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## ORIGINAL ARTICLE

# Bio-ecology of a citrus pest (*Aonidiella aurantii* Maskell) (Hemiptera, Diaspididae): spatiotemporalrelationship with its host plants *Citruslimon* and *C.sinensis* in Algiers region.

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Belguendouz-Benkhelfa R., Biche M., R. Adda, Allal-Benfekih L., Bio-ecology of a citrus pest (*Aonidiella aurantii* Maskell) (Hemiptera, Diaspididae): spatiotemporalrelationship with its host plants *Citruslimon* and *C.sinensis* in Algiers region.

**ABSTRACT**

Our prospective analysis in this work is based on a comparative study of bioecological balances of *A. aurantii* on two *Citrus* habitats (*C. Sinensis var. Washington navel* and *C. Limon var. Eureka*) in Rouiba region east of the Algerian capital Algiers. Our results showed that infestations are high, temporal distributions are most abundant on lemon (77.50%). Our statistical analyzes showed that rainfall, host plant and the evolutionary stage of the pest are the limiting factors for its abundance and its temporal distribution. In our climate conditions, the red scale develops three overlapping generations per year on the two host plants: ($1^{frst}$) in summer ($2^{nd}$) in spring and the (3rd) in autumn. This behaviour can be explained by a further study on the influence of trophic factors.

***Key words:*** *Aonidiellaaurantii*, host plant, Abundance, bioecology, Climate, Algeria

## Introduction

Today, the worldwide production of citrus fruit in 12913 milion tonnes (FAO, 2012). The global Algerian production in citrus fruit, which does not cover internal consumption, reached 844,195 tonnes in 2010 (Bellabas, 2012). The citrus fruit yields keep underneath international average (17,8/ha on 2009) and weaker than those of our Mediterranean neighbours. For economy reasons, Algeria needs to develop its level production in agriculture to eam a place in the citrus international market. To reach this objective, it is necessary to assure a better production by protecting this strategic culture from the most important pest, notably, diaspines cochineal insects which cause infestations often difficult to quantify on all North band of Algeria (Kosztarab, 1990). If works on a lot of scale insects are available (Belguendouz*et al*.,2006, Belguendouz *et al*., 2009a, Belguendouz *et al*., 2009b, Belguendouz *et al*., 2010, Belguendouz *et al*., 2011a et 2011b); Biche *et al*.,(2012a et 2012b; Biche , (2012); those on Aonidiella aurantii remain on the contrary very rare if it is not those of Kihal (1992), Chorfa (1993), Merahi (2002) et Biche *et al*.,(2012).

The temperature and rainfall are essential in the distribution of all living organisms Faurie *et al.* (1980). Because of the fast spreading and the increase of damages related to this insect, fundamental researches are needed to understand the relationship between the insect, host-plant and the abiotic and biotic environment factors including the choice of biotopes and host plants of *A. aurantii*. This knowledge is necessary to plan a better strategy for this pest control, considering a schedule of interventions to minimize infestations for improving yields and protecting the orchard production especially before fruit maturity. In this work, we have studied for the first time, the temporal variations of the red scale abundance related to the host plant and the climatic conditions (temperature and rainfall).

## Materials and Methods

Monitoring was conducted in two citrus orchards: an orange orchard (*C. sinensis Var. Washington Navel*) and a lemon orchard (*Citrus limon Var. Eureka*) located in Eastern Mitidja at Rouiba situated in the wilaya of Algiers (36°44'21 "N, 3° 17'07" E), at 18m above sea level. This region is a part of the sub-humid bioclimatic

