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# ENTOMOLOGICA

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## SPECIAL ISSUE:
## PROCEEDINGS OF THE ISSIS VIII
## INTERNATIONAL SYMPOSIUM ON SCALE INSECT STUDIES

## Preface from the Editor of Entomologica

International Symposia on Scale Insects Studies (ISSIS) have been held every four years, covering almost all aspects of the taxonomy, biology and control of this well-known and economically important group of insect pests. This superfamily within the Hemiptera, Sternorrhyncha, has evolved numerous, often convergently derived, adaptations to a parasitic way of life which affect both their biology (and therefore their control) and their morphology (and therefore their taxonomy). Entomologica, therefore, was flattered by the request of the organiser of the VIIIth ISSIS, Dr. Chris Hodgson, to publish the Proceedings as a volume of Entomologica, which here appear as Volume XXXIII. Respecting the tradition of ISSIS, the scientific committee of the Symposium replaces that of Entomologica, while the editorial committee of the review remains unchanged. We very much hope that you will find this volume of interest.

Prof. Giorgio Nuzzaci
Editor

**International Advisory Committee for ISSIS VIII:**

Chris Hodgson (UK);
Dug. Miller (USA);
Yair Ben-Dov (Israel);
John Charles (New Zealand);
Hu Xingping (China);
Lerzan Erkilic (Turkey);
Jon Martin (UK);
Penny Gullan (Australia);
Evelyna Danzig (Russia).

**Referees for this volume of the Proceedings:**

Dr. Chris Hodgson (Wye College);
Dr. Dug Miller (USDA);
Dr. Doug. Williams (BMNH);
Dr. F. Porcelli (DiBCA);
Dr. Penny Gullan, (UCLA);
Dr. Gillian Watson (BMNH).

Dipartimento di Biologia e Chimica Agro-Forestale ed Ambientale, Sez. Entomologia e Zoologia Via Amendola 165/A - 70126 BARI Tel. +39/080/5442874 - Fax +39/080/5442876 - E-mail: entomol@agr.uniba.it

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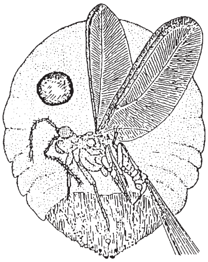
# Proceedings of the
# VIII International Symposium on Scale Insect Studies
# **ISSIS-VIII**



held at Wye (UK)
August 31st - September 6th 1998

Editors of Proceedings
Dr. Chris Hodgson
Dr. Francesco Porcelli

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## REPORT ON ISSIS-VIII and RELATED ACTIVITIES

The Eighth International Symposium on Scale Insect Studies (ISSIS-VIII) was held at Wye College, the University of London, Wye, Ashford, Kent, United Kingdom, 31 August-6 September 1998. About 70 delegates attended ISSIS-VIII, although numbers varied between sessions.

### Business matters

The Plenary Session of ISSIS-VIII was opened on 1 September with a speech of welcome from Prof. John Prescott, Principal of Wye College. The introductory business meeting followed. In his opening remarks, Chris Hodgson, Co-ordinator of the Organising Committee of ISSIS-VIII, welcomed the participants and led a silent tribute to fellow coccidologists who had passed away since the previous ISSIS meeting: Raymond Joseph Mamet (France/Mauritius), David Rosen (Israel), Stergios S. Paloukis (Greece), François Cohic (France), Samia Nada (Egypt), A.P. Kapur (India), Richard F. Wilkey (USA), Z. Duzgunes (Turkey), Bain Lay Young (China), Irena Bielenin (Poland) and Galina Matesova (Kazakhstan).

Committee arrangements for the session were announced. The Recording Committee proposed and elected consisted of: Ferenc Kozár, Jan Giliomee and Gillian Watson (Chair); the Resolution Committee consisted of Dug Miller (Chair and sole member); and the Site Selection Committee consisted of Yair Ben-Dov, Penny Gullan, Agatino Russo and Mike Williams (Chair).

As is customary, greeting cards were signed by participants at ISSIS-VIII during the meeting, to be sent to absent colleagues. The chosen cards showed a picture of Wye College and were signed by about 55 participants.

Business matters were briefly discussed in the evening of 2 September, when it was suggested that ISSIS meetings were too infrequent. There was a majority vote for meetings to be held every three years in future, although variation in timing may sometimes be necessary to avoid clashing with the International Congress of Entomology, which occurs every four years. Mike Williams, Chair of the Site Selection Committee, proposed Giuseppina Pellizzari at the University of Padua as organiser and location for ISSIS IX in 2001 and this was agreed by Giuseppina. Against the eventuality that this might not be possible, alternative organisers and location were suggested as Ismail Karaca and Lerzan Erkiliç at the University of Cukurova, Adana (or possibly Capadokia), Turkey and this was agreed by Ismail and Lerzan.

On the morning of 5 September, Chris Hodgson chaired a discussion on the appointment of an advisory committee for the organiser of ISSIS IX. It was agreed that he would be Chair and sole member of the committee at present, and that the organiser of ISSIS IX should appoint the rest of the committee themselves. A list of the committee members appointed will be published in The Scale in March 1999. It was suggested that information about ISSIS IX could be published either in The Scale or as a news page on SCALENET.

The final business session was held on the evening of 5 September. Chris Hodgson announced that the Proceedings of ISSIS-VIII will be issued as a special volume of Entomologica, Bari, Italy. Papers will be edited initially by Chris Hodgson before being passed to Francesco Porcelli (Editor in Chief) and his Editorial Board for peer review and publication.

Dug Miller, Chair of the Resolutions Committee, read out two resolutions that were adopted. In the first, Chris Hodgson (Symposium Organiser), Mrs. Laura Sessions (Secretary), Mike Copland (Department administration), Miss Sue Stickels and Mrs. Stickels (Registration), Professor John Prescott (College Principal), Trudy Watt (Department Head) and members of the House Department of Wye College were thanked for their efforts and contributions in organising such an excellent symposium and associated activities, accommodation and meals.

In the second resolution, the present quasi-dormant status of endosymbiotic studies in scale insects was recognised, in strong contrast with the research boom occurring on endosymbionts of aphids. With a reminder that the study of endosymbiosis in animals started with research on scale insects, and that the recent boom in aphidology is the effect of close co-operation between students of aphid systematics/phylogeny and biomolecular microbiologists, it was resolved that similar co-operation is strongly needed in coccidology and should lead to stimulating results for both theoretical and applied science.

### Presentations and discussions

The paper presentations took place in 10 sessions in the Carr Lecture Theatre. Each session consisted of 3-5 papers, each paper lasting 10-15 minutes and followed by a short period for questions and answers. A total of 46 papers and 16 posters were presented over the duration of the meeting and are here published in the Proceedings.

The quality of presentations was generally very good, as were the illustrations provided. Several papers of high standard were presented by students; the Division of Botany and Zoology at the Australian National University, Canberra, Australia appears to be a particular centre of excellence.

On 1 September, there were sessions on: Systematics, Phylogeny and Morphology (two sessions chaired by Penny Gullan and John Charles respectively); Zoogeography, Faunistics and Insect-Host Relationships (chaired by Ferenc Kozár); and Biology, Monitoring and Environmental Impact (chaired by Abdel R.H. Amin).

On 2 September, there were sessions on Biology, Monitoring and Environmental Impact (chaired by Ismail Karaca), and Biological and Chemical Control (chaired by Yair Ben-Dov). Michael Kostarab gave a presentation on the Future of Coccidology and expressed concern over the decrease on the number of new students. During the subsequent discussion, Ermenegildo Tremblay appealed for more study of the co-evolution of scale insects and their symbionts. He mentioned the recent expansion of similar studies in aphids and the useful information this was yielding, and suggested a similar treatment of coccoids might be even more fruitful.

On 3 September, there was a session on Phenology, Population Dynamics and Natural Enemies (chaired by Salvatore Marotta), and a presentation by Yair Ben-Dov and Dug Miller on ScaleNet, followed by a workshop session in the Kempe Centre Computer Laboratory. This drew attention to the fact that SCALENET now covers five scale insect families (Conchaspididae, Coccidae, Eriococcidae, Ortheziidae and Pseudococcidae), and provides access to 11,000 annotated references. Three more families (Kermesidae, Cerococcidae and Dactylopiidae) will soon be added, and ultimately all scale insect families will be covered. Everyone was left in no doubt that this important resource will be an invaluable aid to workers on scale insects in the future.

On 4 September, there were two sessions on Systematics, Phylogeny and Morphology (chaired by Bozena Lagowska and Mike Williams respectively). Doug Williams paid tribute to some nonagenarians who have worked on scale insects, and wished them well on behalf of ISSIS-VIII. John B. Steinweden's (1946) paper on *Pulvinaria* is still relevant today; Mohammad Kaussari wrote important contributions on the scale insect fauna of Iran and on Diaspididae; Louise Russell's (1941) publication on *Asterolecanium* is still a key work; Emily Morrison contributed to supplements to the Bibliography and the work on generic names which we all use today; and Lucien Goux, who published 50 detailed papers on scale insects (mainly of France) in the period 1931-1953 and 10 more between 1988-1995, still studies scale insect at his home in Marseilles.

During the evening of 4 September, Penny Gullan and Chris Hodgson led a seminar and discussion session on Cladistics and Phylogenetics, based on preliminary results of cladistical analysis of scale insect families. It was agreed that these studies are very interesting and extremely important. However, it was clear that such studies will require additional data from the analysis of many more genes and of the morphological characters of immature stages, as well as of adult females and males, before major systematic and nomenclatural changes can be adopted.

On 5 September, there was only one session, on Systematics, Phylogeny and Morphology (chaired by Francesco Porcelli). It ended with a most interesting slide show by Rosa Henderson on soft scales native to New Zealand.

