Bol. San. Veg. Plagas, 25: 459-467, 1999

Population dynamics of *Icerya purchasi* MASKELL (Hom; Margarodidae) and *Rodolia cardinalis* MULSANT (Col; Coccinellidae) in two citrus orchards of São Miguel island (Azores)

A. O. SOARES, R. B. ELÍAS y H. SCHANDERL

En dos parcelas de naranjo en el Norte de la isla de São Miguel se ha estudiado la dinamica poblacional de *I. purchasi* y *R. cardinalis*. El muestreo se realizó quincenalmente en 16 árboles desde Mayo a Noviembre de 1.997 y desde Abril a Octubre de 1.998.

I. purchasi ha desarrollado dos generaciones anuales, una al final de la primavera y otra en otoño. Las hembras jovenes son las mas abundantes en invierno. Los estadios larvares del predador se observan al principio del verano y la actividad del vuelo de los adultos es máxima al final de verano. Este máximo contribuye de forma acusada para la disminución de la densidad de *I. purchasi* durante el verano con los valores más bajos al final de la estación. En este momento se observa una elevada sincronización entre la proporción de hembras jovenes de *I. purchasi* y larvas de *R. cardinalis*. En el otoño la abundancia poblacional de *R. cardinalis* es muy baja coincidiendo con la 2ª generación de *I. purchasi*. Después de Noviembre no se han encontrado individuos en las arboles, indicando probablemente el inicio del periodo de hibernación.

La mayoria de los inmaduros y hembras jovenes de *I. purchasi* han sido observado en las hojas y las hembras maduras se han encontrado en los ramas, indicando migración entre los organos de la planta.

SOARES, A. O., R. B. ELIAS y H. SCHANDERL: Secção de Ecologia, Departamento de Biologia, Universidade dos Açores - Rua Mãe de Deus, 58 P-9502 Ponta Delgada.

Palabras clave: Cítricos, dinamica poblacional, ciclo biologico, sincronización estacional, *Icerya purchasi*, *Rodolia cardinalis*.

INTRODUCTION

The polyphagous Margarodidae, *Icerya purchasi* Maskell, is one of the most abundant insects found in the orchards of the Azores islands. It is considered a major pest of citrus trees (CARVALHO, *et al.*, 1996) and for this reason it is common to use chemical control to decrease the economic threshold.

I. purchasi has been known in the Azores since the beginning of the century but the date of its introduction is not well known. It was possibly introduced in 1912 together with acacias to the island of S. Miguel (NEVES DE FONTOURA, 1917 *in* BENSAÚDE, 1927a). BENSAÚDE (1924; 1927b) referred to its introduction as 1915. By 1925 it was considered a common pest and because of this chemical treatments were carried out, firstly in July and afterwards in September or October (BENSAÚDE, 1925). It was referred to as occurring in the Azores by many authors (QUAYLE, 1941; CARNEIRO, 1982; SCHANDERL, *et al*, 1995; SOARES, *et al*, 1992, 1993,

1994, 1996). On the mainland *I. purchasi* has been known of since 1884 but recorded for the first time in 1896 by VERÍSSIMO D'ALMEIDA quickly becoming an important pest to citrus trees (AMARO, 1994; ALMEIDA, 1896).

The Iceria-ladybird *Rodolia cardinalis* Mulsant is, at the moment, the only auxiliary known to control *I. purchasi*. Its presence is commonly referred to on the island of S. Miguel (FÜRSH, 1966; RAIMUNDO & ALVES, 1986). Probably it was introduced to the islands of the Azores from the Portuguese mainland where it is relatively abundant, mainly in the southern orchards of Portugal (CARDOSO, 1990; FRANCO, *et al.*, 1992). In 1927 the Iceria-ladybird was already considered by BENSAÚDE (1927a; 1927b) as subspontaneous at some places of S. Miguel. The biological control against *I. purchasi* using the *R. cardinalis* (introduced from California and South Africa), made by Portugal at the end of the 19Th century, became the first European experiment in integrated pest management.

The knowledge about the population dynamics and life cycle *of I. purchasi* and *R. cardinalis* under the abiotic conditions of the Azores are insufficient. Recent observations showed that a higher abundance of *I. purchasi* occurs at the end of summer and beginning of autumn together with a higher level of immature stages in the population which is related with the beginning of annual generations (SOARES, 1995).