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Mediterranean stage which is generally characterized, by a mild and wet season (Minimum Temperature: 8.21°C to 20.48 °C) and a hot and dry season (Maximum Temperature: 16.04°C to 33.83°C), the annual rainfall varies between (zero mm to 130.8 mm) (Anonymous 2011-2012). The orchards have been planted since the end of the colonial period (1958-1960), with a planting distance of 5 meters between trees. They are surrounded by windbreak hedges at the north, south and east, and by tomato and pepper greenhouses at the west. The experimental unit corresponds to a plot of 100 trees spread over 10 rows of 10 trees. It was divided into 4 blocks with 25 trees each block. Investigations began in September 2009 and ended in August 2010, according to the phenology of the host plant during spring, summer, autumn and winter. To obtain a homogeneous sample, two leaves of the same branch were taken randomly from 4 directions and the centre of each tree. These leaves were collected and put in plastic bags labelled with block number of the tree, date and orientation. In the laboratory, the collected leaves were examined from the lower and the upper side under a binocular microscopic lens. All the stages of the red scale were considered according to the method of Vasseur and Schvester, (1957). The shield was removed to determine the exact stage, and to estimate the abundance. During the counting, leaves were kept in the refrigerator at 4°C to avoid hatching of eggs and development of larvae. The temperatures and rainfall data of the studied period 2009-2010 were handed by the climatic station of Rouiba.

The percentage of individuals per plant host was calculated as follow (Total number of individuals per one host plant) / Total number of individuals on both plant hosts) *100. The percentage of individuals of each biological stage per one plant host was calculated from Total number of individuals of the corresponding stage / Total number of individuals of the hole stages) *100.

The data on the variations of *A. Aurantii* populations depending on time, host plant stages of the insect, were submitted to an analysis of variance using software SYSTAT, ver. 12, 5SPSS, 2009), without the study of correlations between factors (General Linear Model). Differences were considered significant at a risk threshold of P <2%. The mean of time variation abundances was obtained by calculating the barycentre of the data, using the formula: $B = \Sigma(Mi$ * abundance$)/\Sigma($abundance$)$, where $Mi$ is the number of the $i$th month, from 1 to 12. The significance of the lag between temporal distributions of the abundances was assessed by calculating cross-correlation using PAST vers.1.81.

The correlation between the abundance of the different stages of the red scale and the seasonal periods of investigations in the studied orchards was analysed by a correspondence analysis (CFA).The analysis was conducted with the software PAST. Vers.1. on a matrix based on the abundance and times of samplings (Hammer *et al*. 2001).

## Results and Discussion

*Global temporal variation:*

On one hand, the larvae stage represents 53.44% on lemon-tree and 14.32% on orange-tree. On the other hand, the adult'sstage showslow rates: 24.78% on lemon-tree and 07.45% on orange-tree (fig.1). The abundances of the different biological stages (adult and larvae) on the two host plants, are three times higher on lemon-tree than on orange-tree(P = 0.0001453, Ratio = 21, One-way ANOVA test) (Fig. 1). The difference of the global abundances is very highly significant between the living populations on the orange-tree and the one living on the lemon-tree (GLM, p=0,000; Ratio = 38,314, p<1‰). The young stages (movable, set up, and nymph) are more abundant on the two host plants with a very significant difference (P = 0,001; r = 13,324; P<1%). The comparison between every progressive stage showed a highly significant between the nymphs and the adults males on the two host plants, and their abundance is very low compared to the one of the adult females and larvae (p = 0.000, Ratio = 18.365; p<1‰) (Fig.2).

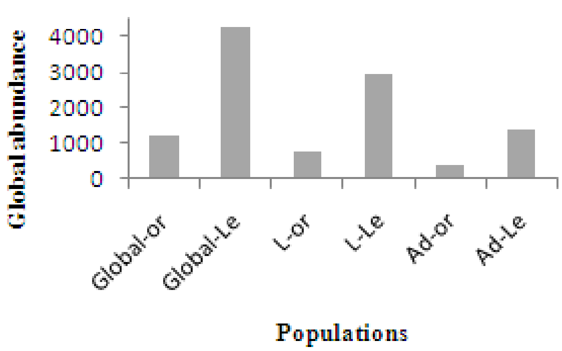


**Fig. 1:** Variabilityof the global *Aonediella aurantii* abundance on the orange-tree and the lemon-tree (L: larvae, Ad: adult, Le: lemon, or: orange)

