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Some ecological and behavioral aspects of the black parlatoria, *Parlatoria ziziphi* (Lucas) (Hemiptera: Diaspididae) and its parasites on mandarin trees

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Abstract

Ecological and behavioural studies of the black parlatoria, *Parlatoria ziziphi* (Lucas) and its parasites were carried out during two successive years (2014 and 2015) in Nobaria district, Beheira Governorate, Egypt. The obtained results revealed that the total population of alive stages had two generation yearly in April and October. The insect prefer to the existing leaves on the southern and eastern branches of mandarin tree. Middle stratum always harboured the highest population density of the insect, the upper stratum showed the lower population while an intermediate population was recorded in low stratum of mandarin trees. *Aphytis lingnanensis* and *Encarsia citrine* (Aphelinidae), were recorded as parasitoids of *P. ziziphi*.

Keywords: Black parlatoria; *Parlatoria ziziphi*; mandarin; *Aphytis lingnanensis*; *Encarsia citrine*

Introduction

The black parlatoria, *Parlatoria ziziphi* (Lucas) (Hemoptera: Diaspididae) is a widely distributed pest of citrus plants (Kozar, 1998) [16]. *P. ziziphi* considered to be one of the major armored scale pests (Beardsley and González, 1975); Miller and Davidson (1990) [18] treated this scale insect as a serious world pest (Miller and Davidson, 2005) [19] and many authors has long been considered it one of the major pests of citrus in many parts of the world. It was reported in the following countries: Brazil, China, Egypt, Iran, Italy, France, Libya, Nigeria, Puerto Rico, Taiwan, and Tunisia. It was noted that in some countries the scale may not be considered a pest, but populations occasionally become a problem in localized areas (Talhouk, 1975; Cruz and Segarra, 1991; Gravena *et al*., 1992; Coll and Abd-Rabou, 1998; Danzig and Pellizzari, 1998; Jendoubi *et al*., 2008) [27, 7, 10, 6, 8, 12]. In recent years, this scale insect has become the most important pest of citrus in Egypt (Ismail, 1989) [11]. It infests the branches, leaves, and fruits of lemon and orange trees (Quayle, 1938) [21]. *P. ziziphi* is biparental and oviparous. All developmental stages are present throughout the year, indicating that the diaspidid completed several overlapping generations annually. In Egypt, there are two generations per year on sour oranges, and three on grapefruit (Salama *et al*., 1985) [23]. In Greece, Stathas *et al.* (2008) [26] report that *P. ziziphi* completed several overlapping generations each year and overwintered in all developmental stages. In China, *P. ziziphi* had three to four overlapping generations per year and overwintered at adult stage. In the Caucasus, the scale produces two and half generations per year, and overwinters in the second instar (Borchsenius, 1950) [5]. In Taiwan, there are up to seven generations each year (Miller and Davidson, 2005) [19]. Abd-Rabou (1997) [2] mentioned that total parasitism of *P. ziziphi* by different aphelinid species reached a maximum during August in Giza, Egypt. In Algeria, the most representative species of parasites diaspididae scale insects were *Encarsia citrine*, *Aphytishis hispanicus* and A. *chilensis* (Rachida and Mohamed, 2015) [22]. In the present study, some ecological and behavioural aspects of the black parlatoria, *Parlatoria ziziphi* (Lucas) and its parasites on mandarin trees has been investigated under the field conditions.

Material and methods

These experiments were carried out in a free insecticides privet farm in Nobaria district, Beheira Governorate, Egypt during two successive seasons from January, 2014 to December, 2015 on 15 years old mandarin trees (*Citrus reticulata*, Blanco) *var.* Satsuma. Fifteen infested mandarin trees, nearly of the same age and size were used for sampling. Samples of sixty leaves (5 trees × 4 directions × 1 leaves × 3 levels of the tree) of mandarin trees were picked every two weeks (15 day) for two years. Leaves were kept in 12 labeled poly ethylene bags each bag represents a particular direction or a specific layer of the tree and transported to the laboratory and carefully inspected using a stereomicroscope. Among each inspection, the first instar, first molt stage, female stages and male nymphs (Jendoubi, 2012) were precisely counted in the sample leaves and recorded.