The present paper aims to know the seasonal abundance of *I. purchasi* and *R. cardinalis*, to describe the seasonal population structure of the phytophagous and its predator and how efficient the predation activity, is.

MATERIAL AND METHODS

Two citrus orchards of sweet orange (*Citrus sinensis* Osbeck, var. *valencia late*), in full production, were selected in the Rabo de Peixe basin, the most productive citrus area of S. Miguel. This selection was based on the fact that these orchards presented stable populations of *I. purchasi* and *R. cardinalis*.

At two weeks intervals two samples were made in each orchard in order to follow (1st) the seasonal abundance of *I. purchasi* and *R. cardinalis* (2nd) the population structure of *I. purchasi*. and *R. cardinalis*.

Between May and November of 1997 we observed, on 8 trees of each orchard, 30 cm segments of 32 branches. In 1998, we started sampling one month earlier and we observed on each branch 5 one-year-old leaves per quadrant. At the same time we counted the number of immature stages of the predator.

In order to study the seasonal abundance of *R. cardinalis* we analysed its flight curve using the beating method. We beat 4 branches (1 from each quadrant) on 8 trees per orchard with the same sampling periodicity.

To evaluate population structure of the cottony-cushion scale and Icerya-ladybird we counted by developmental stage (larvae, young females, adult female, prepupae, pupae and adults). In order to test the association between the variation of the seasonal proportion of the predator larvae and young females of the prey, we applied the nonparametric Wilcoxon paired-sample test to the data observed between June and August. Its correlation was evaluated using the Spearman test (r_s), after tested the normality of data using the statistic test of Kolmogorov-Smirnov (SPSS 6.1 for Macintosh, SPSS Inc, 1995).

RESULTS AND DISCUSSION

Seasonal abundance of *I. purchasi* and *R. cardinalis*

In figure 1 the seasonal abundance of *I. purchasi* and *R. cardinalis* is given.

The population level of the cottony-cushion scale showed a tendency to increase at the end of the spring and decrease after maximum values had occurred. Both maximums occurred in the first half of June with an ave-

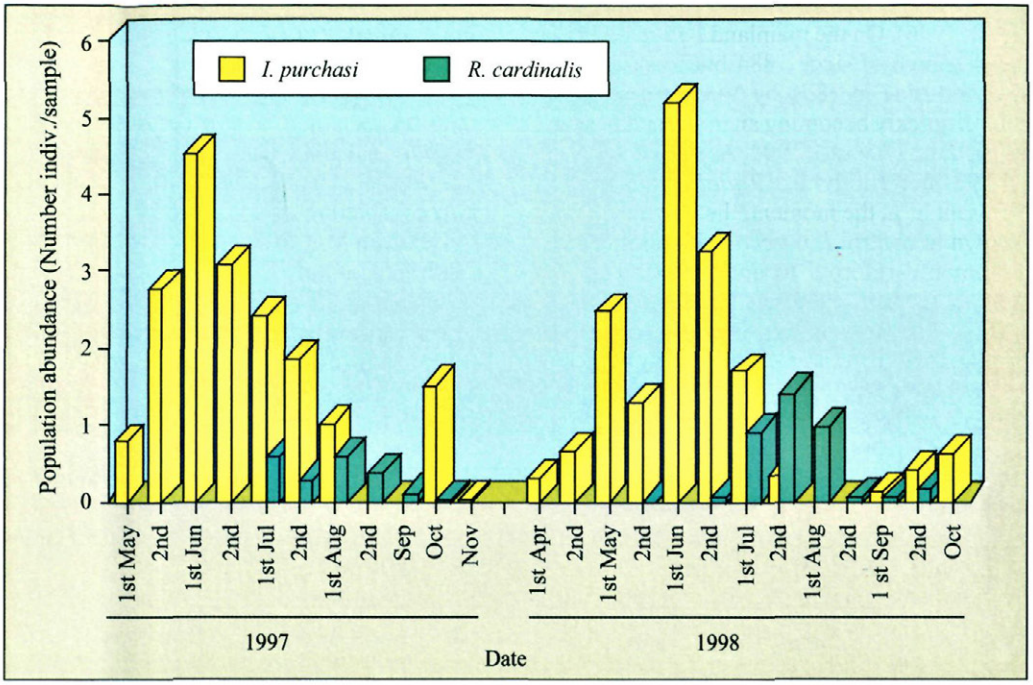

Fig. 1. - Seasonal abundance of *I. purchasi* and *R. cardinalis* .