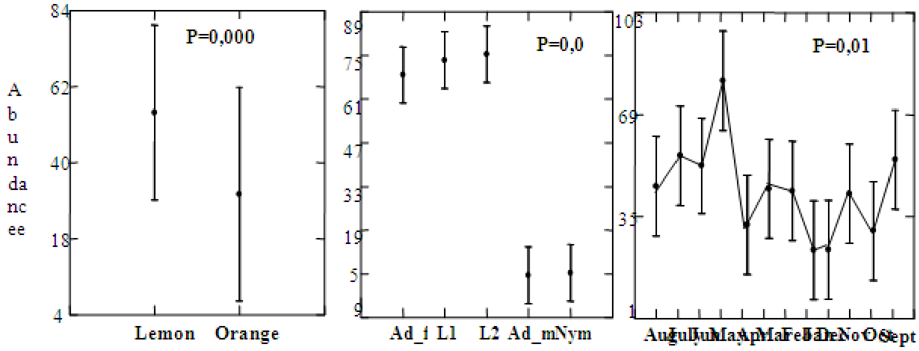


**Fig. 2:** GLM analysis of the Variability of *A.aurantii*abundance on the orange and the lemon-tree. ($L_1$: larva of first stage, $L_2$: Larva of second stage, Ad_F: female adult, Ad_m: male adult, nym: nymph).

Our observations confirm the results obtained by Cameroon*et al*., 1969; Habib *et al*., 1972; Bedford, 1998) whomentioned that the red scale, attacks firstly the lemon tree (*Citrus limon*) then the orange tree (*Citrus sinensis* L.).

From September 2009 to August 2010, *A. aurantii* was able to produce 3 important peaks, one in the autumn, the second one in the winter season, third one in the spring and the fourth one in the summer period (Fig. 3).The population reached a maximum of 14.63% on orange-tree in October, and an other represented by 9.67% on lemon-tree in November. In December, a serious decline in the abundance was observed on the two host plants followed by a progressive increase of the population, which reachs 9.16% in January on orange tree and 15.15 % in February on lemon tree (fig. 3).The activity depends on the period of the year, the climatic conditions and the tree phenology.

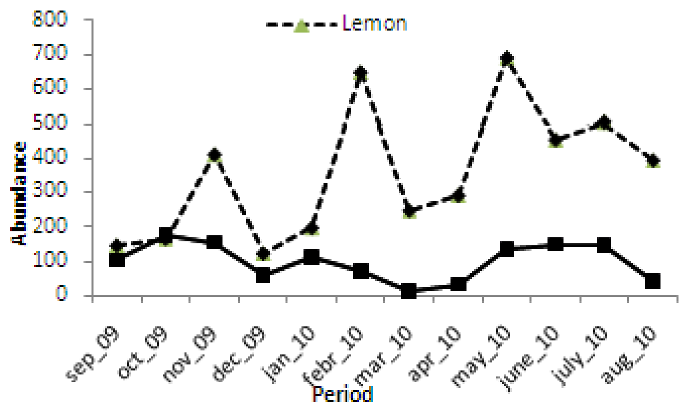


**Fig. 3:** Monthly variation of *A. aurantii* population on lemon and orange host plants.

*Temporal variation of the biological stages:*

The abundances of larval and adult stage are higher on lemon-tree than on orange tree, (P = 0.0001453, p<1%, One-way ANOVA test) (Fig. 2). The larva stage represents 53.44% on lemon-tree and 14.32% on orange-tree; on the other hand the adults stage showlow rates: 24.78% on lemon-tree and 07.45% on orange-tree (fig.2). The young stages (movable, set up, and nymph) are more abundant on the two host plants with a very significant difference (P = 0,001; P<1% GLM test).

The comparison between every progressive stage, showed a highly significant difference between the nymphs and the adults males on the two host plants, and their abundance is very low, compared to the one of the adult females and larva (p = 0.000, p<1‰) (Fig.2). Another similar decline on the two host plants was noticed in March and April. This was followed by a second variable activity between April and July, in which the abundance reached 16.13% on lemontree in May, and 10.65% on orange tree in July. A third decline was noted in August on the two host's plant but it was more important on orange tree (3.78%) than in lemon tree (9,27%) (Fig. 2).