### Accessory activities

After dinner at Wye College on the evening of 1 September, a welcoming talk was given by Chris Hodgson, who read out a letter of greeting from Jan Koteja, who was unable to attend. Most delegates were accommodated at Withersdane Hall, with delightful grounds in a rural setting, a short walk from Wye College. Morning and evening meals were provided at Withersdane while excellent buffet lunches were provided at Wye College refectory.

On the evening of 3 September, a party was held to honour Michael Kosztarab on his retirement, and for his contribution to scale insect studies. Paris Lambdin gave an amusing but highly appreciative account of Michael's influence on his students' development, and presented Michael with a whisky decanter engraved with the ISSIS logo. Michael responded with a short speech of thanks.

Two half-day outings took place during the symposium: on the afternoon of the 2nd September, historic Leeds Castle near Maidstone was visited, and on the afternoon of 4 September a visit was made to the beautiful gardens of Goodnestone Park, near Canterbury. These outings were primarily for sight seeing and conversation, but also allowed visitors to Britain to see some historic Kent buildings, gardens and countryside. In such a temperate country scale insects are not common, and encounters with live scale insects were limited to the collection of some ortheziids from a bog near Ashford by Dug Miller, and observation of some tropical scale insect species in the glasshouses at Wye College on the morning of 6 September with Mike Copland.

The meeting closed with a sumptuous banquet at Withersdane on the evening of 6 September, providing a congenial end to a meeting notable for its interesting coverage, rural setting and relaxed atmosphere, with time for opportunity for scale insect systematists and scientists working on related disciplines, such as scale insect pest control and scale insect products, to meet and interact.

Reported by the Recording Committee
Gillian W. Watson (Chair)
Jan H. Giliomee, Ferenc Kozár.

# AWARD TO MICHAEL KOSZTARAB FOR HIS CONTRIBUTIONS TO COCCIDOLOGY

### Presented by Paris Lambdin on 7 September 1998

It is a great honour to be able to speak to you today regarding some of the highlights of this year's recipient of the Achievement Award, Michael Kosztarab. Michael is an excellent choice for this year's award, not only for his contributions to coccidology over the years, but to all of entomology. Those of you who have read his recent book "Translyvanian Roots" are aware of many of the extraordinary adventures Michael has experienced in his life.

He began his work on scale insects in 1951 at the Hungarian University of Sciences in the Department of Entomology in Budapest, Hungary. But when their homeland was overrun by Soviet troops in 1956, Michael, his wife Matilda, and their daughter, Eva, made their way to the United States. He entered graduate school at Ohio State University where he studied under Dwight DeLong, and became associated with some of the most noted entomologists of the time such as Gordon Ferris, Harold Morrison and Louise Russell. In 1962, he accepted an assistant professorship at Virginia Tech and moved his family to Blacksburg. What he accomplished over the next 30 years is almost beyond comprehension.

While having a major teaching responsibility for most of his career, teaching 8 different courses, he served on 72 graduate advisory committees, directed 6 MSc and 10 Ph.D research programmes, and assisted directly in the professional development of numerous visiting scientists from various parts of the world. He has published 4 books and over 168 publications on a myriad of entomological subjects including, of course, on scale insects. As a result of his expertise in the field, Virginia Tech became a world centre for scale insect research.

He is a member of 17 scientific societies, and some of his numerous awards over the years include: winner of 5 Awards for outstanding teaching, including the W.E. Wine Award; elected Fellow in the Virginia Academy of Science, and Fellow of the Royal Entomological Society of London; designated Counsellor for the Botanical Garden in Costa Rica; selected as an Honorary Member of the Entomological Society of Hungary and the Entomological Society of America; honorary President of the Sixth International Symposium on Scale Insect Studies. He also served as the first President of the newly established Virginia Natural History Society (1993-'94). Although semi-retired since 1992, he has completed two books during this period in addition to trying to finish several of the unfinished projects he became interested in over his career.

He is responsible for the establishment of *The Insects of Virginia* series and *The Studies on the Morphology and Systematics of Scale Insects* series, with 32 monographs published. His scientific contributions and interests have not been limited to scale insects nor to entomology alone. Michael Kosztarab has long been concerned about the destruction of our natural environment and its impact on the diversity of organisms. In 1984, his editorial proposing a national effort toward the initiation of a National Biological Survey was published in *Science* and was a stimulus for the movement to catalogue the insect fauna of North America. Since that time, this initiative has been endorsed by 39 scientific organisations, and the concept is presently being considered in a Bill before the U.S. Congress (HR 585). Michael worked intensively for 5 years as Chairman of the Interdisciplinary Planning Committee for the National Biological Survey (NABIS) to ensure that the project would move forward.

In 1988, he initiated two projects that further expressed his environmental concerns. One was a study of the effect of acid rain on the soil invertebrate fauna in southwest Virginia. Another provided a computerised inventory of the neglected invertebrate fauna of Virginia. Because of his reputation in this area, he has received both national and international invitations to speak on the biodiversity crisis, and on the NABIS project. He almost single-handedly promoted the Tiger Swallowtail Butterfly as the Virginia State Insect and has somehow found time to continuously curate the largest and oldest insect collection in Virginia, consisting of over 1 million specimens.

But, in spite of all his awards and his scientific accomplishments, it is in another realm that those of us who were fortunate enough to have been his students remember and cherish. It would come as no surprise to anyone to characterise Michael as “one of a kind”. We were indeed fortunate in that we came away from our studies with more than information, more than expertise in a discipline - we acquired the life-long interest of a dear mentor and friend. Even after two decades, we still seek out Michael when advice is needed. The scale insect crowd of the late 70s had a slightly different demeanour from those who had come before and, at first, Michael was at a loss as to how to deal with us. We were the type of crew who would work in the lab until late at night, then go turkey hunting the next morning at daylight. Michael could never understand why we would waste our time engaged in such activity.

Michael epitomizes those values that are the cornerstone of success and happiness. Such common but noble words as “work ethics”, “dedication”, “honour”, “pride”, “loyalty”, “preparation” and “persistence” exemplify Michael’s life. All of us who had the privilege of studying under him were fortunate to have had such a noble role model. Michael’s influence exceeds the bounds of the academic world where he, perhaps, will be most treasured by each who came in contact with him, because he always provided a lavish amount of “his Hungarian hospitality”. Michael was a remarkable mentor, a surrogate father and a very special friend to all of us.

Michael, you will always be in our hearts and minds, and we wish you great happiness and success in your future. Now at this time, it is my great pleasure and honour to present you with this year’s Achievement Award to recognise your many contributions to coccidology and education.

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KOSZTARAB, M.
*Department of Entomology, Virginia Polytechnic Institute and State University*
*Blacksburg, Virginia 24061, USA*

# STATUS AND FUTURE OF HUMAN RESOURCES IN COCCIDOLOGY.

## ABSTRACT

STATUS AND FUTURE OF HUMAN RESOURCES IN COCCIDOLOGY.

This paper reviews responses to a survey on the current status of researchers active in coccidology, with an emphasis on systematics but including work on morphology, biology, ecology, biological and chemical control of scale insects and on preparation of data bases. The 39 responses provide a short assessment for 38 countries and 15 U.S. States, with the activities and/or whereabouts of about 243 researchers. Thirteen of the 32 active researchers (41%) will reach retirement age within five years; however, the average time to retirement for this group was 11.7 years. There has been a decline in the number of women in graduate training, while, from the 17 graduate students being trained in coccidology, only six are doing research in systematics.

Key words: funds, training, public awareness, research areas.

## INTRODUCTION

Ferris (1957) prepared a history of coccidology, which reviewed also the types of research that coccidologists were involved in at that time. The recent loss of many coccidologists due to death, retirement or to changes in the emphasis in entomology and systematics suggests that this might be a good time to assess the present status and future prospects for research in this field. A two-page questionnaire was, therefore, mailed to 54 colleagues. This received a 73% response and the replies described the activities and/or whereabouts of about 243 persons, and these are discussed below by continents and alphabetically by countries. The addresses for most of the active workers listed below are found in The Scale, volume XXI (March 1997).

## EUROPE

**Armenia** - L. Mkrtchian, R.N. Sarkissov and A. Zakharian are currently still active, but M.A. Ter-Grigorian has retired. **Austria** - C. Stumpf is a Ph.D. candidate with P.L. Lambdin at the University of Tennessee, working on the asterolecaniids of the Neotropical Region; this suggests a possible reactivation of scale research in Austria. **England** - J. Cox unfortunately resigned from the