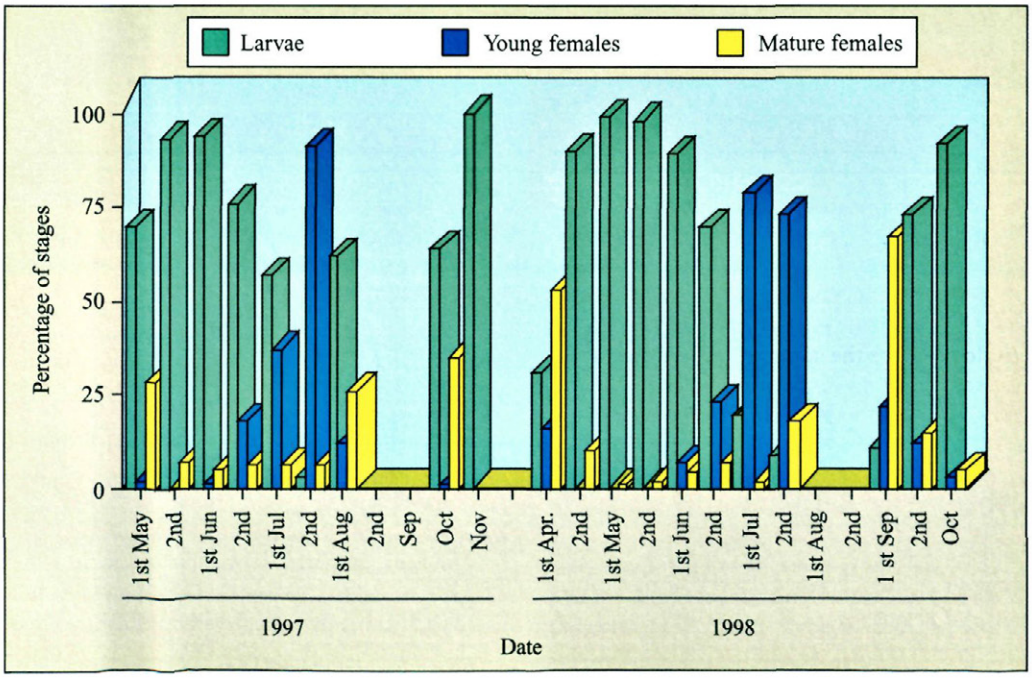

Fig. 2. - Seasonal population structure of *I. purchasi.*

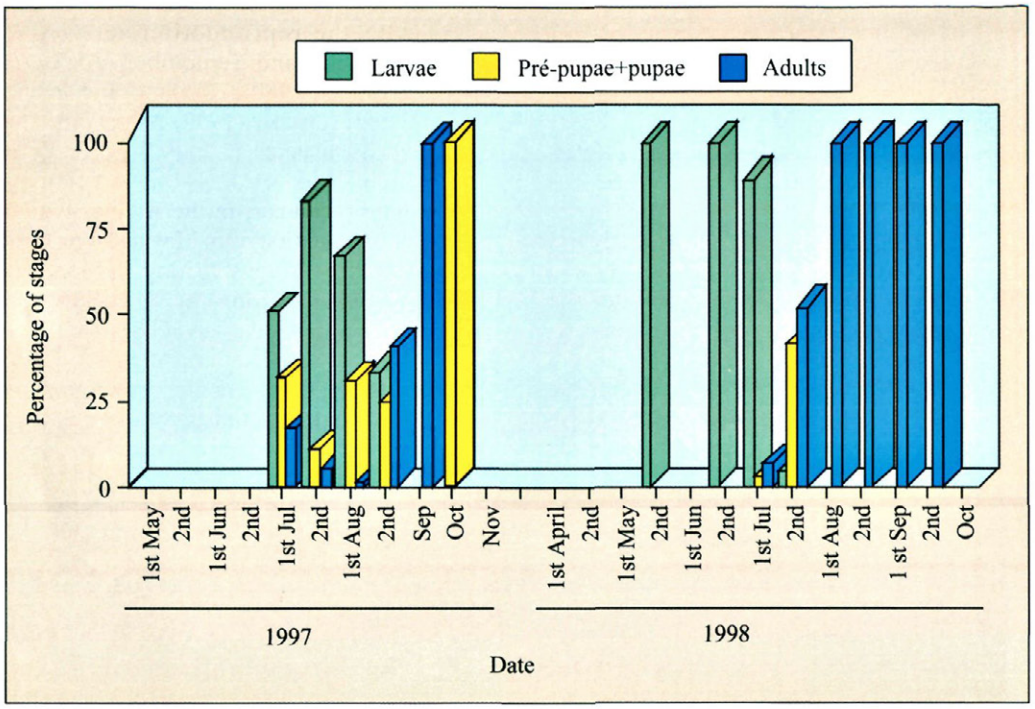

Fig. 3. - Seasonal population structure of *R. cardinalis*.

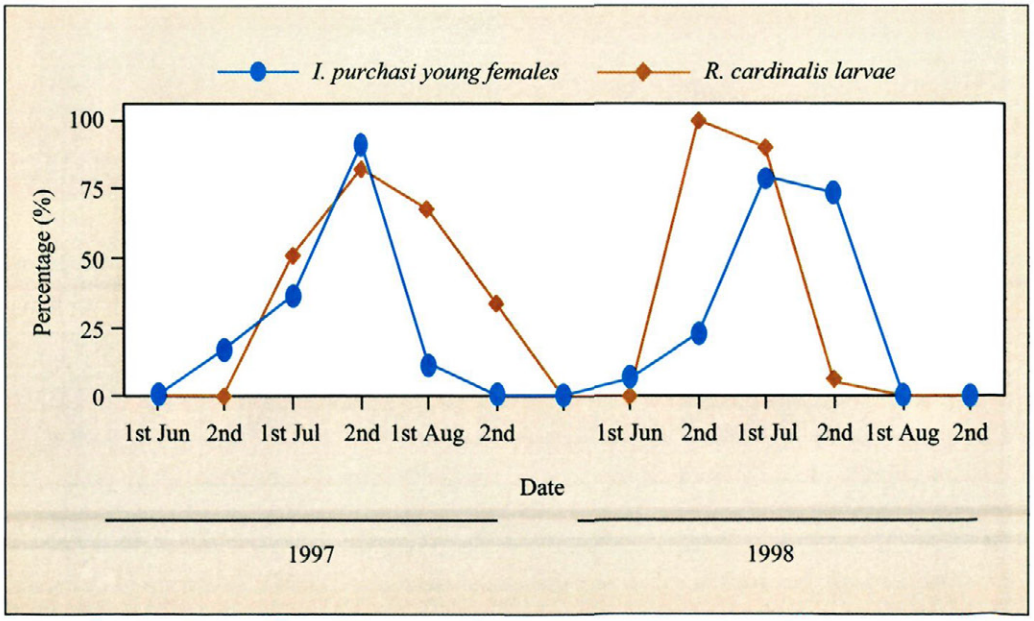

Fig. 4. - Seasonal proportion of young females of *I. purchasi* and larvae of *R. cardinalis*.

rage of 4.5 individuals per sample in 1997 and 5.2 in 1998. The low levels of the population continued until October when we observed a new increase of this level. These results agree with those from SOARES (1995), where the same seasonal abundance was observed.

The flight activity of adult Iceria-ladybird is higher in the summer, between July and September, and started a month after the maximum levels of the cottony-cushion scale (Fig. 1). CARDOSO (1990) observed the higher number of specimens between the second half of July and the beginning of August.

Seasonal population structure of *I. purchasi* and *R. cardinalis*

In relation to the population structure of *I. purchasi*, we discovered in both years two periods of time in which we had high levels of immature stages in the population: at the end of spring and autumn. At this time the levels of immature stages were more than 60% of the total number of individuals (Fig. 2). After that we had an increase in the young female proportion followed by the increase in mature females (Fig. 2). A drastic decrease in the population levels is observed in the summer, between the second half of August and September of 1997 and in August of 1998, when we did not observe any individuals on the leaves and branches (Fig. 2).