The correspondence analysis (CP) shows 40,13% of contribution of the information on the axis 1 and - 29,99% on axis 2. The distribution of the stages is related to seasons and to the host plant. Tow biological groups are represented. The first one corresponds to the emergence period of males, larvae of first and second stage and nymphson the orange host plantduring the autumn (September, October, November), Januaryand June. The second group corresponds to the females and males, larvae of first and second stage and also nymphs on lemon tree during the end of the winter period in February and the spring period during March, May, June, July and august. This result demonstrates the presence of the red scale on lemon in the summer period than on the orange host plant in the autumn period, according to the vegetative rest period.

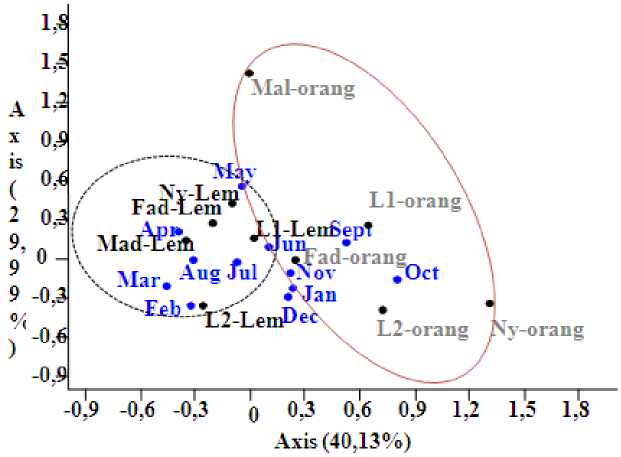


**Fig. 4:** Correspondance analysis on temporal variations of *A. aurantii* on lemon-tree and on orange-tree. (L1-orang: Larvae on orange, L1-Lem: Larvae on lemon, L2-Lem: Larvae on lemon, L2-Lim: Larvae on orange, Fad-orang: female adult on orange, Fa-Lem: female adult on lemon, Pv-orang: period of male flies on orange, Pv-lem: period of male flies on lemon).

*Temporal gap:*

The barycentre shows that the choice of *A. Aurantii* is based on nutritional means of different larvae stages, nymph and adults on the *Citrus limon and Citrus sinensis.* The acquired stocks show that the intervals of appearance from one month to tow months. On the whole, the period of maximum biologics stage activity take place in summer (May- June) on *Citrus limon* and in autumn (September-November) and July on *Citrus sinensis.*

*A. aurantii* appears with a temporal gap of the larvae populations, nymph and adult according to the value of "Lag= 1,2,1 and 1" acquired from the analysis of cross-correlation (tab. 1) as follows: the length of larvae (L1 and L2), nymphs and adult females are more precocious on lemon and the gap is of month, excepted for the males (tow months) which appear on orange tree more – early (in May) and on lemon tree more – late (in July).The linked probability of the difference installation of larvae, nymph and male stages (p= 0.686, p= 0.207, p= 0,428 and p = 0,0671) is not significant (tab. 1). This scale insect makes a choice between lemon and orange trees for which we can argue the following hypothesis:

- The difference in the annual number of poushed saps in both host plant (*Citrus limon var. Eureka*: 4 seasons poushed saps and only 3 ones for *Citrus sinensis* var. Washington navel).
- Thenutritional quality in chemical and biochemical sap compounds during both host plants phenologic periods.

**Table 1:** Temporal Lag between red scale biological stages on the studied host plants (L1: first larvae stage, L2 second larvae stage, Ny: nymph, Adf: adult female, Adm: adult male) (cross correlation test, Past vers. 1.81)

| Stade biologique | Barycentre | Lag | Prob |
|---|---|---|---|
| L1-Lemon<br>L1-orange | 6,34<br>7,34 | 1 | 0, 686 ns |
| L2-Lemon<br>L2-Lemon | 5,62<br>7,6 | 2 | 0,207 ns |
| Ny-orange<br>Ny-Lemon | 6,23<br>7,65 | 1 | 0,428 ns |
| Lemon-Adf<br>Orange-Adf | 5,69<br>6,35 | 0 | 0,116 ns |
| Lemon-Adm<br>Orange-Adm | 6,36<br>5,33 | 1 | 0,0671 * |

(* p <0.05, ns : non significant, (A barycentre at 7.34 means that the maximum Esperance to find the species is between the 7th and the 8th months, i.e. July and August).

