Australian Journal of Entomology (2003) **42**, 271–275

Biological and ecological aspects of Chinese wax scale, *Ceroplastes sinensis* Del Guercio (Hemiptera: Coccidae): a two-year study from Central Greece

George J Stathas,[1] Nickolas G Kavallieratos[2]†* and Panagiotis A Eliopoulos[1]

[1]*Technological Educational Institute of Kalamata, School of Agricultural Technology, Department of Crop Production, 24100, Antikalamos, Messina, Greece.*
[2]*Benaki Phytopathological Institute, Department of Entomology and Agricultural Zoology, Laboratory of Agricultural Entomology, 8 Stefanou Delta str., 14561, Kifissia, Attica, Greece.*

Abstract Biological and ecological aspects of the scale *Ceroplastes sinensis* are investigated on citrus in central Greece through regular samplings during 1999–2001 on *Citrus sinensis* (Sapindales: Rutaceae) in Attiki County. The scale was univoltine. Overwintering stages were the third-instar nymph and the adult female. From the end of May until the end of June the population comprised preovipositing females. Oviposition occurred from mid-June until mid-July and hatching took place during July. First- and second-instar nymphs were recorded from the end of July until the end of August, and from mid-August until the end of September, respectively. Third-instar nymphs appeared at the end of August and were present until the beginning of September. Some of the population of third-instar nymphs reached the adult stage during October and November, whilst the remainder completed development in the following April. Small numbers of male nymphs were recorded during October and November. The mean fecundity of adult females was 3260 ± 770 eggs per female. The most abundant natural enemy of *C. sinensis* was *Scutellista caerulea* (Fonscolombe) (Hymenoptera: Pteromalidae), whose eggs, larvae and pupae were found in up to 42% of the total live population of the scale. Two predators, *Chilocorus bipustulatus* (L.) and *Exochomus quadripustulatus* (L.) (Coleoptera: Coccinellidae), were also observed.

Key words *Ceroplastes sinensis*, *Chilocorus bipustulatus*, *Exochomus quadripustulatus*, fecundity, phenology, *Scutellista caerulea.*

INTRODUCTION

The soft scale insects *Saissetia oleae* (Olivier), *Coccus hesperidum* L., *Coccus pseudomagnoliarum* Kuwana, *Ceroplastes floridensis* Comstock, *Ceroplastes rusci* L. and *Ceroplastes sinensis* Del Guercio are considered to be the main coccid pests of citrus in Greece (Katsoyannos 1996). They cause damage directly by sucking sap and indirectly by releasing honeydew on leaves and fruit, on which sooty mould subsequently grows (Katsoyannos 1996). Previous studies on the genus *Ceroplastes* in Greece have been limited to infestations of *C. rusci* on fig trees (Argyriou & Santorini 1980). Chinese wax scale, *C. sinensis,* is a pest of commercial citrus of Neotropical origin (Qin *et al*. 1994, 1998). It is a cosmopolitan species observed in many regions, such as Europe (Italy, Greece, Spain, Portugal, France, Turkey), Asia (Black Sea and Caspian coasts of Iran), Africa (Canary Islands, Madeira), North America (California, North Carolina, Mexico, Virginia), South America (Ecuador, Argentina, Brazil, Chile, Uruguay), Australia (New South Wales, Norfolk Island), and New Zealand (Leonardi & Silvestri 1920; Pellizzari & Camporese 1994; Qin *et al*. 1994; Katsoyannos 1996). Freeborn (1931) reported that infestations of the scale occasionally caused limited damage in citrus orchards in Spain. Horticultural mineral oils are occasionally used to control infestations on the central coast of New South Wales, where the scale is univoltine (Beattie & Gellatley 1983; Beattie & Kaldor 1990; Beattie *et al*. 1991, 2002). Pteromalids and coccinellids are the most important natural enemies of the scale (Smith *et al*. 1997).

Although it is not regarded as a serious pest of citrus in Greece, *C. sinensis* sometimes causes significant damage and, under such circumstances, chemical treatment is often necessary for its control. Here we report the results of the first study of ecology and biology of the scale in Greece. Our aim was to study the phenology of *C. sinensis* on citrus in Central Greece and determine the impact of natural enemies.

