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Role of hymenopterous parasits Aphelinidae in the regulation of levels of *Lepidosaphes beckii* (Newton, 1869) (Homoptera Diaspididae) populations on orange trees in Rouiba area (Algeria)

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ABSTRACT This present study put in evidence the dynamics of the populations of *Lepidosaphes beckii* (Newton, 1869) (Homoptera Diaspididae), and the study of the impact of its hymenopterous parasites *Aphytis lepidosaphes* Compere, 1955, *Aphytis chrysomphali* Mercet, 1912, *Aphytis proclia* Walker, 1839 and *Aspidiotiphagus citrinus* (Craw, 1831) on orange tree in the area of Rouiba. This diaspine develops three generations: one in autumn-winter, one in spring and one in summer. This scale insect presents a very marked affinity in the middle of the tree and the inferior faces of the leaves where the suitable conditions for its development seems to be offered. The natural mortality of *L. beckii* is of two types: climatic for young stages and physiological for the adult females. The parasitic incidence is almost the same for the young stages and the adult with respectively 22.24% and 23.89%. The global rate of parasitism is 23.24% insufficient to control its host.

KEY WORDS *Aphytis; Aspidiotiphagus; Citrus; Lepidosaphes beckii;* parasitoids.

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INTRODUCTION

The cultivation of citrus fruits is of strategic importance for Algeria where it is a source of fruit supply and opportunities in the international market for citrus products. Among the Citruses, the Orange tree occupies the first place with 69.73%, then the Lemon tree with 6.94%, the Mandarin with 4.73% and the clementine with 1.82%. The citrus orchards are subjected to very high-pressure by several pests, in particular by the cochineals that appear to be the second pest after the Mediterranean fruit fly (Benassy & Soria, 1964). The diaspines represent 42.37% of all the cochineals and the genus *Lepidosaphes* Shimer, 1868 (Homoptera Diaspididae) is the most dominant with 14% (Belguendouz, 2005). While the cochineals in general, and *Lepidosaphes beckii* (Newton, 1869) in particular, cause important damages on citrus fruits, there are, however, predators and pests very poorly known in Algerian conditions. Our work

presents a contribution to the understanding of the ecology of *L. beckii* on Orange trees in the region of Mitidja, and its relationship with the parasites Hymenopter.

MATERIAL AND METHODS

Our study was carried out on a private farm in Rouiba (36°44'00''N and 3°17'00''E), located to the east of the Mitidja, 25 km from the capital Algiers and 7 km from the Mediterranean Sea. It is delimited to the north by the town of Ain-Taya, to the south by the town of Khemis El Khechna, to the east by the town of Reghaia and to the west by the town of Dar El Beida, over a period from September 2016 to July 2017. The plot is 2 hectares, divided into 9 blocks of 25 trees. Prospecting was done once per 10 days, with a sampling of 2 trees from each block on which we took 1 branch of 20 cm long and 2 leaves (in each cardinal direction as well as in the center of the tree). The collected plant material were brought back to the laboratory where we counted for each stage the total live, dead and parasitized individuals of *Lepidosaphes beckii* in order to assess the condition of the insect infestation and the evolution of its pests in according to the method of Vasseur & Schvester (1957).

Identification technique for identified pests

The identification of Aphelinidae is based on the study of their morphological characters (Ferrière, 1965). The technique consists in organizing the parasites harvested under a binocular loupe between blades and lamellae. The latter fixed by Faure's liquid. In our study, 4 species of parasites were identified on the populations of *L. beckii*: *Aphytis lepidosaphes, Aphytis chrysomphali, Aphytis proclia*, which are ectoparasites, and *Aspidiotiphagus citrinus*, which is an endoparasite.

RESULTS AND DISCUSSION

Biology of the insect scale

The analysis of the results reported in figure 1 a cross-breeding between larval and adult elements, which is dictated by the natural life cycle of *L.beckii* where the percentages of these two populations are almost equal until mid-December when the larvae are present with 31.63% of the total number of individuals. Then there is a further progression in mid-January that reaches 76.30%. These are likely from the adult females during autumn. Thereafter, the larval populations will undergo gradual regression and reach their lowest rate by the end of April. A further increase in staffing is then noted for the highest rate in July (81.59%). For adult fluctuations, the adults displayed their highest percentage (68.37%) only at the beginning of December. These females are likely the cause of the larvae observed during the month of November. Thereafter, these adult forms display a second peak (75.33%) in the first then days of May (Fig. 1).