British Museum after a short but distinguished career in coccidology. D.J. Williams, although retired some years ago, continues writing major monographs (Williams & Granara de Willink, 1992; Williams & Watson, 1988a, 1988b, 1990). At Wye College, University of London, where C.J. Hodgson (Hodgson, 1994; Ben-Dov & Hodgson, 1997a, 1997b) and M.W. Copland are active, the former is currently revising the soft scales of New Zealand with R. Henderson and of Australia with P. Gullan; his Ph.D. student H.A. Vahedi from Iran, is working on *Porphyrophora* in western Asia; Copland has had several Ph.D. candidates working on the biocontrol of scales; M. Heidari is also at Wye doing graduate research on mealybugs and their predators. C. Mallumphy works on some of the quarantined pest species at the Ministry of Agriculture; G.W. Watson (Williams & Watson, 1988a, 1988b, 1990) maintains an interest in scale systematics, based at the Natural History Museum. J. Alford, M. Cronin and D. Ponsonby at Canterbury Christ Church College, studied the environmental factors affecting population size of *Pulvinaria regalis*. **France** - M. Canard retired five years ago and is no longer actively working on Coccidae, but I. Foldi, P. Kreiter, D. Matile-Ferrero, A. Panis, M.J. Perrot-Minnot, C. Pinet and C. Richard are active. D. Matile-Ferrero and Y. Ben-Dov are collaborating on a revision of the mealybugs in the Mediterranean Region, while I. Foldi is working on margarodid systematics. L. Goux continues publishing while in his nineties, but R. Mamet, after making significant contributions on the coccoids of Mauritus and the surrounding area, died in 1997. **Georgia -** G.O. Japoshvili works on population dynamics of scales, while V.A. Yasnosh and E.S. Tabatadze are working on the biology and natural enemies of scale insects. Z.K. Hadzibejli died on 2nd Feb. 1999. **Germany** - G. Köhler in Leipzig and H. Schmutterer in Giessen are still active, the latter working on a book on the scale insects of Germany although he retired five years ago; his Ph.D. student, C. Hippe, is completing his research in Switzerland in 1998. H.P. Heckroth, B. Fiala and U. Maschwitz work on scale insect-ant-plant systems in S.E. Asia. **Greece** - S.S. Paloukis has died and L.C. Argyriou has retired; only P. Katsoyannos continues to work on economically important scale insects. **Hungary** - F. Kozár (Kosztarab & Kozár, 1988) is very active; G. Ördögh retired last year but he continues to write on economic pests. G. Vinis took a job in another field and so she is no longer working on coccoids. **Italy** - The largest number of active European coccidologists are working here: D. Battaglia, G. Viggiani and others specialize on chalcid wasp parasites, while G. Tremblay and R. Ponzi are working on scale insect symbionts. At least nine others are active: A.P. Garonna, S. Longo, S. Marotta, G. Mazzeo, S. Nucifora, G. Pellizzari, F.

Porcelli, A. Russo and A. Tranfaglia; in addition, there are at least five graduate students, one working on systematics (P. Fontana), three on coccoid biology and one on biological control. A. Russo, S. Longo and G. Mazzeo are working on the scale insect fauna of Sicily, IPM on *Citrus* and on monitoring models for *Planococcus citri*. V. Lupo, in his nineties, is in retirement. **The Netherlands** - M.G.M. Janzen is active in scale research. **Poland** - A. Dziedzicka, H. Komosinska and B. Zak-Ogaza have retired. J. Koteja, B. Lagowska, E. Podsiadlo and T. Szkleviewicz are all active. I. Bielenin has passed away. **Portugal** - I.M. Fernandes has retired, but José C. Franco is currently active in faunistics and in studying pest scales. E.M.B. Silva and A. Mexia are working on the histology of mealybugs. **Russia** - G.M. Konstantinova (Moscow) has retired but E. Danzig (Danzig, 1993) in St. Petersburg and E. Kozarzhevskaya in Moscow are currently active. Danzig will be publishing a monograph on the mealybugs of Russia in parts. Both V. Trjapitzin and E.S. Sugonyaev, scale parasite specialists, are currently active in St. Petersburg. **Spain** - A. Blay has expressed an interest in Diaspididae; G. Perez-Guerra (Perez-Guerra & Kosztarab, 1992) moved to Germany to work on forest insects. **Switzerland** - C. Hippe is active on scale research. **Ukraine** - E.M. Tereznikova has retired. **Other Countries** - apparently, there are no active scale insect researchers in Albania, Belarus, Belgium, Bosnia, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, Ireland, Latvia, Macedonia, Moldavia, Norway, Romania, Slovakia, Slovenia, Sweden, Ukraine or Yugoslavia (Serbia).

## MIDDLE EAST

**Iran** - M. Kaussari, in his nineties, is retired but Miss M. Moghaddam is now employed to work on scale insects in Tehran. H.A. Vahedi is working on the *Porphyrophora* of Iran for a Ph.D. at Wye College. **Israel** - Y. Ben-Dov, D. Blumberg, E. Dunkelblum, Z. Mendel, M. Wysoki, and co-workers (students and extension officers) work at the Department of Entomology, Volcani Center, on scale insect population dynamics, chemical ecology, IPM, host-parasite relationships and taxonomy. Y. Ben-Dov is an active systematist (Ben-Dov, 1993, 1994; Ben-Dov & Hodgson, 1997a, 1997b), engaged mainly in the development of SCALENET (a computerized database of the scale insects of the world - along with D. Miller, USDA - see Miller *et al.*, this volume) and on a revision of the Mediterranean mealybugs. Z. Mendel and D. Blumberg are active in classical biocontrol and IPM of scale pests. S. Gross, Ministry of Agriculture, Tel Aviv, works on citrus mealybug control. E.

Dunkelblum and Z. Mendel are active in the identification, field bioassay and application of scale insect pheromones. U. Gerson, Faculty of Agriculture in Rehovot, has worked mainly on mites recently. We recently lost a great scientist in David Rosen (Rosen, 1990a, 1990b), specialist on scale parasites. **Turkey** - although P. Önder, O.Z. Soylu and M.S. Tuncyürek have retired, at least ten more remain active: S. Cobanoglu, T. Colkesen, L.B. Erkiliç, F. Erler, I. Karaca, Y. Karsavuran, B. Kaydan, S. Özgökçe, C. Öncüer, D. Senal, C. Sengonca, S. Toros, N. Uygun, S. Ülgentürk, B. Yasar and Z. Yoldas. These colleagues work mainly in biological control and the IPM of scale insects. Z. Düzgünes died in December 1991. **Other Countries** - apparently, there is no ongoing scale research in Jordan, Iraq, Lebanon, Saudi Arabia or Syria.

## AFRICA

Besides the activities on cassava mealybug control, it appears that there is not much scale insect research (especially systematics) anywhere besides the following countries: **Egypt** - the following are active researchers: Ain Shams University, Faculty of Agriculture, Department of Plant Protection, Cairo: A.A. Amam, A.H. Amin, M.A. Risk and H.E.A. Sakr. Ministry of Agriculture, Plant Protection Institute, Dokki, Cairo: S. Abd-Rabou, M.M. Abo-Setta, S. Afifi, M.M. Asfour, S.M. El-emary, S.A. El-wan, S.M. Fahyem, M.W. Ghabbour, A.A. Gomaa (Head of Dept.), A. Hanafi, E. Helmy, N. Hussein, Z.K. Mohammad, M.H. Tawfik (1999-Head) and A.S. Youssef. Also A.I. Ezz, although retired, is still active. Unfortunately Samia M.A Nada died in 1997. National Research Center, Dokki, Cairo: R.M. Salah and H.S. Salama. In addition, F.A. Mahmond, M.K. Hamdy and A.G. Hegazi are working on the antimicrobial activities of scale secretions. Alexandria University, Faculty of Agriculture, Department of Plant Protection: M.F. El-Minshawy and S. El-Khair. Unfortunately, Professor Y.M. Ezzat passed away a few years ago. **Ethiopia -** W. Wakgari is currently completing graduate work on coccoids with J.H. Giliomee in South Africa. **Republic of South Africa** - I.M. Millar, Plant Protection Research Institute, Pretoria, and J.H. Giliomee, University of Stellenbosch, are both active in systematic research; Giliomee is due to retire in three years but has a Ph.D. candidate, W. Wakgari from Ethiopia, who is working on the biology and ecology of *Ceroplastes destructor*. Giliomee has already trained H.J.M. Loubser (male Dactylopiidae) and C.A. de Klerk (Margarodidae), and has supervised the Ph.D. studies of J. Schoonees and M.B. Georgala, who both worked on *Aonidiella aurantii*, but both have died. T. Brink worked on the chemical and biological control of scales, and E.C.G. Bedford works on IPM of citrus pests in Nelspruit.

## ASIA

**China** - three coccidologists are no longer working: Professor B.L. Young (also known as Bain-Lay or Yan Ping-Lan) has died, Z.Q. Wang is very ill and I.O. Zhou has retired. Dr. F.T. Tang (Tang Fangde, 1991, 1992; Tang Fangde & Hao, 1995) is due to retire next year, but Dr. San-an Wu is active. I have had no word from T.C. Wang in Beijing, who is apparently working in administration at present. **India** - K. Bohidar works on the morphology of male coccoids; P.R. Kumar and B.K.R. Gopal are still interested in mealybug ecology and control; S.M. Jalaluddin has expressed an interest in the Diaspididae. Most present researchers are working on lac insects, e.g., S.C. Agrawal. R.K. Varshney retired in 1997 from his extensive faunistic studies at the Indian Zoological Survey and has not been replaced. S.M. Ali and S.A. Shafee died and I have no information on R.K. Avasthi. **Japan** - S. Takagi retired two years ago but continues working on the systematics of the Diaspididae and Beesoniidae. K. Mori, the Science University, Tokyo, works on scale pheromones. I have no records on the present activities of S. Kawai and the biochemist Y. Tamaki although the former is probably working in tropical agriculture. **Kazakhstan -** R. Jashenko (= Yashchenko) is working on Margarodidae. G.I. Matesova has died. **Kyrgyzstan -** N. Abdrashitova is working on scale insects of the local walnut forests. **Pakistan** - A. Latif is maintaining an interest in mealybugs and margarodids, while W.A. Gillani has just graduated from Wye College where he studied the biocontrol of mealybugs. **Philippines** - I.L.Lit and his wife, M. Caasi-Lit, are working full-time on scale insects. **Sri Lanka** - Since E.E. Green's extensive work (1886-1938) little has been done here. Kosztarab did some collecting in 1979 but, due to lack of funds, this is still waiting to be processed at the Smithsonian Institution. **Taiwan -** J-S. Hwang has expressed an interest in Kerriidae and mealybugs. Unfortunately, no information is available on the recent activities of C.C.C. Tao and C.Y. Wong.