MATERIALS AND METHODS

In 1999–2001, field studies were conducted in an untreated citrus orchard in central Greece (Oropos: 38°19′N, 23°48′E,

*Author to whom correspondence should be addressed (email: nick_kaval@hotmail.com).

†Present address: PO Box 50803, 14123 Lykovrissis, Greece.

altitude: 40 m) covering an area of 2 ha planted with orange [*Citrus sinensis* (Sapindales: Rutaceae) (cultivar Merlin)] trees (300 trees/ha) that were about 10-years old. Observations and samplings were undertaken every 15 d from spring to autumn (April–October) and monthly during the rest of the year. Fifteen randomly chosen shoots of 20 cm length were cut from 10 infested trees during each sampling. The shoots were examined under a stereoscope and the live and predated coccid were counted and their developmental stage determined. Monitoring of coccinellid predators was achieved by beating 12 randomly chosen branches of trees with a rubber-covered stick over a 1 m^2 cloth screen. The number of adults and larvae of predators dislodged was then recorded (Iperti & Burn 1969; Stathas 2001). Fecundity was estimated on 25 females of the scale in July 2000 by counting not only the eggs that had been laid under the female body, but also the oocytes that existed internally. Oocytes were counted by dissecting the scale body in water. A hygrothermograph, housed in a meteorological screen located in the interior of the orchard, was used to record daily temperatures and relative humidities.

RESULTS

Ceroplastes sinensis was univoltine (Fig. 1). Hatching of crawlers took place during the first 10 d of July, whilst first- and second-instar nymphs were present from the end of July (mid summer) until the end of September (early autumn), during both years of the survey. A few male nymphs were observed from mid-October until mid-November. Adults and third-instar female nymphs represented almost the total coccid population by mid-December (approximately 80% and 20%, respectively). The entire population consisted of adults by mid-May and oviposition occurred from mid-June until mid-July.

Infestation levels varied between 9.8 and 37.3 individuals per shoot, whilst the number of individuals killed by unknown causes varied between 1 and 7.7 nymphs per shoot (Fig. 2a). Infestation decreased gradually during the study (df = 34; $r^2 = 0.743$; $P < 0.001$; $y = -0.3815x + 14268$), whereas the number of scales killed by unknown causes (df = 34; $r^2 = 0.212$; $P = 0.0047$; $y = 0.0508x + 1928.9$) showed no clear upward or downward trend during the study (Fig. 2a).

Individuals of the scale (preovipositing and ovipositing females) containing eggs, larvae or pupae of the pteromalid *Scutellista caerulea*, reached 42.1% and 41% of the total live population of the scale in July 1999 and June 2000, respectively (Fig. 2a). Dead scales of *C. sinensis* attacked by *S. caerulea* (bearing the characteristic exit hole) were much more abundant than those predated by other natural enemies (Fig. 2b). The number of dead individuals parasitised by *S. caerulea* increased during the study (df = 34; $r^2 = 0.709$; $P < 0.001$; $y = 0.0196x - 695.31$), whereas the number of scales killed by predators (df = 34; $r^2 = 0.0205$; $P = 0.4102$; $y = 0.0021x - 70.183$) did not change significantly. During the beating of the branches, individuals (larvae and adults) of the coccinellid predators *Chilocorus bipustulatus* (L) and *Exochomus quadripustulatus* (L) were collected. The former species was more numerous than the latter one (Fig. 2c).

Fecundity of *C. sinensis* varied between 1440 and 4003 eggs per female (mean ± SD: 3260 ± 770).

DISCUSSION

Our results show that *C. sinensis* is univoltine in central Greece. This is the same as in other countries, such as Italy (Leonardi & Silvestri 1920; Pellizzari & Camporese 1994), Spain (Gómez & Ortega 1937), California and New Zealand (Lo *et al.* 1996). In Australia, the scale is univoltine on the central coast of New South Wales, whereas on the north coast of New South Wales and in coastal Queensland it may be bivoltine (Smith *et al.* 1997). From the small number of male nymphs recorded in autumn, and the many female nymphs developing to adults in May and June (Fig. 1), we assume *C. sinensis* is mainly parthenogenetic. Parthenogenetic reproduction of *C. sinensis* has also been observed in Italy (Pellizzari & Camporese 1994). In Australia, males of this scale reached only the 3% of the total population (Snowball 1970).