The results indicate an overlap of three annual generations in *L. beckii*: spring, summer and autumn generation. Our results confirm those reported by Biche et al. (2011), Biche et al. (2012), Adda (2010) in the same region of the Orange tree. On the other hand, Meghazi (2010) found 2 generations: fall and spring on the Orange tree in Rouiba. Benassy et al. (1975) reported that the Cochineal develops 2 generations per year in France, 3 in Tunisia, 4 in Naples (Italy), Egypt and Morocco. In Chile, Zuniga (1971) reported three annual generations in the northern region, two to three generations in the central region and only one generation in the southern region. On the other hand, in Eastern Cape in South Africa, De Villiers (1998) reported four annual generations.

The overall study of *L.beckii* shows that the central orientation is affected the most by this

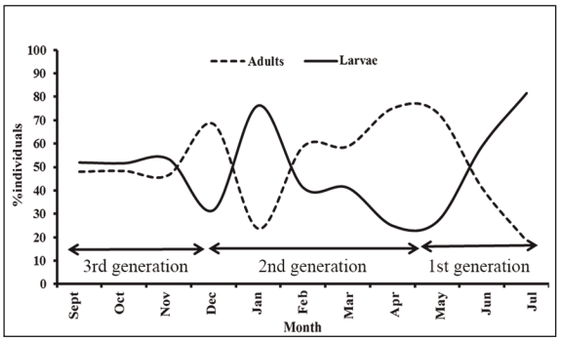

Figure 1. Fluctuation of larval and adult populations of *Lepidosaphes beckii.*

cochineal with 38.36%, followed by the eastern orientation with 22.12% of the total population (Fig. 2). Our results coincide with those obtained by Gherbi (2010) and Meghazi (2010) who worked in the same region. On the other hand, on the clementine trees, Mouas (1987), who worked in Annaba, and Khoudour (1988) in the Chebli region, report that *L. beckii* is found in the northern orientation. The vegetal organ has a very remarkable influence on the abundance of this cochineal, where the leaves contain 91.90% of the total population, mostly on the lower surface (56.31%)than on the upper surface (35.59%) (Fig. 2). This situation provides the cochineal with favorable fixation conditions. Indeed, the leaf blade has a very fine texture, favouring the bites of opophages insects. Our results are consistent with those found by Gherbi (2010). On the other hand, Mouas (1987), Khoudour (1988), Adda (2006) and Adda (2010) note that the highest rate of the living population of *L. beckii* is located in the upper surface of the leaves.

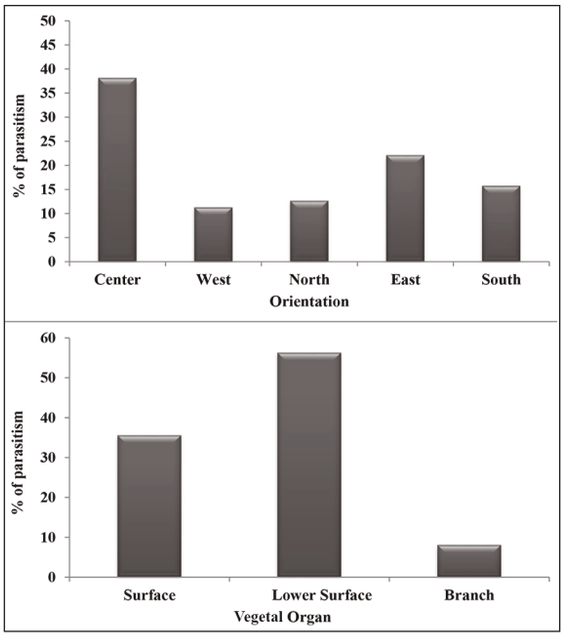

Figure 2. Spatiotemporal distribution of the overall population of *Lepidosaphes beckii*

Study of mortality

In view of the results shown in the figure below, we note that overall mortality is significantly higher in larval populations (43.87%) than in adult populations (30.86%). Nevertheless, considerable fluctuations have been recorded throughout the period of study, stretching from September to July (Fig. 3). This mortality is likely related to the structure of the larval shield and the climatic conditions of the winter season where the minimum temperatures displayed 6.2°C in December, 2.3 °C in February and 7.6 °C in March. Instead, the strong rainfall recorded during the month of May was 75 mm, compared to 18 mm in April and 2.55 mm in June. Regarding adult mortality, it is mostly physiological. Indeed, the females after oviposition, die immediately. Mouas (1987), Meghazi (2010), and Gharbi (2010) found that overall adult mortality is quite significant in larvae.