## AUSTRALIA AND NEW ZEALAND

**Australia** - H.M. Brookes has retired and is able to do only limited work. D.W. Cameron works on the chemistry of pigmentation at the University of Melbourne. Most of the scale insect activities are concentrated in P.J. Gullan's laboratory in Canberra at present. She has already provided graduate training to a number of past or currently active researchers, including S. Bhatti and T.K. Qin. She currently has a Ph.D. candidate, L. Cook, working on Eriococcidae, and a 4th-year honours student, H.E. Trueman, working on the

Margarodidae. She is also the external adviser for I.L. Lit's Ph.D. research on the Kerriidae at the University of Philippines. Besides systematics, her students are also doing molecular studies. J.F. Donaldson, at Brisbane, is due to retire within a few years. T.K. Qin is currently working for the Australian Quarantine and Inspection Service, Canberra. **New Zealand** - Coccidology lost a very able researcher in C.F. Butcher-Morales (Morales, 1991). R.C. Henderson works for Landcare Research, and now curates the New Zealand coccoid collection and is also working with C.J. Hodgson on a revision of the Coccidae of New Zealand; M-C. Lariviere continues to work on Hemiptera systematics. Within the Horticulture and Food Research Institute of New Zealand (HortResearch), R.H. Blank, J.G. Charles, K.J. Froud, A.R. Tomkins, C. Thompson, P. Lo, G.F. McLaren and C.H. Wearing are working on various aspects of the biology, ecology and control of coccid, diaspidid and pseudococcid pests.

## CENTRAL AND SOUTH AMERICA

Little active research on scale insect systematics is currently being conducted in this vast continent: **Argentina** - M.C. Granara de Willink (Williams & Granara de Willink, 1992) is actively working in scale insect systematics (Williams & Granara de Willink, 1992; Granara de Willink, 1999) and has a Ph.D. candidate in training. Both L.E. Claps and P. Gonzalez at Tucuman are active on armoured scale biology and systematics. M.E. Haro Barba, also in Tucuman, is interested in dactylopiid biology and systematics. **Chile** - R.H. González worked in scale insect research but I have no news from him on his present activities. R. Munoz has a group of people working with her on scale insect identification. **Mexico** - After the untimely death of Raul McGregor, there is little work on scale insect systematics here, except for a fauna list by D.R. Miller of USA (Miller, 1996). S.N. Myartseva has recently moved to this country.

## NORTH AMERICA

**Canada** - R. Foottit, an aphidologist, is in charge of coccoid work at present. G.P. Gibson is working with D.R. Miller and Y. Ben-Dov on the SCALENET, a systematic information system on scale insects (see Miller *et al.*, this volume). **United States** - has the largest concentration of active coccidologists but, unfortunately, without much replacement training. J.W. Beardsley, J.A. Davidson and M. Kosztarab have recently retired but are remaining active with research activities. Other active workers are: **Alabama** -

M.L. Williams has trained a number of students in Coccidae and continues to publish, usually in co-authorship with them; he currently has a Ph.D. candidate, D.T. Kondo, from Colombia, who is working on the immature stages of the Myzolecaniinae. Williams is also interested in the scale insects of Guatemala and Honduras and works with E. Danzig on a joint project on Mexican coccids. **California** - R.J. Gill, as well as working on the whitefly and scale problems and identifications for this large state, has produced three identification manuals (Gill, 1988, 1993, 1997) and has revised some poorly known genera. He is also producing a volume on mealybugs of this state. Others interested in scale insects include: S.I. Frommer, collection curator at Riverside, R. Garrison (Los Angeles Co.), N. Nisson (Orange Co.), and J. Sorensen; the latter is an aphidologist but also works on coccoids when needed. J.B. Steinweden, now in his nineties, is in retirement. Unfortunately, when Richard Wilkey died, we lost the best expert slide maker. **Connecticut** - M.S. McClure has written some excellent papers on the biology, ecology and biocontrol of scale insects but, unfortunately, he has switched to work on the Adelgidae. **Florida** - A.B. Hamon identifies scale insects and whiteflies and is the adviser for this semi-tropical state but is due to retire in four years; he currently has a summer intern from the Florida Agricultural and Mechanical University. F.W. Howard, with a background in scale studies, works at the University of Florida on the control of *Aulacaspis yasumatsui* Takagi on cycads, while maintaining an interest in Halimococcidae. **Georgia** - R.J. Beshear and H.H. Tippins have retired and have not been replaced. J.O. Howell, although involved in administration and teaching, maintains his interest in the false pit scales and in the immature stages of armoured scales; G. Hodges is completing Ph.D. research in his laboratory. H.J. Hendricks has recently moved back to this State and will continue his work on mealybugs; his Ph.D. dissertation on legless mealybugs was printed (1999) in Germany for Das Tierreich. **Hawaii** - When J.W. Beardsley retired to California, Hawaii lost an excellent coccidologist. B. Kumashiro, Hawaii Department of Agriculture, is working on the biological control and systematics of scales. **Louisiana** - F.W. Howard worked on the armoured scales in this State, but moved to Florida a few years ago. **Maryland** - Has the largest concentration of coccidologists. W.F. Gimpel, although in an administrative position, still does some scale insect research, as does J.A. Davidson, who has retired. R.F. Denno and L.M. Hanks have studied the biology, ecology and adaptation of coccoids; Hanks is now located in a midwest State. Because the U.S. Department of Agriculture Systematic Entomology Laboratory is located in Beltsville, Maryland, D.R. Miller (Miller & Miller, 1993) and G.L. Miller and

M.B. Stoetzel (both received M.Sc. and Ph.D. degrees for scale insect studies and both now in aphid research but latter also in administration). D. Odermatt is doing scale identifications for the U.S. Quarantine. L.M. Russell, who retired a long time ago and is now in her nineties, kept up with the pit scales and aphids until recently. D.R. Miller, Y. Ben-Dov (Israel), M. Gimpel (USDA), and K. Veilleux (Virginia Tech) are compiling "SCALENET" using the database system BASIS, developed by G. Gibson and J. Read, Agriculture Canada. **Massachusetts -** X. Hu expressed an interest in evolution and systematics of coccoids. **New York** - After a productive career in scale insect genetics, U. Nur has retired without leaving a successor. Emily Morrison, in her nineties, is probably still in retirement in this State. **North Carolina** - L.L. Deitz maintains his interest in diaspidid and halimococcid systematics, although he works now on the Membracidae. **Pennsylvania** - J.F. Stimmel is in charge of coccoid work and identifications and provides reports on some of the pest species. **Tennessee** - P.L. Lambdin leads an active research group, including two graduate students in systematics: C. Stumpf working on neotropical asterolecaniids and John Nelson working on the ecology of scale insects; Lambdin's laboratory has attracted a number of foreign researchers in the past. Current work includes studies on an oak eriococcids and the wings of male scales. **Texas** - Only T.X. Liu is currently active but in his own time, as his assignment is on vegetable IPM. Both E. McDonald and A.I. Mercado are active in preventing new scale introductions at the Houston Intercontinental Airport. **Virginia** - P.B. Schultz, now an administrator, still does some work on the biology and control of scale insects on ornamentals. Karen Veilleux continues the cataloguing and indexing of the world scale literature. M. Kosztarab (Kosztarab, 1996; Kosztarab & Kozár, 1988) retired six years ago, after training 12 students in the field of coccidology (five still active) and has continued to work part-time on scale insects. Unfortunately, no systematist or "biodiversity specialist" has been employed as a replacement at Virginia Polytechnic Institute and State University.

## STATISTICAL CONCLUSIONS FROM SURVEY

Of the 39 respondents, 32 were employed and seven retired; five worked for their federal government, nine for a state government, 16 for a public college or university and one for a private university. There were no private company employees or graduate students among the respondents. Some colleagues kindly provided the names and activities of additional scale insect researchers, including graduate students and retired colleagues.

Among the 39 respondents, 35 were doing some work on systematics as part of their professional workload; those who retired spent an average of 36% of their time on systematics. Ten respondents included work on morphology (average: 15% of their time); 21 on biology (average: 14% of their time); 15 on ecology (average: 9.6% of their time); nine in database preparation (average: 16% of their time); 13 on biological control (average: 21.5% of their time); and four on chemical control (average: 5.5% of their time). In addition, one person stated some work on phylogenetics, one on zoogeography (9%); one on biogeography (10%); one on faunistics (20%); one on palaeontology (10%); one on administration (70%); one on integrated pest management (11%); one on extension (5%) and on collection and curating (5%).

Twenty-two people obtained assistance through 17 graduate students (average: 36.7% (10-50%) of their time); 16 had technicians, using 56% (range 10-100%) of their time; three had stenographers, using 32% (5-50%) of their time; two had illustrators, using 5.5% (1-11%) of their time; one had a cataloguer, using 100% of his/her time; and two had computer programmers, using 5% (0.1-10%) of their time.

Many colleagues expressed dissatisfaction with the support provided for their work from their institute/office. For example, 19 received what they considered insufficient funds, 11 lacked satisfactory research space, 13 were not allowed enough time for scale research, and four were provided with unsatisfactory facilities.

Unfortunately, a number of active researchers working at universities were unable to train graduate students due to lack of funds or time, or both.

Of the 32 active researchers who responded, the average time to retirement was 11.7 (1-33) years, with 13 of them reaching retirement age within five years. Currently, 17 graduate students (including six in systematics) are in training in scale research as possible replacements for 12 retirees during the next five years. It is encouraging that 13 researchers have expressed a willingness to continue working on scale insects even if no financial support is provided after their retirement. Many other colleagues also planned to continue their research on scale insects after retirement, pending support in funding and/or space.

After the untimely retirements in Eastern and Central Europe, there are now only 23 women active in coccidology, including three in graduate training at present. Three women were trained at Virginia Tech. but, after their excellent thesis/dissertation work, none continued their scale insect studies.