We attributed the presence of numerous adults of the scale, bearing an exit hole, to the action of *S. caerulea*, as no other parasitic species was found. The damaged nymphs (Fig. 2c) were due to the action of the predators *C. bipustulatus* and *E. quadripustulatus*. The gradual reduction of the infestation level of the trees by *C. sinensis* (Fig. 2a) we attribute mainly to *S. caerulea*; seen by the increase of the number of dead scales with an exit hole (Fig. 2b).

The population decline of *C. bipustulatus* during summer months (Fig. 2c) was presumably caused by parasitoids. Higher parasitisation percentages by the parasitoids *Homalotylus flaminius* Dalman (Encyrtidae) and *Tetrastichus coccinellae* Kurdjumov (Eulophidae) of larvae of *C. bipustulatus* during that period has previously been observed in Greece (Stathas 2001). We explain the reduction in numbers of the predator *E. quadripustulatus* by the summer diapause of this species in Greece (Katsoyannos 1976). *Scutellista caerulea* is, thus, the most important natural enemy of *C. sinensis* in Greece.

The average fecundity of *C. sinensis* (3260 eggs per female) is higher than that reported in Italy by Leonardi & Silvestri (1920) (mean: 2000 eggs, maximum: 3836 eggs). Lo (1995) claimed that maximum fecundity of *C. sinensis* in New Zealand reached 4304 eggs, whilst in Australia, the adult scale can lay up to 3844 eggs (Snowball 1970). We attribute this variation to the different host-plants and the different climatic conditions at the sampling sites. The growth and phenology of the scale may also be influenced by the nutrient contents of host plants (Beattie *et al.* 1990).

Citrus is a crop where most pests are controlled effectively by their natural enemies (Katsoyannos 1996) and chemical spraying is avoided in order to maintain a balance