The recorded results show that the overall mortality rate remains very high where the abundance of the cochineal is very pronounced. Nevertheless, the highest mortality rates were recorded at the central and southern orientation of the tree, with 19.78% and 16.84%, respectively, while on leaves is 52.72% (52.72%) (Fig. 4). This

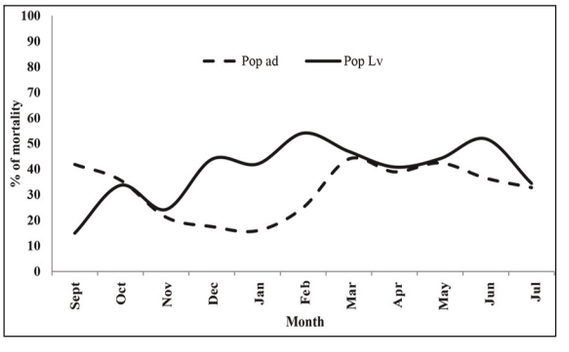

Figure 3. Mortality of *Lepidosaphes beckii* larvae and adults on the orange tree.

result is probably related to the exposure of these leaves to the different climatic hazards during the winter or summer period, namely high temperatures, winds, and hail, as well as the chemical treatments carried out in the orchard.

Inventory of cochineal pests listed on Orange tree at Rouiba

Periodic and random sampling of parasite populations remains an efficient method that allows, in addition to the inventory, to clarify

certain bioecological parameters, on the one hand, and, on the other hand, to assess possibly the entomological role of each species identified for their biological control jobs. The parasite inventory of *L. beckii* highlights 4 species of Hymenoptera Aphelinidae represented by *Aphytis lepidosaphes* Compere, 1955, *Aphytis chrysomphali* Mercet, 1912, *Aphytis proclia* Walker, 1839 and *Aspidiotiphagus citrinus* (Craw, 1831) (Table 1).

Aphytis lepidosaphes is an ectoparasite that develops at the expense of females adult and 2nd stage male larvae.

Aphytis chrysomphali, *Aphytis proclia* are ectoparasites that develop at the expense of 2nd stage male larvae.

Aspidiotiphagus citrinus is an endoparasite that develops at the expense of the larvae of 2nd stage larvae of *P. ziziphi* and of young females (Ferrière, 1965). We found it for the first time on female larvae in Algeria.

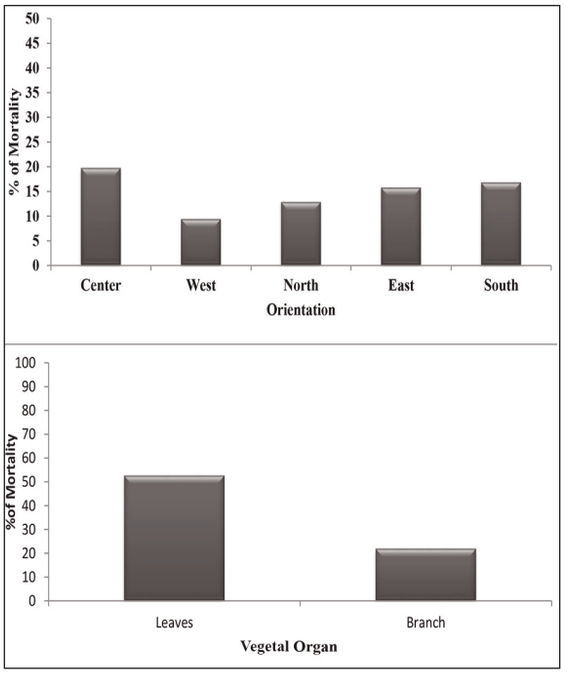

Figure 4. Spatiotomporel mortality of de *Lepidosaphes beckii*.

Study of the Parasite incidence

The results recorded in the graph below show that the overall rate of all-stage parasitism in *L.beckii* fluctuates throughout the study period. This fluctuation first passes through a first peak during November with a rate of 30.49% and the second peak in April with a rate of 20.64% and reached the highest rate of parasitism during the month of July with 67.62% (Fig. 5). Overall, the parasitism recorded in the populations of *L.beckii* is 23.24%. This rate is similar to that reported by Meghazi (2010) who worked in the same region of the Orange tree (20.45%). On the other hand, compared to the work of Adda (2006), the parasitic incidence was higher, as the author noted 4.01% adult parasitism. This is likely due to the declining chemical treatments carried out in the study orchard.