The population of *P. ziziphi* nymphs were counted every month as an index for the calculation of the annual number of generations of *P. ziziphi* which were represented by number of peaks of the insect all over the year. The monthly variation rate (MVR) in population density was calculated according to the following formula (Abdel-Fattah *et al*, 1978) [1]:

$$MVR = \frac{\text{Average count given at a month}}{\text{Average count given at a preceding month}}$$

The number of generations of this scale was estimated from the changes in the half-monthly nymphal stage percentages throughout the two successive years.

Distribution preference of mandarin tree directions:

Directional preference was determine by applying the following formula (Mahmoud, 1981) [17]:

$F1 = E – W$

$F2 = N – S$

$\tan Q = F2 / F1$

Where

F1: Mean number of *P. ziziphi* in the east direction minus its numbers in west direction, if the former is higher. (and the reverse if the latter is higher).

F2: Mean number of *P. ziziphi* in the north direction minus insect numbers in south direction, if the former is higher. (and the reverse applies if the insect number in south direction is higher). The figure obtained represents the tangent: the corresponding values of which was obtained from the mathematical table.

tan. Q: Tan of the angle between the two forces.

To study the rate of parasitism and seasonal fluctuation of the main associated parasitoids, four heavy infested leaves from each strata were stored in a well-ventilated glass tube and monitored daily for parasitoid emergence. Rate of parasitism was determined by dividing the number of emerging parasitoid from each glass tube by the number of hosts existing. Simple correlation was calculated to obtain information about the relationships between the population of *P. ziziphi* and its parasites.

Results and discussion

Seasonal activity of *P. ziziphi* on mandarin trees

The fortnightly means of the 1st, 2nd nymphal instars, female stages and male nymphs of *Palatoria ziziphi* per one mandarin leaf through two successive years started from January 2014 till December 2015 are tabulated in in Tables (1&2). The obtained data showed that the insect population followed a curve of two peaks of infestation throughout the two years of investigation with average of 30.5 and 66.67 individuals /leaf recorded in mid-April and mid-October 2014, respectively. In the consecutive season 2015 the two peaks were recorded during the beginning of May (43.17 individuals) and Mid-October (104.83). Two obviously depressive numbers were occurred during the beginning of March (9.17 individuals) and mid-May (18.17 individuals) in 1st year, 2014 and in mid-February (9.83 individuals) and the beginning of July (16.83 individuals) in 2nd year. The lower population density during these periods could be attributed to the few of immatures and the most population was consisted of adults. Data presented in Tables (1&2) also demonstrated that the most dominant stage was the first instar (crawlers), which was represented by 46.08 and 42.71% from the total population, followed by the 1st molt stage, which was represented by 27.87 and 28.2% then female stages which was represented by 21.08 and 23.59% and finally male nymphs which represented by 4.97 and 6.18% from the total population in the 1st and 2nd season, respectively.

The appropriate time for control the black parlatoria, *P. ziziphi*

In general, scale insects are difficult to control, even with insecticides (Wallner, 1978; Johnson, 1982) [28, 14]. Because of the insect's body covering wax, many insecticides are ineffective. Only the crawler stage (the active first instar of a scale insect) may be killed, therefore the insecticide must be applied at a specific time in which the most dominant instar was the crawlers. The appropriate time for control the black parlatoria was in mid-April and mid-October because of the population of 1st instar reached reach its peaks in these times.

Table 1: Fortnightly numbers of different stages of *P. ziziphi* and its total population on mandarin trees during 2014 season.