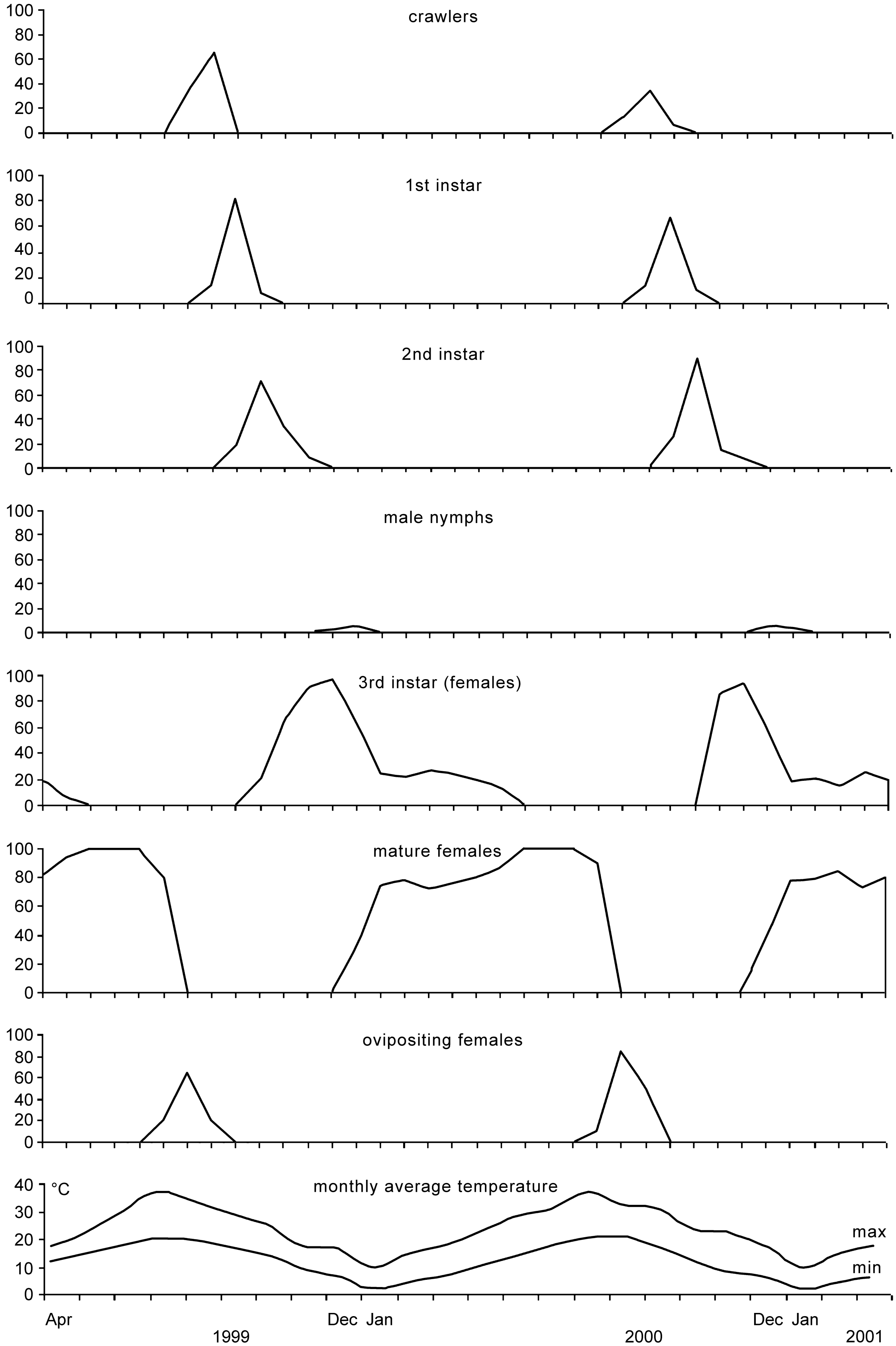

Fig. 1. Developmental stages of *Ceroplastes sinensis* on citrus and monthly average temperatures from April 1999 to March 2001 in central Greece.

