975, 1-21.

[9] Sigwalt B, Soria F. La lutte chimique contre les Diaspines des agrumes de Tunisie. C R C A Z' F Tunis, 1965, 52-57.

[10] Sigwalt B. Les études de démographies chez les cochenilles diaspines. Applications à trois espèces nuisibles à l'oranger en Tunisie. Cas particulier d'une espèce a générations chevauchantes: *Parlatoria ziziphi* . Ann Zool Ecol Anim , 1971, 3: 5-15.

[11] Balachowsky A S. Note on a Coccidae of the fauna Neotropical recently acclimatized and harmful to the fig tree in Algeria. Bull Soc. Hist Nat Afr Nord, 1926, 1: 63-69 [in French].

[12] Balachowsky A S. Biological study of scale insects of the Western Mediterranean basin. In Encyclopédy Entomologic XV P. Le chevalier & Fils. Paris, France, 1932, pp 59-62.

[13] Blackburn V L, Millert D R. Pests not known to occur in the United States or of limited distribution. N° 44. Black parlatoria scale, 1984.

[14] Thomsbury S, Romano E. Linking Risk and Economic Assessments in the Analysis of Plant Pest regulations: The Case of U.S. Imports of Argentine Lemons. G II Working Paper, n°1, 2007.

[15] Praloran J C. Les agrumes, techniques agricoles et production tropicale. Ed. Maisonneuve et Larose Paris France, 1971, pp. 113-115.

[16] Gómez-Clemente F. Cochinillas que atacan a los agrios en la región de Levante. Bol Patol Veg Entomol agric, 1943, 12: 17-18.

[17] Monastero S. Le cocciniglie degli agrumi in Sicilia (*Mytilococcus beckii* New, *Parlatoria zizyphus* Lucas, *Coccus hesperidum* L., *Pseudococcus adonidum* L., *Coccus oleae* Bern., *Ceroplastes rusci* L.). Bollettino dell' Istituto di Entomologia Agraria dell Università di Palermo, 1962, 4: 65-151.

[18] Benassy C. Soria F. Observations écologiques sur les cochenilles diaspines nuisibles aux agrumes en Tunisie. Annales de l' INRAT, 1964, 37: 193-222.

[19] Huang L L, Wang D W , Zhang Q B, Lei HD , Yue B S. Study of bionomics and control of *Parlatoria ziziphus*. Acta Phytophylactica Sinica, 1988, 15: 15-21.

[20] Stathas G. J, Eliopoulos P A, Japoshvili G. A study on the biology of the diaspidid scale *Parlatoria ziziphi* (Lucas) (Hemiptera: Coccoidea: Diaspididae) in Greece. Proceedings of the XI International Symposium on Scale Insect Studies, Lisbon, Portugal, 2008, 95-101.

[21] Adnan Abdel-Fattah E D. Some ecological and behavioral aspects of the black parlatoria scale, *Parlatoria ziziphi* (Lucas) (Hemiptera: Diaspididae) and its parasites on mandarin trees. Int. J. Entomol. Res, 2016, 4: 33-38.

[22] Garcia-Marí F. Plagas de los cítricos. Gestión integrada en países de clima mediterráneo. Ed. Phytoma Valencia Spain, 2012.

[23] Pekas A, Aguilar A, Garcia-Marí F. Host size availability for *Aphytis* parasitoids in field populations of California red scale *Aonidiella aurantii*, in Eastern Spain citrus groves. Integrated control in citrus fruit crops. IOBC/wprs Bull, 2008, 38: 34-40.

[24] Rodrigo E, Garcia-Mari F. Comparación del ciclo biológico de los diaspinos *Parlatoria pergandii*, *Aonidiella aurantii* y *Lepidosaphes beckii* (Hemiptera, Diaspididae) en cítricos. Boletín de Sanidad Vegetal, 1990, 16: 25-35.

[25] Garcia-Marí F. The scale insects of citrus in Spain: pest status and control, 1994, pp. 47-66. In S. Gravena and L. C. Donadio (Eds), integrated management on insect and mite pests of citrus. A world overview. Proceedings Third international citrus seminar. Estaçao experimental de citricultura de Bebedouro. State of Sao Paulo, Brasil.

[26] Tawfeek M E, Abu-shall A M H. Seasonal Population Dynamics of *Parlatoria ziziphus* (Lucas) (Hemiptera: Diaspididae) in Menoufia Gavernorate, Egypt. Alexandria Science exchange journal, 2010, 31: 231-237.

[27] McLure C J. Patterns of temporal and spatial distribution, 1990, pp. 309-311. In D. Rosen (ed), Armored scale insects their biology, natural enemies and control, vol. A. Elsevier, Amsterdam, The Netherlands.

[28] Statgraphics. Statgraphics Centurion XVI: User's Manual. Manugistics Inc Rockville,

MD USA, 2010.

[29] Fasulo TR, Brooks R F. Scale pests of florida citrus. University of florida Ifas extensión ENY814; 1997.

[30] Tawfeek M E. Distributions of Armoured Scale Insects Infesting Citrus Trees in Different Localities in Egypt. J Ent, 2012, 9: 429-34.

[31] Beardsley J W, Gonzalez R H . The biology and ecology of armored scales. Annu Rev Entomol, 1975, 20: 47-73.

[32] Quirion P, Bourbeau P. Lexique des sciences biologiques. Faculté des Sciences et Génie. Université Laval. Sainte-Foy Québec, Canada, 1994, pp. 90-95.

[33] Derridj S. Nutrients on the leaf surface,1996, pp. 348-362. In C. E. Morris, P. C. Nicot and C. Nguyen (eds). Aerial and plant surface microbiology. Plenum Press, New York, U.S.A.

[34] Barbosa P, Wagner M R. Introduction to forest and shade tree insects. Academic Press. San Diego, California, U.S.A, 1989, pp. 108-115.

[35] Vanloon J J A. Chemosensory basis of feeding and oviposition behaviour in herbivorous insects: a glance at the periphery. Entomol Exp Appl, 1996, 80: 7-13.

[36] Jolivet P. Interrelationship between insects and plants. CRC Press. Boca Raton, Florida, U.S.A, 1998.

[37] Barbehenn RV, Reese J C , Hagen K S. Chapter 4: The food of insects, In C. B. Huffaker, and A. P. Gutierrez. 1999, pp. 87-90. Ecological entomology 2nd Ed. John Willey & Sons, New York, U.S.A.

[38] El- Bolok M M, Sweilem S M, Abdel-Aleem R Y. Effect of different levels of trees, different cardinal directions, tree core and leaf surface on the distribution of *Parlatoria ziziphi* (Lucas) in correlation with the year seasons. Bull. Soc. Entomol. d'Egypte, 19984, 65: 289-299.

[39] Sinclair A R E, Mduma S, Brashares J S. Patterns of predation in a diverse predator-prey system. Nature, 2003, 425: 288-90.

[40] Hance T, Van Baaren J, Vernon P, Boivin G. Impact of extreme temperatures on parasitoids in a climate change perspective. Annu Rev Entomol, 2007, 52: 107-126.

How to cite this article:
Haddad N, Sadoudi D, Garcia-Mari F. Management of a main citrus pest black parlatoria scale *Parlatoria ziziphi* (Lucas) (Hemiptera: Diaspididae) in the mediterranean basin. J. Fundam. Appl. Sci., 2019, *11(1), 184-199*.