Date of inspection	First instar	First molt stage	Female stages	Male nymphs	Total population	M.V.R.*
1 Jan. 2014	0.92	1.83	3.17	1.42	7.33	-
15 Jan.	1.42	3	3.08	1.83	9.33	
1 Feb.	2.75	4.33	4.83	1.92	13.83	1.455
15 Feb.	2.33	4.42	2.5	1.16	10.42	
1 Mar.	4	3.25	1.5	0.42	9.17	0.98
15 Mar.	7.67	3.5	2.83	0.67	14.67	
1 Apr.	9.75	4.5	3.08	0.5	17.83	2.03
15 Apr.	21.25	5	3.5	0.75	30.5	
1 May	10.33	6.67	3	0.5	20.5	0.8
15 May	8.67	6.83	2.33	0.33	18.17	
1 Jun	2.75	7.08	7.92	1.17	18.92	1.05
15 Jun	4.12	5.83	8.17	3.5	21.67	
1 Jul.	4.58	6.5	9	2.42	22.5	1.13
15 Jul.	6	6.33	9	2	23.33	
1 Aug.	6.42	7.5	8.42	1	23.33	1.09
15 Aug.	7	9.17	8.83	1.67	26.67	
1 Sep.	10.5	10.58	9.83	2.42	33.33	1.93
15 Sep.	30.42	13.75	14.25	4.92	63.33	
1 Oct.	35	11.67	15.83	1.25	63.75	1.35
15 Oct.	48	11.42	6.42	0.83	66.67	
1 Nov.	37.08	14.83	7.33	2.42	61.67	0.91
15 Nov.	30.58	17.42	7.5	1.08	56.583	
1 Dec.	21.67	19	4.5	0.67	45.83	0.68
15 Dec.	15.75	14.5	3.75	0.67	34.67	
Mean	13.71	8.29	6.27	1.48	29.75	
Coexistent	46.08%	27.87%	21.08%	4.97%	100%	

MVR: monthly variation rate

Table 2 Fortnightly numbers of different stages of *P. ziziphi* and its total population on mandarin trees during 2015 season.

Date of inspection	First instar	First molt stage	Female stages	Male nymphs	Total population	M. V. R.
1 Jan. 2015	3.08	5.25	11.25	5.42	25	0.58
15 Jan.	2.67	6.75	8.75	3.5	21.67	
1 Feb.	3.25	4.83	6.58	2.83	17.5	0.58
15 Feb.	2.08	3.25	2.75	1.75	9.83	
1 Mar.	8.25	6.17	3.17	1.42	19	1.72
15 Mar.	13.83	5.75	6.58	1.75	27.92	
1 Apr.	17.42	8.17	7.08	1.5	34.17	1.55
15 Apr.	25.83	6.33	5.67	1.08	38.92	
1 May	20.42	13.17	7.5	2.08	43.17	1.17
15 May	19.5	15.5	5.83	1.67	42.5	
1 Jun	7.58	7.08	10.08	2.58	22.17	0.46
15 Jun	4.1	4.42	7.92	2.92	17.67	
1 Jul.	2.08	4.75	7.5	2.5	16.83	0.88
15 Jul.	3.67	4.25	7.75	2.58	18.25	
1 Aug.	6.25	7.17	10.42	2	25.83	1.91
15 Aug.	10.17	14.25	13.92	3	41.33	
1 Sep.	15.42	14.67	13.67	3.25	47	1.71
15 Sep.	32.75	15.92	14.83	4.5	68	
1 Oct.	49	16	22.08	2.17	89.25	1.68
15 Oct.	65.83	26.5	10.58	1.92	104.83	
1 Nov.	48.5	26.25	13.17	4.58	92.5	0.81
15 Nov.	25.83	24.67	12.42	2.75	65.67	
1 Dec.	24.42	21.5	9.25	1.5	56.67	0.61
15 Dec.	9.12	15.42	13.75	1.67	40	
Mean	17.54	11.58	9.69	2.54	41.07	
Coexistent	42.71%	28.2%	23.59%	6.18%	100%	