Regarding annual generations, the numbers are between 2 and 4, when we consider regions with different abiotic conditions. In Palestine 3,5 generations per year are the rule. In exceptional years, either 3 or 4 generations may occur (BODENHEIMER, 1951). On the «Coast Plain», the scale is capable of producing 3-4 generations a year according to weather conditions (AVIDOV & HARPAZ, 1969). In the north-western Argentine its numbers are 3 (NASCA, *et al*, 1981) and 2 in Valdivia, Chile (REBOLEDO & CARRILLO, 1988). On mainland of Portugal it is possible for 4 annual generations to occur but the rule is 3 with the reproduction activity in February, July and September (AMARAL, 1982; SOARES, 1980). GARRIDO and BUSTO (1987) and CLIMENT (1990) report different results: for instance in Italy 3 generations with the hatching of the larvae in February, June and September; in the Antibes with 2 generations, the first from May to August and the second from August to May; in Morocco, 4 annual generations the first between February and June, the second between June and August , the third from August to October and the last in the winter. In Spain there are 3 generations starting at the same time as the Algarve.

The first individuals of *R. cardinalis* were observed at the end of spring. In July and August of 1997 and 1998, the population was heterogeneous with larvae, pre-pupae and adults (Fig. 3). The decrease in the proportion of larvae is followed in the next month by the maximum proportion of pre-pupae, pupae and adults (Fig. 3).

Seasonal synchrony between the life cycles of *I. purchasi* and *R. cardinalis*

A drastic population level decrease of the cottony-cushion scale was observed at the end of the flight activity period of adult Iceria-ladybird when we observed, on leaves and branches, all the individuals of the predator population in the adult stage. (Fig. 3.) In the previous month the population of the predator was composed mainly of larvae thus coinciding with a high level of young females of the scale. The values obtained from the nonparametric Wilcoxon paired-sample test between the variation of the seasonal proportion of the predator larvae and young females of the prey was 0.463 in 1997, 0.893 in 1998 and 0.598 for the two years. The result showed no differences for $\alpha = 0.01$. The correlation obtained was 0,64 that showed a good correlation between the data for the two years to a confidence of 0.05. These results show that we have a good seasonal synchrony between these two components of the

Table 1. - **Results of nonparametric Wilcoxon paired-sample and correlation tests between seasonal variation of Y. purchasi young females - prey (p) and R. cardinalis arvae- predator (P)**

Tests	P_{97}/p_{97}	P_{98}/p_{98}	Pt/pt
Asymp. Sig. (2-tailed)	0.463*	0.893*	0.594*
r_s	–	–	0.64**

t - 1997 + 1998
* - Not significant at the 0.01 level
** - Correlation is significant at the 0.05 level

population (Table I). Apart from that we observed a half-month of displacement between the two maximums of the referred stages (Fig. 4). We think that the decrease of the prey population is due mostly to the high voracity of the larvae against young females of the prey, even before the formation of the ovisac and before the beginning of the second generation. The displacement observed is due to the higher thermal constant of *I. purchasi* in relation to *R. cardinalis* that makes the predator more sensitive to the variation in temperature. In fact, in 1998 the mean summer temperature was higher (21C) than in 1997 (19,9C).

Seasonal distribution of the population of *I. purchasi* into the organs of the plant

In figure 5, values of the proportion of the different development stages of the population of *I. purchasi* in leaves and branches are given. The majority of larvae and young females were found on the leaves and more than 50% of mature females were found on the branches.

In relation to the seasonal distribution of the population of *I. purchasi* into the organs of the plant, we observed, in the first half of April, an heterogeneous distribution of the individuals but the majority of the population, (53%), are mature females (Fig. 6). The proportion of larvae increased until the second half of May (in which we recorded them as more than 90% of the individuals), first with a high level in the branches and after that with an increasing proportion of larvae on leaves. From the first half of June until the second half of July we observed a decrease in the proportion of larvae at the leaves with an increasing proportion of the larvae on branches and young females on the leaves. After that our observation showed a high level of young females mainly on the branches in which we had 50 and 54.5% of young females in the first and second half of July. At this period of time the flight and predation activity of *R. cardinalis* increased.

We think that there is a spring generation in which the oviposition and eclosion of eggs started in April. This is due to a high proportion of mature females on the branches and leaves. Afterwards we observed a high level of larvae in the second half of May. At this time the offspring started a migration from the branches to the leaves. The decrease of larvae in July happened at the same time as the increase of young females, mainly on branches. We think that the offspring made a new migration to the branches after that would start the summer generation if it hadn't occurred a high level of predation.

CONCLUSIONS

The population level of the cottony-cushion scale showed a tendency to increase at the end of the spring with the maximums in the first half of June.