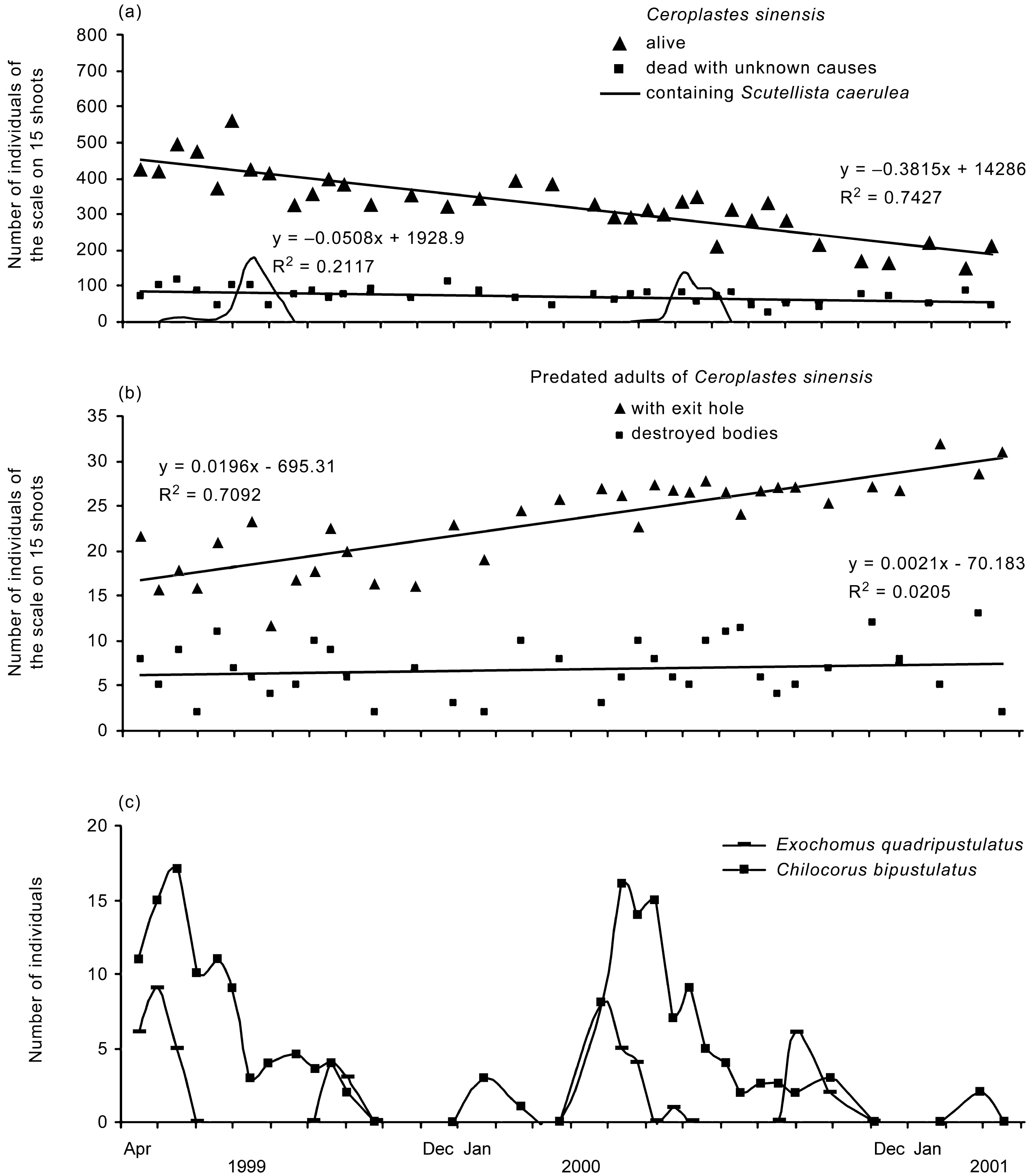

Fig. 2. Numbers of *Ceroplastes sinensis*, parasites and predators found on citrus in central Greece from April 1999 to March 2001: (**a**) alive, dead from unknown causes and alive containing immature stages of *Scutellista caerulea*; (**b**) killed by *Scutellista caerulea* (dead with exit holes) and by other predators (dead with a damaged body); (**c**) number of individuals (larvae and adults) of *Exochomus quadripustulatus* and *Chilocorus bipustulatus*.

between pests and biological-control agents. Our findings add to the development of such integrated management strategies for *C. sinensis*. We showed that *C. sinensis* can be controlled satisfactorily by its natural enemies in Greece. Furthermore, our study of the coccid's phenology showed that, in cases where the chemical control is unavoidable, it could be more effective if it is limited only to infested trees during July and August; this is when *C. sinensis* is in the early stages of its development, stages that are most sensitive to insecticides. In this case, altering factors such as nitrogen fertilisation may also be useful, as they influence the developmental time of the scale (Beattie *et al*. 1990).

REFERENCES

Argyriou LC & Santorini AP. 1980. On the phenology of *Ceroplastes rusci* L. (Homoptera: Coccidae) on fig-trees in Greece. *Mededelingen van de Faculteit Landbouwwetenschappen Rijksuniversiteit Gent* **45**, 593–600.

Beattie GAC, Clift AD, Allender WJ, Jiang L & Wang YA. 1991. Efficacies of low- to high-volume (960–10 700 litre ha^{-1}) citrus sprayers for applying petroleum spray oil to control Chinese wax scale. *Pesticide Science* **32**, 47–56.

Beattie GAC & Gellatley JG. 1983. *Citrus Scale Insects.* Agfact H2.AE.2. Department of Agriculture, Sydney, Australia.

Beattie GAC & Kaldor CJ. 1990. Comparison of high-volume oscillating boom and low-volume fan-assisted rotary atomiser sprayers for the control of Chinese wax scale, *Ceroplastes sinensis* del Guercio (Hemiptera: Coccidae), on Valencia orange, *Citrus sinensis* (L.) Osbeck. *General and Applied Entomology* **22**, 49–53.