*Number of generations and life cycle:*

The number of generations was determined by taking into accountthe evolution of the first larvae stage (L1), because the generations are overlapping.*A. aurantii* develops 3 generations per year with represented clearly by 3 peaks at the beginning of November, the end of February and the end of May (fig. $5_a$). The maximum of larvae population is found on lemon tree in spring season (20,53%) and on orange tree in autumn season ( 8,56%) (Fig.$5_b$). The GLM test reveals that the "host plant" has a very significant effect on the seasonal abundances (p = 0.001) but the "season" does not have any significant effect (p=0,368),(fig.$5_b$).

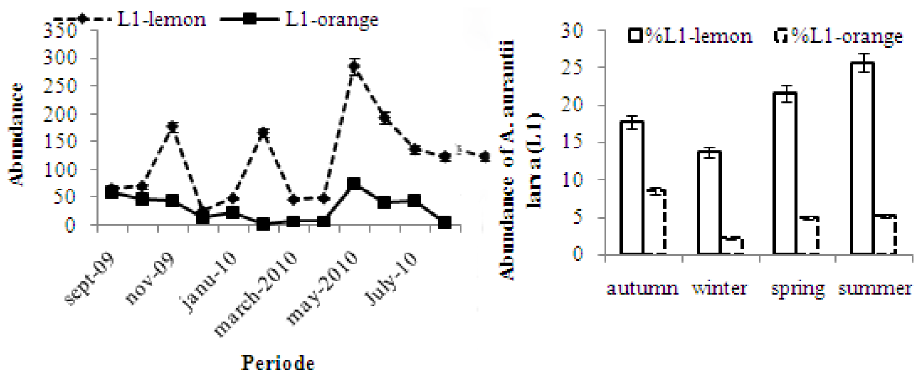


**Fig. 5:** Seasonal variability of the first larvae stage (L1) Abundance on orange and lemon-trees.

*Interpretative cycle of A. aurantii on both plant hosts (Fig. 6)"*

The first larvae population is only abundant from September to November and from May to July on orange tree.On lemon tree, it is abundant from September to November, February to May and from June to July. The spring-summer generation is the most remarkable on lemon and the autumn generation on orange (Fig.6). This insect seems to change host according to the micro-climatic conditions product by the orchards, climatic conditions of the region and of the nutritional quality which varies according to the phenology stage and kind.

The maximum of the population (14,63%) is obtained on orange tree in October (autumn) and (16,13%) is obtained on lemon-tree in July (summer). This shows that this insect prefers the old trees exposed to the sun (Bala., 1950), the Pearson's correlations analysis shows that the rainfall have a negative effect on the breeding activity (p = 0.013) prevent the mating of the adults males on lemon-tree (p = 0.060) and prevent the females on orange-tree, to unveil its inferior part of pigydium to facilitate the fertilization by the males. The temperature has a positive effect on males that fly (p = 0.010; p = 0.0063) on lemon-tree. Itis according to the local climatic conditions, principally the temperature and relative humidity (Beardsley and Gonzalez, 1975).

This explains the impact of phyllotaxy and size of the tree to protect the individuals and facilitate the mating againstharsh climatic conditions by creating a specific microclimate (fig. 6)..