MVR: monthly variation rate

The obtained data provided that the insect had two generations a year, the 1st generation (early summer generation) started from early March in the both years until early June in the 1st year and mid-July in the 2nd one. The generation peaked in mid-April in the 1st year and early May in the 2nd year and lasted for 3.5 - 4 months. The 2nd generation (autumn generation) started in early July, peaked in mid-October and continued until December in both years, this generation lasted for 7 months. These results are in agreement with Salama *et al*. (1985) [23], Kamel (2010) [15] and Moustafa (2012) [20], in Egypt who reported two generation a year for this insect. In the area of Boufarik, in Mitidja, Algeria, Sellami and Biche (2006) [24] showed that the black louse had four generations per year. While in Greece, Stathas *et al*. (2008) [26] report that *P. ziziphi* overwintered in all developmental stages and completed several overlapping generations each year. The favorable periods for insect development and population increase were at April and September 2014 with MVR values of 2.03 and 1.93, respectively. In the 2nd season the highest values of MVR were 1.72, 1.71 and 1.68 in March, August and September, respectively (Table 1&2).

Behavioral of *P. ziziphi*

Direction distribution of *P. zizphi* population

Data presented in Tables (3&4) emphasize that parlatoria stages considerably differ from one direction of mandarin trees to another one. Branches located on the south direction harbored the maximum population of first instar, first molt stage and male nymphs where 34.63 %, 30.15 % and 28.35% of the population were counted, respectively. While the east direction harbored the maximum population of female instars. The lowest percentages of different stages of this insect were counted in north direction. A similar results were obtained in the second season, 2015 concerning the distribution pattern of the insect stages. According to these results it is obvious that the parlatoria scale occurs on the whole mandarin trees with special preference to southern and eastern sides. The crawlers are the only moving instar (the main dispersal stage), so the preferred feeding site of other instars as a results of the distribution of crawlers. The preference of this scale insect to the existing leaves on the southern and eastern branches of the mandarin tree may be due to the direction blowing winds from the northern to the southern carrying the newly hatched crawlers and enabling them to settle on the leaves of those directions or to sunlight and other environmental factors.

Table 3: The mean numbers of *P. ziziphi* stages located on mandarin trees at different direction in Nobaria district during the 1st season, 2014.

Direction	First instar		First molt stage		Female stages		Male nymphs	
	Mean±SD	%	Mean±SD	%	Mean±he SD	%	Mean±SD	%
East	17.58 ± 17^{a}	31.5	9.17 ± 5.06^{a}	27.66	7.05 ± 4.58^{a}	28.08	1.5 ± 1.15^{a}	25.03
South	18.99 ± 18.47^{a}	34.63	10 ± 5.67^{a}	30.15	6.76 ± 4.34^{a}	26.97	1.67 ± 1.25^{a}	28.35
North	10.69 ± 10.2^{b}	19.49	7.58 ± 4.51^{ab}	22.84	5.78 ± 3.29^{a}	23.01	1.37 ± 1.08^{a}	23.14
West	7.87 ± 7.99^{b}	14.36	6.41 ± 3.99^{b}	19.32	5.5 ± 2.94^{a}	21.94	1.37 ± 0.96^{a}	23.19
F	3.357		2.63		0.907		0.409	
L.S.D	8.0997		2.781		2.20945		0.638	

Means followed by the same letters, within a column, do not significantly differ at the 5% level according to the LSD test.

Table 4: The mean numbers of *P. ziziphi* stages located on mandarin trees at different direction in Nobaria district during the 2nd season, 2015.