The flight activity of adult Iceria-ladybird is higher in the summer, between July and September. A drastic population level decrease of the cottony-cushion scale was observed at the end of the flight activity period of adult Iceria-ladybird.

The decrease of the prey population is due mostly to the high voracity of the larvae against young females of the prey, even before the formation of the ovisac.

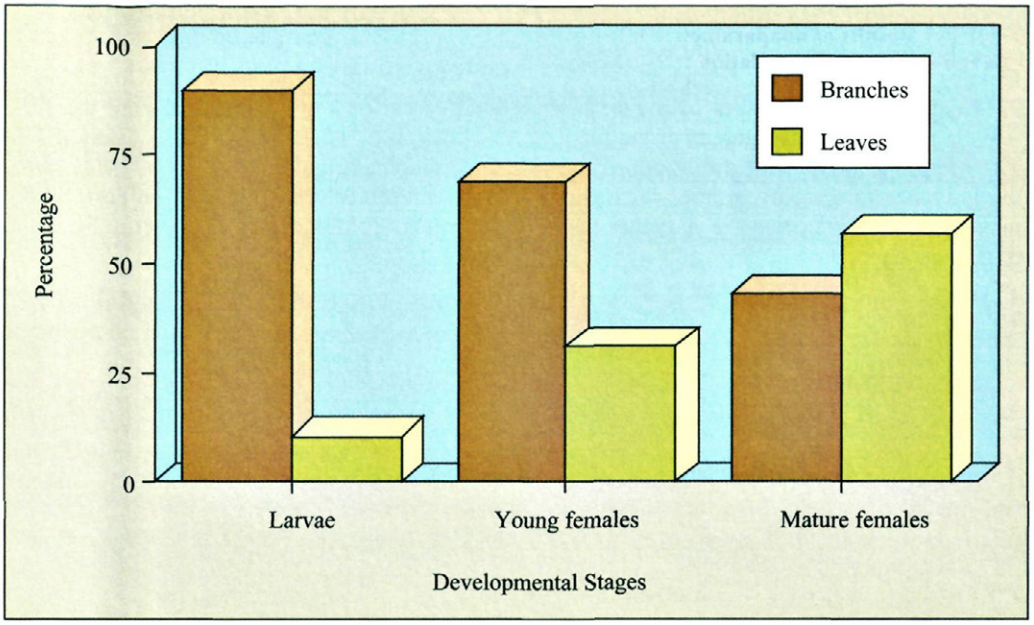

Fig. 5. - Proportion of different stage of the population of *I. purchasi* into the organs.