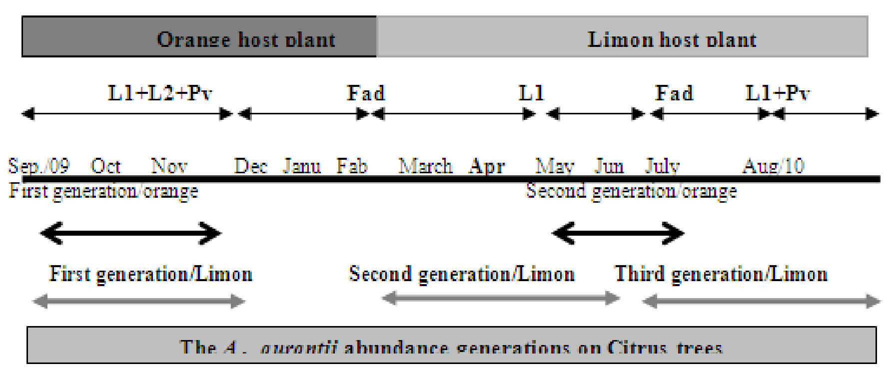


**Fig. 6:** Interpretative cycle on lemon-tree and orange-tree. (L1:larvae stage, L2 larvae second stage, Pv: fly period of males: Fad: adult female).

*Correlation between A.aurantii populations and climatic parameters:*

The monthly temperatures, causing the installation of*A. Aurantii*on orange tree and lemon tree, ranging from 33,83C ° in July to 8,21C ° in January, and the monthly rainfalls varies between zero mm and 130,8 mm.

Bodenheimer **(**1951) reported that the scales insect reproduce and grow between 23 and 27.5c°. This corresponds to our results, which show that the maximal infestation on orange tree (14,63 %) is acquired of 26,86C °- 14,68C ° in October, but on lemon tree (16,13%) is obtained between 20,39C°- 33,83C° in July. We can say *A. aurantii* seems to develop a big adaptation to climate conditions, especially if plants guests are old and exposed to the sun (Bala. 1950), (fig. 7).

The correlations analysis of Spearman's shows that rainfall acts negatively on reproductive activity (P = 0,0132, Ratio= -0,68) by preventing the theft of the adult males on lemon-tree, (P = 0,060, Ratio= -0,55) for the sliding of the females towards the party inferior of the buckler, to display their pygidium to the coupling on the orange-tree. The temperature acts positively (P = 0,010; P = 0,0036) on steal it from males on the lemon tree. It explains the impact of the tree phyllotaxy and the sling size on the protection of the populations and their reproduction, against climatic factors that can create a specific microclimate (Tab.2).

**Table 2:** Effect of the climatic conditions (temperature and rainfall) on *A. Aurantii.*

| Correlation of Spearman's | Probab /T°max | Probab /T°min | Probab /raifall (mm) |
|---|---|---|---|
| Males/Limon | 0,00365 | 0,0102 | 0,0132 |
| Flemalle adulte /orange | NS | NS | 0,060 |

## *Conclusion:*

In Algeria, the abundance of *Aonidiella aurantii* is higher on lemon-tree than on orange-tree. It is can be, because of : type of *Citrus limon var. Eurika* 's phyllotaxy which is aired enough and condensed in*Citrus sinensis*, the nature of the orange tree sap and it's periods of phonology which are disadvantageous for development of this insect scale. The micro-climate created by these treesaffects the breeding activity of the males and females; this is the primary explanation of the populations abundance. Any increase of the population on the trees is the result of the interaction between the climatic factors, the natural enemies, the application of different chemical products and all the elements of the environment. In the North centre of Algeria, we obtain three (3) generations per year of *A. aurantii*, very defined on *Citrus limon* than on *Citrus sinensis*; the autumnal generation is higher on orange tree, but the summer generation is higher on lemon tree. This is according to plant host and the local climatic conditions, principally the temperature and the rainfall. The maximum of abundance of *A. aurantii* (16, 13%) is obtained at the temperature between 20,49C° and 32,82C° on lemon tree and between 8,21C° and 16.04 C on orange-tree. Therefore, the plant can be as restricting factor and change the length of cycle and the number of generations during one or several periods, thanks to these phenologic stages, age and its health state. This insect is endowed with a big capacity of adaptation in change of the climatic factors. This study allows us to envisage a calendar fixing different periods of controlintervention on both host plants.Therefore,it is necessary to take care to maintain a biological balance of the non target fauna in our orchards.

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