Direction	First instar		First molt stage		Female stages		Male nymphs	
	Mean±SD	%	Mean±SD	%	Mean±SD	%	Mean±SD	%
East	18.83±18.41^{ab}	26.83	11.63±7.48^{ab}	25.11	9.44±3.99^{ab}	24.37	2.79±1.18^{a}	27.52
South	25.95±25.1^{a}	36.97	14.43±9.12^{a}	31.16	11.45±5.01^{a}	29.56	2.58±1.03^{a}	25.44
North	14.16±13.76^{bc}	20.17	11.93±7.78^{ab}	25.73	9.88±4.44^{ab}	25.48	2.41±1.29^{a}	23.77
West	7.87±10.75^{c}	16.01	8.33±5.34^{b}	17.78	7.98±3.7^{b}	20.59	2.36±1.21^{a}	23.25
F	3.105		2.64		2.64		0.655	
L.S.D	10.23		4.229		2.473		0.6781	

Means followed by the same letters, within a column, do not significantly differ at the 5% level according to the LSD test.

Distributional preference of mandarin directions by *P. ziziphi*

Mathematical determination of mandarin tree directional preference by different stages of *p. ziziphi* depicted in Fig. (1&2). Results indicated that the insect's stages showed an obvious tendency to be concentrated in high density in southern east direction of the mandarin tree. The values of angular deflection from the south which apparently tended the highest density of population were 40º 52̍ 34̎, 41̊ 24̍ 46̎, 32̊ 30̍ 34̎ and 66̊ 57̍ 13̎ towards the east for first instar, first molt stage, female stages and male nymphs through the 1st season, respectively. In the 2nd season these angular deflections were 47̊ 08̍ 94̎, 37̊ 14̍ 66̎, 47̊ 07̍ 91̎ and 21̊ 57̍ 13̎, respectively. These results showed that south direction followed by east direction were preferred by the various stages of *P. ziziphi* as distribution directions. The main wind direction in Nobaria district was north-west, therefore differences in the insect distributions might be attributed to the effect of the wind direction or the duration of leave exposure to the sun rays or to the pooled effect between them. These results were agreeable with Eraki, (1998) [9] and Bakry, *et al.* (2015) [3] on their studding on white date palm scale insect, *Parlatoria blanchardii* on date palm. These results are important in the development of pest control programs.

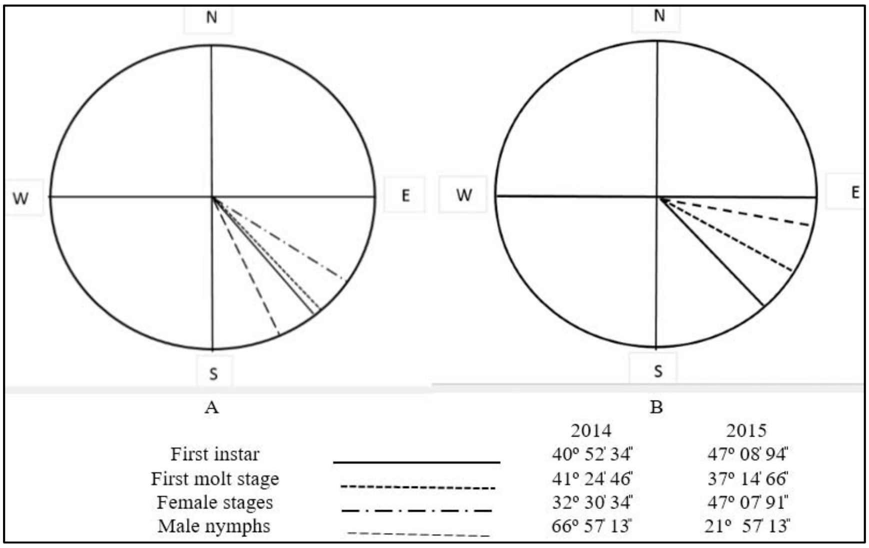

Fig 1: Directional preference of *P. ziziphi* stages on mandarin leaves in Nobaria district, Beheira Governorate, Egypt, over a two years, 2014 (A) and 2015 (B).