The fluctuation of parasitism goes through two main periods: autumn-winter and spring-summer. During the first period, rates varied between 53.81% (September) and 25.58% (December), due to the availability of host larvae for parasites during this period. Thereafter, Parasitism parasitism considerably decreases to vary between 13.78% (January) and 11.03% (February). This decrease is likely related to pesticide application in the study orchard. There was not parasitic activity in the

Class	Order	Family	Species	
Insecta	Hymenoptera	Aphelinidae	*Aphytis lepidosaphes*	*Ectoparasites*
			Aphytis chrysomphali	
			Aphytis proclia	
			Aspidiotiphagus citrinus	*Endoparasite*

Table 1. Description of the parasites of *Lepidosaphes beckii* on the orange tree in the region of Rouiba.

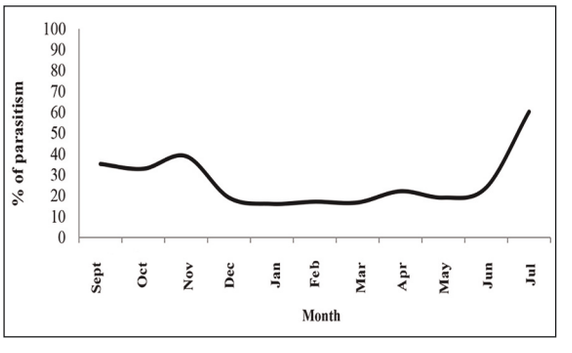

Figure 5. Overall Parasite Incidence of *Lepidosaphes beckii* populations

larval populations until the end of March. In fact, the parasitism of this second period varies between 24.94% (April) and 28.65% (July) (Fig. 6).

Due to the availability of agreater presence of adult cochineal stages, and in contrast to larval populations, the parasite incidence in adults noted for 3 periods: autumn-winter, spring and summer. The first peak of the parasite incidence was recorded in November with 30.49%, the second in April with 21.72% and the third in July with 67.62% (Fig. 7).

Based on the results obtained, it appears that the orientation and the vegetal organ do not have a significant effect on the distribution of the parasite on the tree. Abundance of host cochineals would result in a synchronous increase in the numbers of the parasite populations (Fabres, 1979). Nevertheless, the highest parasitism were recorded in the, east and South, orientations, with 28.86% and 28.75%, respectively (Fig. 8). It should be noted that the lowest rate recorded was in the population in the central orientation of the trees. Pests seem to avoid shady areas of the tree and prefer to look for cochineal fixed in sunny places. Our results are similar to those reported by Adda (2006) and Meghazi (2010) , whose northern orientation is the most preferred by parasitism.

For the spatial distribution of pests, it should be noted that the latter are more active on the upper surface (27.16%) than on the lower surface of the leaves (21.47%) and twigs (18.24%). These places seem to explain the requirement of parasites in micro-climatic conditions since in these places the sunshine is better.

The host's females perforated shields correspond to the release of adult parasites and reveal the presence of parasitoids. During the study period, we found the presence of a very large number of these females shields and puparia holes. However, they display three peaks, including 217 females shields and puparia holes in the month of October, then 509 in March and lastly in June with 436 females shields and puparia holes (Table 2).

Comparative global parasitism rate

Based on the results recorded in figure 9, it is apparent that the parasitoids attack much more the female stages of the cochineal, in wich 23.89% of the adults are parasitized. On the contrary, the males are attacked throughout their life cycle, which provides the parasitoid with nutritional conditions for better development. We also noted that parasitism remains constant in the female population throughout the study period with fluctuations in three peaks; the first in November (30.70%), the second in April (21.7%) and the third in July (67.90%) (Fig. 9). A similar work in Egypt, on the incidence of external parasites of *L. beckii*, has shown that rates of parasitism are not very high. In fact, Hafez et al. (1987) reported rates of parasitism between 29.7 and 40.2% in October-December, 21.6% in January, 16,1% in May and 15.4% in June.

The rate of parasitism of the males remains low compared to that of females with 19.11%. Probably, the male stages do not offer the optimal nutritional conditions for better development of the parasitoid because they no longer feed during the nymph stages to become adult (Fig. 10).