It is a very unfortunate trend in a number of institutions and countries that positions vacated through retirements of 13 coccidologists were not filled with coccidologists; often not even with systematists. Apparently, this has been the case with the retirements of J.W. Beardsley, H.M. Brookes, M. Canard, J.M. Cox, J.A. Davidson, F. Lellakova-Duskova, L.R. MacGregor, B. McDaniel, G. Ördögh, A. Savescu, S. Takagi, H.H. Tippins and M. Kosztarab. It is assumed here that this is also true for the four retired colleagues from Poland and the four from the former Soviet Union.

At the same time, at least 12 colleagues who completed graduate work in scale insect research are underemployed or are working in fields other than coccidology; for example, S. Bhatti, R.G. Baer, L.L. Deitz, H.J. Hendricks, R.G. Knipscher, T-X. Liu, G.L. Miller, B.J. Muse, D. Pollet, C.H. Ray and M.B. Stoetzel.

## IDEAS AND SUGGESTIONS RECEIVED THROUGH THE SURVEY

Comments received from colleagues follow in alphabetic order:

### How to obtain funds for research and for graduate or postdoctoral stipends?

**Davidson, J.A.:** I do not see any institution hiring a coccidologist per se to just do this work, except a museum. The strategy should be to place people in applied positions (i.e., jobs such as on aspects of ornamentals), where they can work part time on scales. **Erkiliç, L.B.:** we have to include a biological control and integrated pest management approach in our projects to get reasonable funding, because basic research such as taxonomy should be considered together with applied sciences. **Gullan, P.:** although I could apply for funds for Ph.D. or postdoctoral positions from Australian Government Funding agencies, I do not have time to supervise additional people at present, and could not be guaranteed of finding suitable candidates for such positions. However, I currently do supervise three students in scale insect systematics. **Hamon, A.B.:** concentrate on the most economically important species. **Hodgson, C.J.:** concentrate on biocontrol of coccoids of important crops. Perhaps we should be dealing with taxonomy of important groups in geographical areas that are not currently well known? **Kosztarab, M.:** request funds from government funding agencies for stipends for research that includes an integrated approach, combining biology, ecology, morphology, and systematics of scale insect genera or families, and gather information on their potential biological control agents. We should publicize that institutions could capitalize on the accumulated library, database, and facilities to save funds, by hiring replacements for retiring coccidologists, who could work in the same general area of research. **Lambdin, P.L.:** look to the agencies that are interested in biodiversity and community structure, such as NSF, Nature Conservancy, USDA conservation and biology. **Lit, I.L.:** biodiversity-documentation? UNDP? UNESCO? **Miller, D.R.:** train as many students as possible. Some may find jobs that allow them to study scales. **Panis, A.:** we could mass produce coccidiphagous insects for companies that sell beneficial insects. Seek European Economic Community Funding for multidisciplinary research programs. Bring together researchers from various European countries with companies, in the field of genetics and population biology of scales and their entomophages. **Porcelli, F.:** try for E.C. (European Community) funding. **Takagi, S.:** I do not think that emphasizing economic importance alone is sufficient to evoke an interest in scale insects, especially in systematics. In the field of systematics, classification in higher categories suffers the most from lack of theories. By 'theories', I do not mean cladistic logic and algorithms now in fashion, but biological theories applicable to and testable by observations. To be a really attractive field of biology, systematics has to be able to produce theories from its own field, which are testable in other fields of biology. This may require inter-disciplinary research rather than museum or single-laboratory work. Scale insects can be an attractive group of organisms from the viewpoint of such research. In my experience, for example, manifestations of remote ancestral phenotypic patterns are frequent in this insect group. I believe that this phenomenon is not only useful for elucidating relationships among higher taxa but also worthy of multi-disciplinary study from the viewpoint of phenotypic manifestation in the evolution of higher taxa. In my view, evolution is not merely an accumulation of DNA changes. **Williams, M.L.:** combine scale training with another area, such as urban entomology.

### HOW TO IMPROVE CHANCES FOR TRAINING FUTURE COCCIDOLOGISTS?

**Erkiliç, L.B.:** the importance of training in special subjects should be explained by use of public communication systems such as TV, newspapers, magazines and especially to influence politicians. Maybe this is not a subject for developed countries but in countries like Turkey, we need explanation. **Gullan, P.:** coccidology training courses, especially in developing countries. **Hamon, A.B.:** if I and other current coccidologists did not do identifications for free, perhaps more organizations would support a practising coccidologist. **Kosztarab, M.:** let's get our graduate students involved in selecting the topic for his/her research. If a foreign student, the selected project should also benefit his/her country. Resurrect summer short courses in coccidology, such as those that were so successful at the University of Maryland, and expand these to each continent where the need and interest is present. Request funding from sources such as government, NSF and FAO. **Koteja, J.:** either transform coccidology into a "modern" and profitable discipline (for the student) or, create people with real scientific interest. **Kozár, F.:** increase the interest of students in systematics and taxonomy through University courses. **Lambdin, P.L.:** the proposed federal policy statement regarding the need to catalogue the fauna and flora of the U.S. will require taxonomists to identify tens of thousands of species. **Lit, I.L.:** promotion of coccidology should be part of promoting systematics of insects as well as biodiversity conservation, especially because the latter is the "in" thing nowadays in terms of funding and student interest. **Panis, A.:** training by coccidologists who work in molecular biology or genetics and biomathematics. **Stimmel, J.:** private industry and high-level U.S. Government (i.e., SEL) lobbying with State legislature and executive branches, particularly the Secretary of Agriculture. But they might not be receptive!

### HOW TO INCREASE PUBLIC AWARENESS OF OUR RESEARCH AND ITS VALUE WITH EXAMPLES FROM OUR AREA?

**Beardsley, J.W.**: several serious new mealybug pests have appeared in Hawaii during the past 10 years; i.e., *Maconellicoccus hirsutus, Phenacoccus parvus, P. solenopsis* for which I provided initial identifications. **Erkiliç, L.B.:** we have new mealybug species on citrus near to the Syrian border in Hatay, which was not known previously from this host. **Gullan, P.:** Australia exports citrus to New Zealand and other countries, and shipments can be rejected if they contain mealybugs or other scales not known in those countries. My identifications of "suspect" species, therefore, can save the Australian industry large sums of money, especially if the importing country incorrectly rejects fruits, because their authorities have misidentified introduced insects (the latter has happened at least once in the past few years). **Hamon, A.B.:** cycads in Dade County, Florida have been severely damaged by *Aulacaspis yasumatsui* Takagi. This is an introduction (via commerce) from Asia. Little is known about the scale and it arrived without natural enemies. It will take several years of effort to conduct biological controls. It will also result in the loss of millions of dollars worth of plants (Cycads). **Kosztarab, M.:** there is a need to write more popular articles on scale insects, pointing out their economic importance, and unique facts about them. Collect and publish records on the cost of scale prevention and control, on each major crop, and the value of losses due to their infestation. We have to become better sales people in promoting public and government awareness about the menace of new pest scale introductions, and the need for experts that provide timely species identifications. **Kozár, F.:** publicize the rapid spread of important scale pests in Europe such as *Ceroplastes japonica, Pseudaulacaspis pentagona, Pulvinaria regalis*, etc., without efficient biological control agents. **Lambdin, P.L.:** because of the explosion in international and inter-regional trade that is now occurring throughout the world, plants, building and food products often harbour exotic species that threaten the native species of the new region. With the advent of Internet purchasing of plant materials (trees, shrubs, garden plants) from nurseries from around the U.S., identification and control of plant pests will only increase in this global economy. It is imperative that the basic research be completed on the species before successful attempts at suppressing or controlling the species can be implemented. **Lit, I.L.:** in 1988-1989, I was asked to examine oranges imported from New South Wales that were supposed to have passed our plant quarantine office. I found them infested with live armoured scales (Florida red scale, etc.) on the outside as well as mealybugs (*Pseudococcus calceolariae* Maskell) on the navel. The oranges were already out in the market. **Panis, A.:** public awareness increased when I enhanced biological control of Olive black scale, of armoured scales and mealybugs on ornamentals under glasshouse. **Russo, A.:** introduction of several injurious species into Italy, e.g., *Aonidiella citrina, Unaspis yanonensis, Pseudaulacaspis cockerelli, Ceroplastes japonicus*, etc. **Schmutterer, H.J.:** two important pests have been introduced into Germany in recent years, namely: *Pulvinaria regalis* and *Unaspis euonymi*. (He will publish a paper on the latter species in 1998). **Williams, D.J.:** I do think there is a dearth of posts. It is posts that are lost, not a lack of budding coccidologists willing to fill them. There seems to be a growing emphasis on molecular taxonomy, medical entomology and anything that brings in money. Funds are available for taxonomic research on scale insects as I found out when I did the Pacific and South American works. Research must be on a fairly grand scale and on subjects that are topical and of interest for the big funding agencies. I am working on the mealybugs of southern Asia without funds, merely for something worthwhile to do. If I were to ask for funds I would be under immediate pressure, which I do not want. **Williams, M.L.:** scale insects are one of the top pest groups in the ornamental and landscape plant industry.

## CONCLUSIONS

Ferris in 1957 estimated that only about 20% of the world scale insect fauna had been described. More recent estimates (Kosztarab *et al.*, 1990) put the figures at one-third to one-half of the species in the more intensively studied North American fauna as still undescribed, and about three-fourths of the species in the tropics as still undescribed (Kosztarab *et al.*, 1990). When considering the males and immature stages of all species, probably more than 90% are still undescribed.

In addition to the missing morphological descriptions, we are still lacking a substantial amount of information on the biology and ecology of the species that are already named. Now that there are so few of us left, with so little time, I would like to suggest that each of us help with a strategy to narrow this gap in scale knowledge.