Beattie GAC, Watson DM, Stevens ML, Rae DJ & Spooner-Hart RN. 2002. *Spray Oils Beyond 2000*. University of Western Sydney, Richmond, Australia.

Beattie GAC, Weir RG, Clift AD & Jiang L. 1990. Effect of nutrients on the growth and phenology of *Gascardia destructor* (Newstead) and *Ceroplastes sinensis* del Guercio (Hemiptera: Coccidae) infesting citrus. *Journal of the Australian Entomological Society* **29**, 199–203.

Freeborn SB. 1931. Citrus scale distribution in the Mediterranean basin. *Journal of Economic Entomology* **24**, 1025–1031.

Gómez J & Ortega M. 1937. *Coccidos de España*. Instituto de Investigationes Agronomicas, Estation de Fitopatología Agricola de Almería, Madrid, Spain.

Iperti G & Burn J. 1969. Rôle d'une quarantaine pour la multiplication des Coccinellidae coccidiphages destinés à combattre la cochenille du palmier-dattier (*Parlatoria blanchardi* Targioni) en Adar Mauritanien. *Entomophaga* **14**, 149–157.

Katsoyannos P. 1976. Etude d'un predateur. *Exochomus Quadripustulatus* L. (Coleoptera: Coccinellidae) en vue d'une eventuelle utilisation contre: *Saissetia oleae* Olivier (Homoptera: Coccoidea – Coccidae) dans les oliveraies de la Greece. PhD Thesis, Université des Sciences et Techniques du Languedoc, Montpellier, France.

Katsoyannos P. 1996. *Integrated Insect Pest Management for Citrus in Northern Mediterranean Countries.* Benaki Phytopathological Institute, Athens, Greece.

Leonardi G & Silvestri F. 1920. *Monografia Delle Cocciniglie Italiane*. Ernesto della Torre, Portici, Italy.

Lo PL. 1995. Size and fecundity of soft wax scale (*Ceroplastes destructor* Newstead) and Chinese wax scale (*Ceroplastes sinensis* Del Guercio) (Hemiptera: Coccidae) on citrus. *New Zealand Entomologist* **18**, 63–69.

Lo PL, Blank RH & Penman DR. 1996. Phenology and relative abundance of *Ceroplastes destructor* Newstead and *Ceroplastes sinensis* Del Guercio (Hemiptera: Coccidae) on citrus in Northland, New Zealand. *New Zealand Journal of Crop and Horticultural Science* **24**, 315–312.

Pellizzari G & Camporese P. 1994. The *Ceroplastes species* Del Guercio (Homoptera: Coccoidea) of the Mediterranean basin with emphasis on *Ceroplastes japonicus* Green. *Annales de la Société Entomologique de France (N.S.)* **30**, 175–192.

Qin T-K, Gullan PJ & Beattie GAC. 1998. Biogeography of the wax scales (Insecta: Hemiptera: Coccidae: Ceroplastinae). *Journal of Biogeography* **25**, 37–45.

Qin TK, Gullan PJ & Beattie GAC *et al.* 1994. The current distribution and geographical origin of the scale insect pest *Ceroplastes sinensis* Del Guercio (Hemiptera: Coccidae). *Bulletin of Entomological Research* **84**, 541–549.

Smith D, Beattie GAC & Broadley R. 1997. *Citrus Pests and Their Natural Enemies; Integrated Pest Management in Australia.* Horticultural Research and Development Corporation and Queensland Department of Primary Industries, Brisbane, Australia.

Snowball GJ. 1970. *Ceroplastes sinensis* Del Guercio (Homoptera: Coccidae), a wax scale new to Australia. *Journal of Australian Entomological Society* **9**, 57–64.

Stathas GJ. 2001. Ecological data on predators of *Parlatoria pergandii* Comstock on sour orange trees in southern Greece. *Phytoparasitica* **29**, 207–214.

Accepted for publication 13 February 2003.