The rate of parasitism in 2nd stage male larvae remained low at 7.42% compared with lin 2nd stage

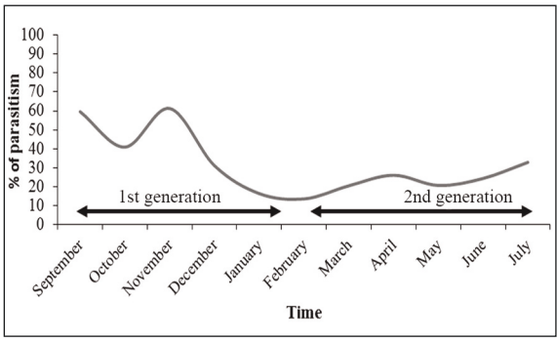

Figure 6. Parasite impact of larval populations of *Lepidosaphes beckii*

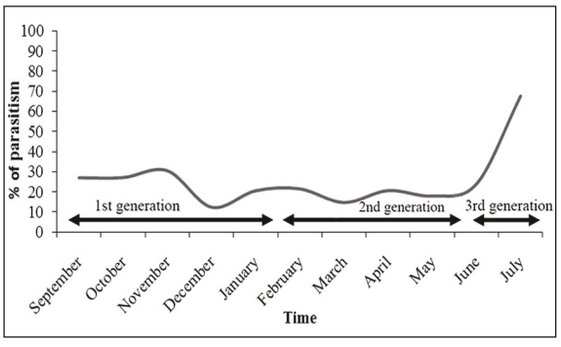

Figure 7. Parasite incidence of adult populations of *Lepidosaphes beckii*

female larvae. Presumably, these male larvae do not offer optimal nutritional conditions for better development of parasitoid. Three peaks of parasitism have been observed: the first in October (43.18%), the second in March (18.42) and the last in June (8.33%) (Fig. 11).

Based on the results recorded in figure 12, it is apparent that parasitoids attack much more the female larval stages of the cochineal (24.82%).

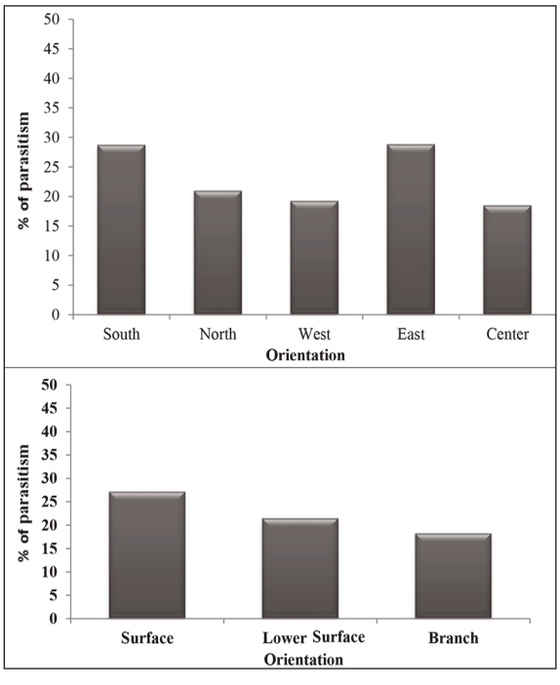

Figure 8. Parasite incidence of *Lepidosaphes beckii* populations according to the orientations and vegetal organs.

Date	Shields holes	Puparias holes	(S+P) Holes
September	70	2	72
October	196	21	**217**
November	134	11	145
December	103	12	115
January	112	15	127
February	163	8	171
March	495	6	**501**
April	333	3	336
May	242	6	248
June	435	1	**436**
July	290	10	300
Total	2573	95	**2668**

Table 2. Parasitic incidence of parasites in *Lepidosaphes beckii* populations by taking into account holes puparias and females shields.

Given the availability of these larvae throughout our sampling, parasitoids provide the nutritional conditions for better development. We also noted that parasitism in these larvae goes through three peaks: the first during the month of September (59.60%), the second during the month of November (61.32%) were the highest rate and the third were recorded during the month of July (32.82%) (Fig. 12).

CONCLUSIONS

The study allowed us to undertake a new relative approach to the role of parasites Hymenoptera Aphelinidae in limiting populations of *L. beckii*. However, the study of the population dynamics of the pest is a key element in understanding the biological phenomena that govern the evolution of the pest during the seasons and to better define the techniques of control to adopt.

Based on the results obtained, we conclude that there is an overlap of three generations in year of *L. beckii*: one in autumn-winter, one in spring, and one in summer. The spatial distribution of this species on the tree is closely related to the microclimate created within the tree from which the species has a marked preference for its central orientation. This place seems to give it the favorable conditions for its optimum development.