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KOTEJA, J.
*Department of Zoology and Ecology, Cracow Agricultural University, al Mickiewicza 24,*
*30-059 Kracow, Poland.*

# FOSSIL COCCIDS DO EXIST.

## ABSTRACT

FOSSILS COCCIDS DO EXIST.

Scale insects (Coccinea) have been discovered in almost all Tertiary and Cretaceous amber and in a few other deposits, and the number of known coccid fossils has increased from about 100 to approximately 900 in the last twenty years. This material represents a variety of forms and constitutes a reliable basis for serious palaeo-entomological studies.

Key words: fossil abundance, Eocene, Mesozoic, Cretaceous, Tertiary, Baltic amber, Ortheziidae, Xylococcidae, Matsucoccidae, Electrococcidae, Monophlebidae, Putoidae, Eriococcidae, Inkaidae, Kermesidae, Diaspididae.

Fossil coccids do exist and their study is continuing to develop. As with many other insect groups, palaeo-entomological studies on scale insects (Coccinea) started in the middle of the 19th Century with the Eocene Baltic amber inclusions. These studies were then forgotten for about 100 years until they were rediscovered by Ferris (1942). The studies of Beardsley (1969) then extended the period of coccid palaeo-entomology into the Mesozoic, with the establishment of the Cretaceous *Electrococcus canadensis*.

By the beginning of the 1980's, some 100 coccid fossils were known from various institutions and 10 species had been formally described, although only a few of them can be recognized on the basis of their original descriptions, drawings and preserved specimens. In the second half of the 1980's, about 15 papers on fossil scale insects were published (for references, see Koteja, 1990a) and the number of established species had increased to 36, affiliated to the Ortheziidae, Xylococcidae, Matsucoccidae, Electrococcidae, Monophlebidae, Putoidae, Eriococcidae, Inkaidae, Kermesidae and Diaspididae. In addition, many more fossils have been discovered in various collections or have been collected in the field, so that the number of specimens (including fossil impressions and amber inclusions) had grown to around 350. The results of those studies were summarised at the VIth ISSIS (Koteja, 1990b).

After a break for other duties, I was able to continue with my interest in fossil scale insects in 1995. It became obvious that, for serious taxonomic and palaeo-ecological research to be done in the future, the main task for coccid palaeontology should be to collect and catalogue fossil material, and protect specimens from damage and dispersal, so that descriptions of new species could be based on more than a single specimen. Thus, the search for coccid fossils has been extended to private collections and the open market. Many fossils and inclusions have been found by amateurs searching for coccids in their collections, and at fairs, shops, etc selling minerals, gems and amber (Koteja, 1998). Owing to the interest and generous assistance of these amateurs and the curators of many public institutions, the number of catalogued coccid fossils has increased to 900 specimens, while another 200 are known to be present in public museums. My own collection has also grown during the past two years to 170 specimens. All this work has required thousands of hours of polishing, preparing and cataloguing.

It appears, from the still undescribed material, that all the main coccid groups were present in the Tertiary, with the "archaeococcids" still the dominant "group" in the Eocene. However, from the phylogenetic point of view, the Cretaceous fossils are much more intriguing. Among these are the Turonian New Jersey inclusions, which contain representives of 7 or 8 families, including the well-defined Eriococcidae, the "living-fossil" Matsucoccidae and several highly derived and, apparently, extinct "archaeococcids". The presence of these extinct groups suggests that the scale insects may also have been touched by the hypothetical Cretaceous biological crisis (Koteja, 1999).

So, the time has now come to deal with fossil taxa and not just with fossil specimens.

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MILLER, D.R.[1]; BEN-DOV, Y.[2]; GIBSON, G.A.P.[3]
[1]*U. S. Department of Agriculture, Agricultural Research Service, Systematic Entomology Service, Beltsville, Maryland 20705 U.S.A.*
[2]*Department of Entomology, ARO, The Volcani Center, Bet Dagan 50250, Israel*
[3]*Biological Resources Program, Eastern Cereal and Oilseed Research Centre, Agriculture and Agri-Food Canada, Ottawa, Ontario, Canada.*

# SCALENET: A SEARCHABLE INFORMATION SYSTEM ON SCALE INSECTS.

## ABSTRACT

SCALENET: A SEARCHABLE INFORMATION SYSTEM ON SCALE INSECTS.

Systematic information on the scale insects of the world is currently being compiled and synthesized in a database system called BASIS. The information is organized by scale insect family and is searchable at a site on the World Wide Web called ScaleNet (http:\\www.sel.barc.usda.gov\scalenet\scalenet.htm). The site provides general information on scale insects, including sections on economic importance, life histories, distribution and ecology, classification and biographies. A query system provides information on valid names and provides a complete systematic catalogue for any valid genus or species. For a particular taxon, queries will give the following information: all hosts of a scale, distribution of a scale, references for a scale, a checklist of all valid species in a family or genus, biological notes and remarks for a scale. It also will give the scales that occur on a particular host, all systematic references on scales that were published between two dates, all references published by an author, all references with any of five selected words in a title or annotations, a list of all scales described by a particular author, all scales from a particular zoogeographic region, country or country subunit, and the scientific name of any common name of a scale.

Key words: BASIS, Biological and systematic information service, Coccoidea, Coccinea, Aclerdidae, Asterolecaniidae, Beesoniidae, Cerococcidae, Coccidae, Conchaspididae, Dactylopiidae, Diaspididae, Eriococcidae, Halimococcidae, Kermesidae, Lecanodiaspididae, Margarodidae, Micrococcidae, Ortheziidae, Phoenicococcidae, Phenacoleachidae, Pseudococcidae, Tachardiidae.

## INTRODUCTION

Literature on scale-insect systematics is scattered in more than 11,000 scientific articles and books and has been published in nearly every extinct and extant country in the world. Classification systems, the names of taxa, and taxon descriptions have changed dramatically since the early works in the middle 1700's and often it is difficult for persons interested in a particular group or species of scale insect to determine which concept is currently accepted by the scientific community. This situation results in frustration and confusion for individuals and organizations interested in finding information on scale insects, and often it is necessary for them to consult with a scale-insect systematist to get an answer to their specific questions. In some situations, this is a workable solution but, in most regions of the world, there are few or no coccidologists available for consultation, and those who do exist could better serve humankind by developing more accurate information about scale insects rather than responding to enquiries prompted primarily because of difficulties in locating current, reliable, organized information on scale insects. A project designed to alleviate some of these problems is the subject of this paper. The project is a queriable website, called **ScaleNet** (http:\\www.sel.barc.usda.gov\scalenet\scalenet.htm), that provides immediate access to systematic, biological and bibliographic information on scale insects and is available to anyone who has access to the Internet. The query system is set up so that a client can discover the information needed in a matter of minutes without consultation with a scale-insect specialist. If additional consultation is still needed, ScaleNet allows clients to send questions to the developers of the system.

In comparison with many other groups of insects, the information on scale insects is relatively well organized. There are more or less up-to-date systematic catalogues on most of the major families, including the Coccidae (Ben-Dov, 1993), Conchaspididae (Ben-Dov, 1981), Diaspididae (Borchsenius, 1966), Eriococcidae (Hoy, 1963), Pseudococcidae (Ben-Dov, 1994), and Tachardiidae (Kapur, 1958). Bibliographies of scale-insect literature have been published covering the period from 1758 to 1985 (Morrison & Renk, 1957; Morrison & Morrison, 1965; Russell *et al.*, 1974; Kosztarab & Kosztarab, 1988) and a bibliographic database is kept up-to-date by the Systematic Entomology Laboratory, US Department of Agriculture, Beltsville, Maryland, USA, and the Virginia Polytechnic Institute and State University in Blacksburg, Virginia, USA. The genus-group names of all scale insects have also been compiled and updated to 1985 (Morrison & Morrison, 1966; Russell, 1970; Kosztarab & Russell, 1974; Kosztarab *et al.*, 1986).

The information described above has been the basis of the ScaleNet initiative, especially the scale-insect bibliographies and the Coccidae and Pseudococcidae catalogues as computerized databases. The process of developing ScaleNet was complicated and ultimately involved collaborators from industry and scientific organizations in Canada, Israel and the United States. Significant funding was provided by the Binational Agricultural Research & Development Fund (BARD). With appropriate financial support, the first step was to find a database system that could handle complex relational catalogue information and at the same time could be used as a resource for developing a queriable website on the Internet. Fortunately, Gary Gibson had already developed such a system called BASIS (Biological and Systematic Information System) and, with a few scale-insect enhancements and modifications, it worked beautifully. The next step was to enter as many references of scale-insect publications into the BASIS system as possible because bibliographic information is the keystone of the BASIS system. Contracts were written to input data from the published bibliographies, to convert various bibliographic databases developed by co-operators from Procite into BASIS (Karen Veilleux and Michael Kosztarab from Virginia Polytechnic Institute and State University, USA) and to update and keep the reference files current. The next step was to develop an interface between the BASIS database and the World Wide Web and to write programs for the query system. Richard Carson & Associates, Advanced Research Division, Reston, Virginia, USA, was awarded the contract and, through the efforts of Jane Lemmer, Robert Todd and Arek Grantham, the system became available on the Internet in 1996. Enhancements will continue for the next year, when a complete system of queries will be available.