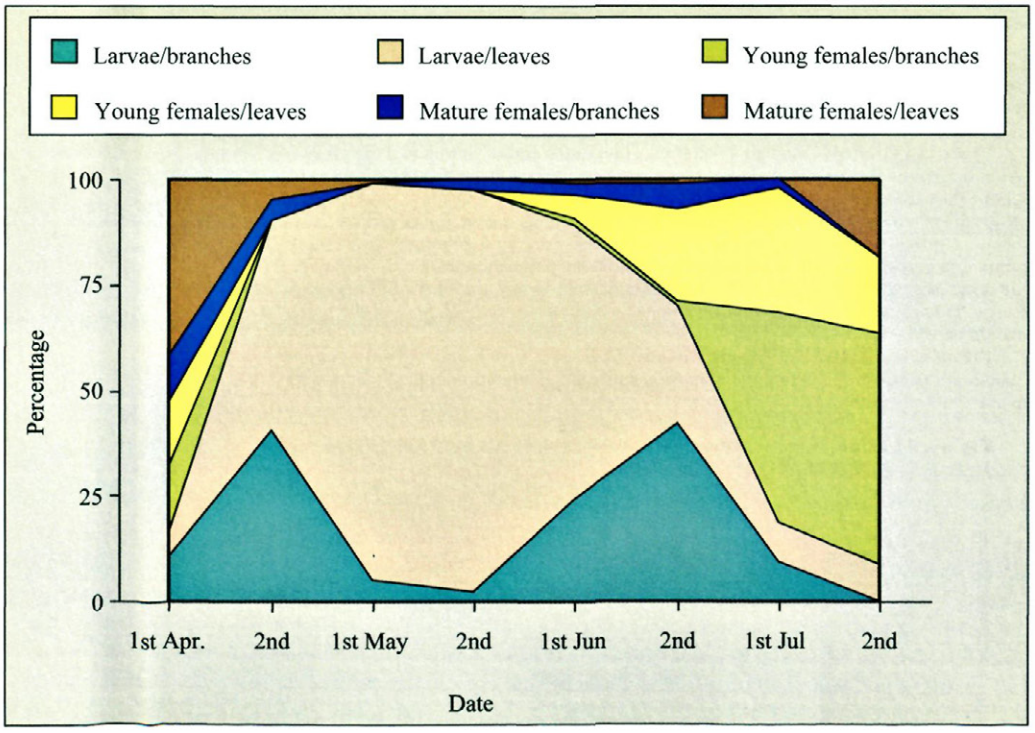

Fig. 6. - Seasonal distribution of the population of *I. purchasi* in the organs of the plant.

The majority of larvae and young females were found on the leaves and the mature females were found on the branches.

The developmental stages of *I. purchasi* make a migration in the organs of the plant. The offspring larvae start a migration from the branches to the leaves, after wich they make a new migration to the branches starting a new generation.

ACKNOWLEGEMENTS

We would like to thanks Mr. José Manuel Tavares for his assistance during the field work and Ian Bunn for his comments to correct the English.

This study was supported, in part, by the project SRAP-Citrinos of Governo Regional dos Açores.

ABSTRACT

SOARES, A. O., R. B. ELIAS y H. SCHANDERL, 1999. Population dynamics of *Icerya purchasi* MASKELL (Hom; Margarodidae) and *Rodolia cardinalis* MULSANT (Col; Coccinellidae) in two citrus orchards of São Miguel island (Azores). *Bol. San. Veg. Plantas,* **25** (4): 459-467.

Two citrus orchards in the North side of São Miguel island (Rabo de Peixe) were selected in order to evaluate the populations dynamics of *I. purchasi* and *R. cardinalis*. For that purpose sixteen trees were sampled from May to November 1997 and from April to October 1998.

I. purchasi develops 2 annual generations, one in the end of Spring and the other in Autumn. Young females are the most abundant stage during the winter. The larvae stages of the predator appear mainly in the beginning of summer and adults start to appear in July reaching the peak of abundance in the end of that season. This maximum probably contributes to the decrease of *I. purchasi* density during the Summer reaching its minimum in the end of this season. During autumn the population level of *Rodolia* beetle decreases which coincides with the second generation of *I. purchasi*. After November no individuals were found on trees probably indicating the beginning of the hibernation period.

The majority of larvae and young females of the scale were found on the leaves and mature females were found on the branches, indicating a migration in the organs of the plant.

Key words: Citrus, population dynamics, life cycle, seasonal synchrony, *Icerya purchasi*, *Rodolia cardinalis*.

REFERENCES

ALMEIDA, J. V., 1896: Novo parasita das laranjeiras em Portugal. *A Agricultura Contemporanea.* 7(5): 182-187.

AMARAL, J. D., 1982: *Os Citrinos.* Colecção Técnica Agrária. Clássica Editora. 781 pp.

AMARO, P., 1994: Portugal pioneiro da luta biológica na Europa através do combate à icéria com a vedália. *Actas do 1º Congresso de Citricultura, Silves 20-22 Jan.* 1993: 393-402.

AVIDOV, Z. & HARPAZ, I., 1969: *Plant pests of Israel.* Israel Universities Press. 549 pp.

BENSAÚDE, M., 1924: Alguns insectos inimigos da laranjeira: as cochenilhas. *Boletim Agrícola e Económico da Sociedade Corretora, L^tda^,* 2: 12-15.

BENSAÚDE, M., 1925: O pomêlo ou grape fruit. *Boletim Agrícola e Económico da Sociedade Corretora, L^tda^,* 8: 6-10.

BENSAÚDE, M., 1927a: Inventário das moléstias das plantas agrícolas da ilha de S. Miguel. *Boletim Agrícola e Económico da Sociedade Corretora, L^tda^,* 4: 3-4.

BENSAÚDE, M., 1927b: Insectos amigos: vespas e parasitas. *Boletim Agrícola e Económico da Sociedade Corretora, L^tda^,* 6: 2-3.

BODENHEIMER, F. S, 1951: *Citrus entomology in middle east.* Uitgeverij Dr W. Junk, S. Gravenhage. 663 pp.