Distribution of *P. ziziphi* population in different strata of mandarin trees

Results shown in Tables (5&6) reveal that the distribution pattern of *P. ziziphi* stages varies according to mandarin tree strata throughout the two successive seasons. During the 1st season, 2015 the middle stratum always harbored the highest population density of the insect stages where 50.54%, 48.15%, 46.69% and 43.7% were recorded for first instar, first molt stage, female stages and male nymphs, respectively. In the 2nd year these percentages were 46.81%, 42.35, 44.39 and 43.58% for first instar, first molt stage, female stages and male nymphs, respectively. The upper stratum showed the lower population while an intermediate population was recorded in low stratum of mandarin trees.

Table 5: Average numbers of *P. ziziphi* located in different strata of mandarin trees during 2014.

Strata	First instar		First molt stage		Female stages		Male nymphs	
	Mean±SD	%	Mean±SD	%	Mean±SD	%	Mean±SD	%
Upper	14.06±13.31^{ab}	34.19	8.43±4.87^{a}	33.91	6.54±3.92^{a}	34.74	1.61±1.18^{a}	36.33
Middle	20.78±19.41^{a}	50.54	11.97±7.06^{a}	48.15	8.79±5.7^{a}	46.69	1.93±1.59^{a}	43.7
Low	6.27±7.4^{b}	15.26	4.45±2.76^{b}	17.93	3.5±1.9^{b}	18.57	0.89±0.63^{b}	19.95
F	6.234		12.522		9.88		4.18	
L.S.D	8.2045		2.9973		2.383		1.054	

Means followed by the same letters, within a column, do not significantly differ at the 5% level according to the LSD test.

Table 6: Average numbers of *P. ziziphi* located in different strata of mandarin trees during 2015.

Strata	First instar		First molt stage		Female stages		Male nymphs	
	Mean±SD	%	Mean±SD	%	Mean±SD	%	Mean±SD	%
Upper	15.57±13.38^{ab}	29.59	11.97±7.39^{ab}	34.44	9.69±4.38^{b}	33.35	2.77±1.07^{a}	36.39
Middle	24.63±23.08^{a}	46.81	14.71±9.49^{a}	42.35	12.9±5.29^{a}	44.39	3.31±1.64^{a}	43.58
Low	12.41±15.56^{b}	23.6	8.06±5.82^{b}	23.2	6.46±4.05^{c}	22.25	1.52±0.85^{b}	20.02
F	3.037		4.505		11.07		13.3	
L.S.D	10.2693		4.44345		2.323		0.711	

Means followed by the same letters, within a column, do not significantly differ at the 5% level according to the LSD test.

Percentages of parasitism

During the course of this work, two hymenopterous species were recorded as parasitoids of *P. ziziphi*. They were *Aphytis lingnanensis* and *Encarsia citrine* (Aphelinidae). Data given in Table (7) showed that there were positive highly significant correlation between numbers of *A. lingnanensis* and *E. citrine* and population of *P. ziziphi* whereas (r) values in the 1st year were 0.852 and 0.807 while in the 2nd year these values were 0.812 and 0.899, respectively. The mean of parasitism rate reach to 12.69 % and 14.8 % for *A. lingnanensis* in 2014 and 2015 years, respectively. In case of *E. citrine* these rates reached to 4.66% and 3.03% in 2014 and 2015, respectively. During the present work the results indicated that *A. lingnanensis* was the most important parasitoid attacking the black parlatoria, these results are in agreement with the findings of Moustafa (2012) [20] but disagreement with Coll and Abd-rabdou (1998) who found *E. citrine* was the most important parasitoid attacking the black parlatoria, *P. ziziphi.*

Table 7: Relative abundance of the main *P. ziziphi* parasites, observed on 12 mandarin leaves during two successive seasons 2014 and 2015.