Once a preliminary bibliographic file was developed, and web software was implemented, it was possible to begin adding systematic data on the various families. The Coccidae and Pseudococcidae data that had been used to generate the hard-copy catalogues by Ben-Dov (1993, 1994) were resident in a database system developed in The Natural History Museum in London, and these were converted to BASIS by Gary Gibson and Jennifer Read. It was a laborious task for the Israeli team of Yair Ben-Dov, Viktoria German and Yulia Bir to add new and modified data to the pseudococcid and coccid data files so that the information was brought up-to-date and consistent with the BASIS format. When this was accomplished, more than one third of the scale-insect species were available in ScaleNet. The Israeli team has also completed the Conchaspididae file which is available on the Internet and currently has preliminary files for the Aclerdidae, Asterolecaniidae, Beesoniidae, Dactylopiidae, Lecanodiaspididae and Tachardiidae. The United States team of Dug Miller and Maren Gimpel has completed the Eriococcidae and Ortheziidae files, which are now available on ScaleNet, and have preliminary files for the Cerococcidae, Halimococcidae, Kermesidae, Micrococcidae, Phoenicococcidae and Phenacoleachidae. A catalogue of the Margarodidae is currently being written by Imre Foldi (Museum National d'Histoire Naturelle, Paris, France), and it is anticipated that this will be the basis of the margarodid file in ScaleNet. Karen Veilleux is constantly adding new data to the bibliographic database which now comprises more than 11,000 records and is expanding at over 500 references each year.

The most important task remaining is to complete the Diaspididae. This project has been divided between the two teams; the Israeli team is inputting the data for the Aspidiotinae and related groups and the US team is entering data for the Diaspidinae. Most of the armoured scale genera has been entered by the Israeli team and the US group is actively inputting data on the Diaspidinae. It is anticipated that this task will be completed by the end of 2000. In the interim, hard copy editions of each family will be published, and the entire electronic system will be updated annually. It is also anticipated that a new Coccoidea bibliography will be published after all families are available in ScaleNet.

## RESULTS

ScaleNet provides various kinds of information on scale insects. The home page provides a number of options that allow access to information on scale insects. One section of ScaleNet deals with general information, providing an introduction to ScaleNet itself, a description of the BASIS database system, and information on collaborators and funding sources. In addition, there are general discussions about scale insects, including economic importance, life histories, distribution and ecology, classification and references to biographies of deceased coccidologists. A miscellaneous section provides a glossary of terms, maps of the world and publications that have resulted from the ScaleNet initiative.

The most valuable portion of the ScaleNet site is the query system. Specific instructions on the various queries are given in the background section of ScaleNet. As clients can link to these instructions from each query, they will not be repeated here. For the purposes of this paper, we will restrict ourselves to a brief description of the query system and the kinds of information that can be obtained.

In order to access a significant portion of the information available in ScaleNet, it is essential to know the valid or correct name of the taxon in question. To use this query, click on "**Find a Valid Name and Catalog**" on the query page. The client will be asked to provide a family, genus and species name (if the family is unknown use "ALL"). For example, if they wish to know the correct name of *Conchaspis baiensis,* they type "*Conchaspis"* in the genus field and "*baiensis*" in the species field, and choose "all" in the family field. The response will be *"Conchaspis angraeci* Cockerell (Family Conchaspididae) is the valid name." This query is useful for clients who need to know if a name used in the literature is still valid or if they need the author or family name of the taxon in question. Below the valid name statement are three options to retrieve a taxonomic catalogue: 1) the species, 2) the genus, and 3) all of the species in the genus. If the first option is selected, the output will be a catalogue of *Conchaspis angraeci* that includes the following sections: Synonymy, Common Names, Distribution, Associations (hosts), Citations, Keys (references to any time that the species or genus was used in a key) and Remarks. The "valid name and catalog" query also outputs information on homonyms or misidentifications involving the entered name, so that the client has the option of selecting the valid name that is pertinent to their query. For example, if a client wanted information on the name *Opisthoscelis globosa*, based on some literature record or identification, they would type *"Opisthoscelis"* in the genus field, *"globosa"* in the species field, and Eriococcidae (or "ALL") in the family field. They would receive the following reply: "*Opisthoscelis globosa* Rübsaamen (Family Eriococcidae) is the valid name (originally described from AUSTRALIA: New South Wales, on *Eucalyptus*) BUT there is another species that once had the same name *Opisthoscelis globosa* Froggatt (Family Eriococcidae) (originally described from AUSTRALIA: Victoria, on *Eucalyptus* sp., by C. French and New South Wales, by Honsby) and its valid name is *Opisthoscelis ruebsaameni."* Therefore, if the client was looking for information about *Opisthoscelis globosa* Froggatt, they would need to locate a catalogue of *Opisthoscelis ruebsaameni* not *O. globosa* Rübsaamen. Catalogue options for the valid name of the homonym or misidentification can be accessed directly from the valid name statement without the need to run another query. If a request is made for a valid subspecies (and the subspecies is valid), clients will be given four catalogue options, including a catalogue of the subspecies.

After the valid name of the taxon in question is known, several specific queries can be made, such as "**Hosts of a Scale**," "**Distribution of a Scale**," "**References for a Scale**," or "**Remarks for a Scale**." These queries are straight forward, requiring the client to fill in the genus field and species field, and to choose a name from the choices in the family field. Output is all of the known hosts, distribution, references or remarks for a scale. **The known hosts and distribution queries include links to one or more references that validate each record**. The "remarks" query outputs separate sections giving information on the systematics, structure, biology, economic importance and control, and general remarks for any scale species. The "Scales in a Family/Genus" query requires input of a valid family or valid family and genus name and the output is a checklist of the valid species in the taxon requested.

In addition, there is a series of queries that do not require a valid name. For the "**Scales on a Host**" query, the client has the option of entering one or more of the host family, host genus and host species. The client can enter only a Host Family (and be given a table including all of the scales on the selected family), or a Host Genus alone (and be given a table of all of the scales on the selected genus), or a Host Genus and Host Species name alone (and be given a table with all of the scales that occur on the selected host species). The resulting table has column headings for: Scale Family, Genus, Species, Subspecies, Author (of the scale species) and Validation Source (reference where the host record was published). The validation source is hot linked (i.e. by clicking the mouse on the source, a full reference will be provided) so that the complete reference and associated annotations that describe the contents of the publication can be retrieved. Each species name is hot linked so that the client can immediately produce a complete catalogue for any of the scale species.

A query for "**References Between Two Dates**" was designed for clients to find all of the scale-insect literature published between two dates. Click on this choice and the client is given a screen that allows entry of a Begin Date and End Date. If the latter is not filled in, the default is the current year. There is a restriction of no more than a 10 year span. The result of this query is a list of all of the references in the database between the years selected, including the associated annotations for each reference.

The "**Reference for a Citation Code**" query was programmed to allow clients to find a complete reference for any citation code that is encountered in ScaleNet. Each reference in the BASIS database is designated by a unique code that is formed from the names of the authors and the date. For example, the citation code for Cockerell & Bueker 1930a is CockerBu1930a. In most query outputs this code is hot-linked to the reference, so that a client can simply click on the code to receive a complete citation and associated annotations. In a few instances, however, direct hot-linking was not possible, so a query was developed to allow clients to determine the complete reference citation for any unknown citation code. If a citation code is found that is not already hot-linked to a reference, the client can either use the Internet browser's "copy" option to copy it, or "<Control> C." Then go to the "Reference for a Citation Code" selection. When this option is selected, the next screen is a blank field to enter a citation code, in which the client pastes the copied citation code with "<Control> V" or the browser "paste" option. Thus, if "CockerBu1930a" is entered in the "Reference for a Citation Code" query, ScaleNet will return the complete reference and any associated annotations. Please be aware that when entering citation codes, they are case sensitive. That is, you must have capital letters in the correct positions. This is another reason for “copying” and “pasting” the codes.

When a client clicks on the “**References for an Author**” option, the resulting screen provides blank fields for the last name of an author. When entering this information, be certain that the capitals, hyphens and diacritical marks are in the correct place. Directions for obtaining diacritical marks to place in the blank field are given in the instruction section for the query. The output for this query is a list of references by the author selected, including junior author papers. The client is given the option of including begin and end dates. The list includes the complete reference and associated annotations and gives papers of all authors with the selected last name. Clients should be aware that multiple authors with the same last name will be obtained in this query. Therefore, if a request was submitted for papers by Williams, the resulting output would include papers by D.F. Williams, D.J. Williams, J.R. Williams, K.S. Williams, L. Williams, M.L. Williams, P. Williams, and R.N. Williams!

“**References with Words in Article Title/Journal Title/Notes**” is a powerful query, but is a bit complicated. Click on this selection and the client will be given a screen with the option of entering from one to five words that they would like to search for in the article title, journal title, or associated annotations of the references. The client also has the opportunity to limit the search with the last name of an author and the begin and end year of publication. Thus, if the first word field is filled in with “apple”, the output will be a list of approximately 115 references and the associated annotations. Several of these will have hits on the word “pineapple.” This problem can be alleviated by putting a space before the word apple, i.e. if “_apple” is submitted, the output will include about 80 hits. Adding new words in the word fields will restrict the number of hits. Please be aware that this query is case sensitive, i.e. if all papers with apple in them are required, separate searches with “_Apple” and “_apple” must be made. The alternative is to search for “pple” but this might add other inappropriate references with words like “supplement.” If a person wanted to find literature on the pink hibiscus mealybug (*Maconellicoccus hirsutus*), a search using the words “Maconellicoccus” and “hirsutus” would give a list of 34 references. A query using “ealybug” for a person interested in the literature on mealybugs gives more than 700 references and a search using “ealybug” with a year restriction of 1980 to 1990 gives 258 references. Use of “itrus” and “ealybug” for someone interested in the citrus mealybug gives 48 references.

“**Scales Described by an Author**” is a query designed to list all of the taxa described by a particular author. If a client chooses this selection, they will be given a screen that requires the last name of an author. When entering this information, it is important to put capital letters, hyphens and special characters in the correct place. The query can be restricted by including a begin and end date. If this isn’t included, the default is to provide all of the scales described by the author. By clicking on the appropriate circle, the client is given the option of receiving the generic names described by the author, the species names or the subspecies names. The output for this query is a list of scales described by the selected author. The list includes the cited name, year, current status of the name and the valid name. We did not distinguish between authors with the same last name, so a list might include species described by more than one person.