CARDOSO, A., 1990: Estudo prévio dos Coccinelídeos encontrados sobre os citrinos em Portugal. *Bol. San. Veg. Plagas,* 16: 105-111.

CARNEIRO, M. C., 1982: Pragas das Culturas na Ilha de S. Miguel. *Bolm. da Soc. port. Ent,* 7 (Supl. A): 7-33.

CARVALHO, J. P.; FRANCO, J.C.; AGUIAR, M. F.; and SOARES, A. O., 1996: Insects pests of citrus in Portugal. «VIII Congress of the International Society of Citriculture» 12- 17 Maio 1996. Sun City, South Africa. *Proc. Int. Soc. Citriculture,* Vol. I. 613-618.

CLIMENT, J. M. L.,1990: *Homóptera I. Cochinillas de los cítricos y su control Biológico.* Pisa Ediciones 260 pp.

FRANCO, J. C., MAGRO, A. and RAIMUNDO, A., 1992: Estudo comparativo da dinâmica de populações de coccinelídeos em pomares de citrinos no sul de Portugal. *Bol. San. Veg. Plagas,* 18: 69-80.

FÜRSH, H., 1966: Die coccinelliden der Azoren. *Boletim do Museu Municipal do Funchal,* 20:29-33.

GARRIDO, A. & BUSTO T. DEL, 1987: Algunas cochinillas no protegidas que pueden originar daños en los cítricos españoles, I: *Icerya purchasi* Mask (subfamilia: Margarodinae). *Levante Agricola,* 267-268: 63-71.

NASCA, A. J.; TERÁN, A. L.; FERNÁNDEZ, R. V., e PASQUALINI, A. J., 1981: *Animales prejudiciales y benéficos a los cítricos en el noroeste Argentino.* CIRPON. 362 pp.

QUAYLE, H. J., 1941: *Insects of citrus and other subtropical fruits.* Comstock Publishing Company, Inc. 582 pp.

RAIMUNDO, A. A. C. & ALVES, M. L. L. G., 1986: *Revisão dos coccinelídeos de Portugal.* Évora. 103 pp.

ROBOLLEDO, R. & CARRILLO, R., 1988: Ciclo estacional, fenologia y plantas hospederas de *Icerya purchasi* Maskell en Valdivia, Chile. *Rev. Chilena Ent.,* 16:25-32.

SCHANDERL, H., SOARES, A. O. and ALMEIDA, J. P. A, 1995: Identificação de Pragas de Citrinos em Pomares da Ilha de S. Miguel (Açores). Açoreana, 8(1): 89-93.

SOARES, A. O.; SCHANDERL, H. and ALMEIDA, J. P., 1992: Algumas pragas nos pomares de citrinos da ilha do Pico (Açores). *Relatórios e Comunicações do Departamento de Biologia, Pico/92*: 49-52.

SOARES, A. O., SCHANDERL, H. and ALMEIDA, J. P., 1993: Algumas Pragas de Citrinos da Ilha de S. Jorge (Açores). Rel. Com. do Dep. de Biol. S. Jorge e Topo/92, 21:21-26.

SOARES, A. O.; SCHANDERL, H.; ALMEIDA, J. P. A.; COSTA-COMELLES, J. C., and VERCHER, R., 1994: Alguns Insectos Fitófagos em Pomares de Citrinos da Ilha do Faial (Açores). Expedição Científica Faial/93, Rel. Com. do Dep. de Biol. 22: 45-48.

SOARES, A. O.; SCHANDERL, H.; ALMEIDA, J. P. A.; and BRUN, P., 1996: Insectos e ácaros fitófagos presentes em pomares de citrinos da ilha Terceira (Açores). Rel. Com. do Dep. de Biol. Terceira/94. 23: 27-31.

SOARES, A. O. C. M., 1995: Caracterização de uma comunidade de Homópteros *Coccoidea* em citrinos e dinâmica populacional das principais espécies. Provas de Aptidão Pedagógica e Capacidade Científica. Universidade dos Açores. Ponta Delgada. 144pp.

SOARES, J. A. C., 1980: A protecção dos citrinos. Ministério da Agricultura e Pescas. Direcção Regional de Agricultura do Algarve. 263 pp.

(Recepción: 21 diciembre 1998)
(Aceptación: 13 octubre 1999)