The incidence of natural enemies is the result of the action of Hymenoptera parasites of the genus *Aphytis* Howard, 1900 and *Encarsia* Foerster, 1878, whose activity is mainly noticeable in full and spring. Three ectoparasites Hymenoptera species have been identified in the populations of *L. beckii*, *A. lepidosaphes, A. chrysomphali*, and *A. proclia*, and a single endoparasite species, *Aspidiotiphagus citrinus*, during our study. It should be noted that this is the first time in Algeria that the presence of these parasitoids on the larval forms of the cochineal is observed. All of the studies conducted so far on the Diaspines have never reported this type of information.

We noted that *A. lepidosaphes* is present only in adult males and females. However, they are much more present on the females of the cochineal as it offers optimal nutritional conditions. The overall rate of parasitism approximates 23.89%. Two

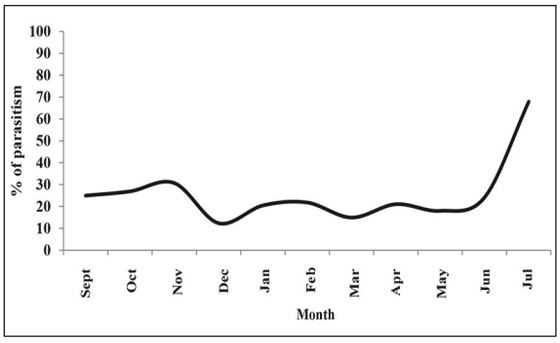

Figure 9. Parasite incidence of *A. lepidosaphes* on females *Lepidosaphes beckii*.

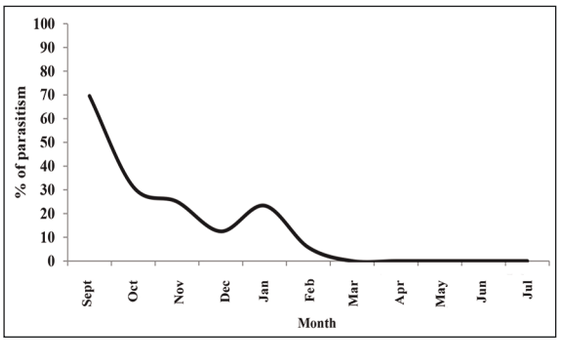

Figure 10. Parasite incidence of *A. lepidosaphes* on the males of *Lepidosaphes beckii.*

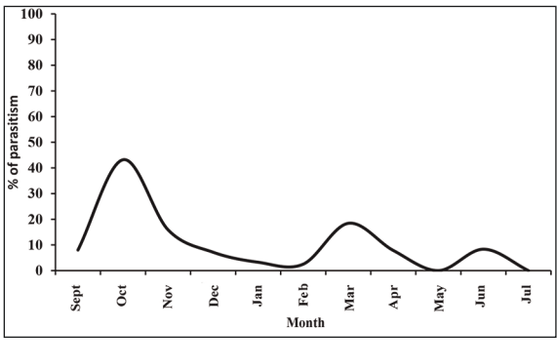

Figure 11. Parasite incidence of *A. chrysomphali* and *A. proclia* on 2nd stage male larvae of *Lepidosaphes beckii.*

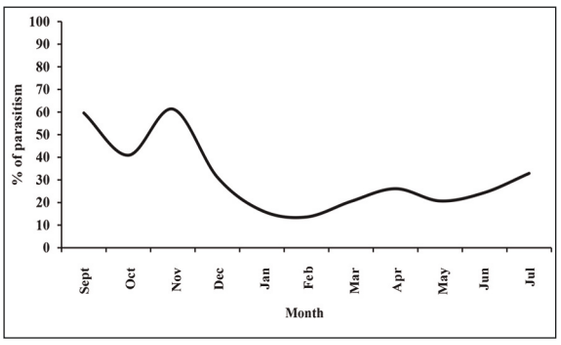

Figure 12. Parasite incidence of *A. citrinus* on 2nd stage female larvae of *Lepidosaphes beckii*

ectoparasites, *A. proclia* and *A. chrysomphali*, with a parasitism rate of 7.01%, and an endoparasite *A. citrinus*, were identified on 2nd stage male larvae. The latter is the only parasite that develops on 2nd stage female larvae with an overall rate of 22.19%.

Our work provides further information on the impact of parasitoids *A. lepidosaphes*, *A. chrysomphali, A. proclia* and *Aspidiotiphagus citrinus,* for a possible rational management of integrated control methods in good conditions.

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