Date of inspection	1st season 2014					2nd season 2015				
	P. ziziphi	*A. lingnanensis*		*E. citrine*		*P. ziziphi*	*A. lingnanensis*		*E. citrine*	
	*	**	***	**	***	*	**	***	**	***
1 Jan.	69	2	2.89	0	0	265	23	8.67	3	1.13
15 Jan.	110	6	5.45	2	1.82	226	22	9.73	3	1.32
1 Feb.	154	7	4.54	5	3.24	210	18	8.57	2	0.95
15 Feb.	106	12	11.32	4	3.77	111	24	21.62	0	0
1 Mar.	103	10	9.71	5	4.85	210	17	8.1	4	1.9
15 Mar.	163	15	9.2	8	4.91	282	29	10.28	10	3.54
1 Apr.	200	22	11	9	4.5	350	33	9.42	12	3.43
15 Apr.	307	33	10.75	10	3.25	490	51	10.41	11	2.24
1 May	209	39	18.66	10	4.78	453	71	15.67	17	3.75
15 May	187	57	30.48	19	10.16	496	85	17.13	13	2.62
1 Jun	234	51	21.79	16	6.83	286	69	24.12	15	5.24
15 Jun	258	60	23.25	22	8.53	196	60	30.61	8	4.08
1 Jul.	246	40	16.26	18	7.32	168	63	37.5	5	2.97
15 Jul.	267	38	14.23	13	4.86	235	70	29.78	9	3.82
1 Aug.	248	30	12.09	15	6.05	246	50	20.32	8	3.25
15 Aug.	321	37	11.52	17	5.29	479	55	11.48	19	3.96
1 Sep.	375	58	15.46	26	6.93	535	82	15.32	27	5.05
15 Sep.	661	72	10.89	32	4.84	803	119	14.81	31	3.86
1 Oct.	721	92	12.76	27	3.74	868	110	12.67	31	3.57
15 Oct.	824	67	8.13	26	3.15	1240	102	8.22	33	2.66
1 Nov.	650	83	12.76	27	4.15	978	109	11.14	32	3.27
15 Nov.	650	86	13.23	25	3.84	715	113	15.8	36	5.03
1 Dec.	536	56	10.44	16	2.98	618	90	14.56	17	2.75
15 Dec.	390	30	7.69	8	2.05	470	63	13.40	11	2.34
Mean	332.87	41.8	12.69	15	4.66	455.41	63.7	15.81	14.8	3.03
r		0.852**		0.812**			0.807**		0.899**	

* Number of insects / 12 mandarin leaves
** Number of parasite individuals / 12 leaves
*** Rate of parasitism

Concerning the distribution pattern of *A. lingnanensis* and *E. citrine* on *P. ziziphi*in mandarin trees strata, the given data in fig. (2) refer to the rate of parasitism varies according to mandarin tree strata throughout the two seasons. Concerning *A. lingnanensis*, the scales in the upper stratum always harboured the highest rate of parasitism of the insect where 16.06 and 23.15% were recorded for 1st and 2nd season, respectively. In the middle stratum these percentages were 13.25 and 15.27%, respectively. The least percentages of parasitism were recorded in the low stratum where 10.62 and 13.88% were recorded. While in case of *E. citrine* the maximum rate of parasitism was recorded in middle stratum (5.3 and 3.49%) follow by low stratum (4.15 and 2.71%) and finally upper stratum (3.87and 2.59%).

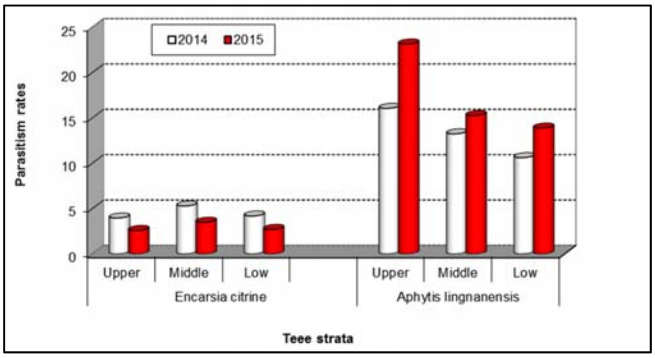

Fig 2: Distribution of *P. ziziphi* parasites on mandarin trees strata during two successive seasons 2014 and 2015.

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