“**Scales from a Zoogeographic Region/County or Country Subunit on a Host”** provides a checklist of all of the species of scale insects that occur in a specified geographical area. Click on this selection and a client is given the option of choosing any of the geographic units listed in a picklist. The choices will include any of the zoogeographic regions, countries within the selected zoogeographic region, and subunits within the selected country. The results will give all of the scale species that occur in the selected zoogeographic region, country or country subunit. Clients also have the option of restricting the query by choosing a host plant and will be able to fill in any of host family, host genus and host species. The same selection criteria are used for this query as were used in the “Scales on a Host” query described earlier. Clients also have the option of choosing a scale family to restrict the query further. The results give all of the scale species in one or “ALL” scale families that occur in a particular zoogeographic region, country or country subunit on a particular host plant (host family, host genus, or host species).

“**Find a Scientific Name of a Scale Known only by a Common Name”** is a query designed to assist clients who want more information about a scale insect but know only a common name. Selection of this query gives a screen with a common name field which is filled in by the client. Capital letters should only be used when a proper name is part of the common name, e.g., Putnam scale; small letters should be used when there are no proper names, e.g., white peach scale. Output from this query is one or more valid scientific names. These names will be hot-linked and a catalogue for the species will be displayed when the scientific name is clicked. Currently, most common names in ScaleNet are in English, but we are constantly adding names in other languages. A scale-insect species may have several different common names. For example, *Saissetia oleae* (Olivier) is called “the black scale” in North America and is “the olive scale” in Mediterranean areas. If a client fails to retrieve information under one common name, it may be necessary to try another one, if known.

## DISCUSSION

ScaleNet is a valuable and easily accessible information resource on scale insects. As more families are included in the system, it will become more and more comprehensive and thus more and more useful. Current (optimistic) plans are for the first round of data entry to be completed by the end of the year 2000. After that time, the system will be updated on an annual or more frequent basis as needed. Future enhancements of the system might involve additional query options; or increasing the information content of ScaleNet by including a companion database covering all of the natural enemies of scale insects; or a system of images with an illustration or photograph of each species and a description; or unpublished specimen-label information from all of the various museums with scale-insect holdings. There are numerous other possibilities. The primary issue, of course, is funding

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## INTERPRETIVE SUMMARY

Scale insects cause millions of dollars in damage each year, but information relating to the group is found in thousands of scientific journals and books and is difficult or impossible to locate. A new web site called “ScaleNet” provides access to this diverse information through a series of synthetic and user-friendly queries. In order to put information in ScaleNet, it is necessary to validate certain taxonomic changes in print. The purpose of this paper is to describe the ScaleNet system and give instructions on how to use the query system. This information will benefit all who are interested in the control, ecology, life history, pest exclusion and pest management of scale insects, including home-owners, nurserymen, quarantine specialists, extension agents, and state and university researchers.

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PORCELLI, F.[1]; GARONNA, A.P.[2]

[1]*Istituto di Entomologia Agraria, Facolta' di Agraria-Campus, Universita' degli Studi di Bari, Via Amendola 165/A-70126 Bari, Italy*

[2]*Dipartimento di Entomologia e Zoologia agraria, Università di Napoli "Federico II", Portici, Italy*

# A MULTI-CONTRIBUTORS DATABASE FOR ALL ASPECTS OF THE BIOLOGY AND CONTROL OF THE DIASPIDIDAE.

## ABSTRACT

A MULTI-CONTRIBUTORS DATABASE FOR ALL ASPECTS OF THE BIOLOGY AND CONTROL OF THE DIASPIDIDAE.

The difficulties of studying the Diaspididae from an Agricultural Entomology point of view are recognized by the authors. A "multi-contributors" database, which includes all aspects of biological control, host-plant interactions, world distribution and taxonomy, is submitted for the attention of researchers engaged in the control of armoured scale insect pests. The database will be available before the end of 1999 by a link on the Scale Insect Forum (http://193.204.185.103/scaleinfo/scale.htm).

## DISCUSSION

The need to access a database containing information about the Diaspididae and related arguments arose from the application in Agricultural Entomology. It was quickly realised that neither researchers nor field scientists could know everything about the Diaspididae, covering such diverse knowledge as the host-plant name, the taxonomy of parasitic *Septobasidium* and the ultrastructure of diaspidid spermatheca. It is therefore proposed to make a database where it will be possible for specialists not only to check information but also to correct old data and introduce new records and other information.

The Catalogue by Borchsenius (1966), the Annotated List by Morrison & Morrison (1966) and the Selected Bibliography (third supplement) of Kosztarab & Kosztarab (1988) are lists of reference papers available to every coccidologist. The Catalogue contains mainly taxonomic, biological (via the host plants) and zoogeographical data, while the Annotated List contains mainly taxonomic data. The Selected Bibliography has brief comments about each of the included references. The structure of these publications follows the ideas of each author, but basically they are species- or publication-related books. The ScaleNet database (see elsewhere in this volume) uses the facilities of the computer to speed the searching of data and, moreover, allows greatly improved cross-searching between topics, greatly increasing the ease of use and importance of the database. Unfortunately for Agricultural Entomologists, all these sources need a previous identification of the pest insect before they can access the information. The proposed multi-contributors database is intended to also allow the adding of data, either as text or pictures or both, by researchers. The newly added data will be submitted to a committee who will access the database by Internet and can reject or accept the new entry.

The database will be available before the end of 1999 by a link on the Scale Insect Forum (http://193.204.185.103/scaleinfo/scale.htm).

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BEARDSLEY, J.W.
*1026 Oak Dale Lane, Arcadia, CA 91006, U.S.A.*

# *NIPAECOCCUS NIPAE* (MASKELL) AND TWO APPARENTLY UNDESCRIBED SIBLING SPECIES (HEMIPTERA: COCCOIDEA: PSEUDOCOCCIDAE).

## ABSTRACT

*Nipaecoccus nipae* (Maskell) and two apparently undescribed sibling species (Hemiptera: Coccoidea: Pseudococcidae).

This paper argues that there are at least two species belonging to the *Nipaecoccus nipae*-species complex in Hawaii, one with white wax and the other with buff wax. These two species differ in a number of features but perhaps the most important is that the encyrtid parasitoid *Pseudaphycus utilis* Timberlake is only known to parasitise the white-wax species. A brief history of the two species (and another in Florida) is outlined, followed by a discussion of the morphological reasons for believing them separate. The problems of nomenclature are then outlined and it is concluded that the buff-wax species is *Nipaecoccus nipae* (Maskell) and that *Nipaecoccus pseudonipae* (Cockerell) is a synonym. The two other species (i.e. the white-wax species from Hawaii and the species from Florida) are then described as *Nipaecoccus paranipae* **n.sp.** and *Nipaecoccus floridensis* **n.sp.** respectively.

Key words: coconut mealybug, neotropics, palms, *Pritchardia*, guava, *Psidium*, bisexual, morphology, nomenclature, types, key, Mexico.

## INTRODUCTION

*Nipaecoccus nipae* (Maskell 1893), called the coconut mealybug in the USA, is a widely distributed species currently known from South America (type locality: Demerara, Guyana), Central America, California, Hawaii, Europe and Asia. It is almost certainly of Neotropical origin, from which region a number of closely related species have been described (Williams & Granara de Willink, 1992). Although these authors considerably increased the number of known species in the genus *Nipaecoccus*, they did not explain satisfactorily the apparent existence of unnamed sibling species that are morphologically very similar to *N. nipae*. Williams & Granara de Willink (1992) mentioned (p. 279) the existence in Hawaii of two “forms” of *N. nipae*: one with largely white external wax and the other with “yellow” wax, but stated that “in life the yellow and white forms are often found together.” The implied conclusion is that they are not distinct species. It has been my experience that the two forms do not normally occur together in the field in Hawaii, and for reasons that are given below, they do appear to be distinct species. In fact, as its wax is a dull yellowish-tan, the "yellow" species is perhaps better described as buff, while often the wax of the "white" species from Mexico and Hawaii is tinged faintly with canary yellow.

It appears, therefore, that *N. nipae*, as presently defined, is a species complex, one species of which has been dispersed widely, and a second of which is presently known from Mexico and Hawaii. In addition, a species previously identified as *N. nipae* in Florida (Merrill, 1953) is here considered to be a third species of that complex, as specimens that I have seen from there are not conspecific with the type. It seems likely that additional closely related but distinct and unnamed species exist in the Neotropical Region.

**Short history:**

A review of the history of these mealybugs in Hawaii will serve to illustrate this sibling species problem.

According to Zimmerman (1948), a mealybug believed to be *Dactylopius nipae* Maskell, was noted for the first time in Hawaii at Honolulu by R.C.L. Perkins in 1902. How long before that time it had been present there is unknown. Kirkaldy (1904) listed the species as *Trechocorys nipae* (Maskell) and stated that it was the cause of "considerable destruction to alligator pears, guava, etc." Crawford (1921) mentioned that avocado leaves were frequently encrusted with a "smut" fungus (sooty mould) due to the honeydew from this species. During 1922, several coccinellid beetle species and an encyrtid wasp (named *Pseudaphycus utilis* by Timberlake, 1923) were introduced into Hawaii from Mexico to combat this and other pestiferous mealybugs (Osborn, 1938). The encyrtid was reported as having become established in October 1922 (Fullaway, 1923), and later Timberlake (1927) stated that it had achieved "spectacular control" of the mealybug which "had been a bad pest of avocado, fig, mulberry, guava and banyan trees" for many years. Osborn considered the white-wax species to be true *nipae*, although he found the buff-wax species also present in Orizaba, Mexico, where he worked. The latter species also was determined for him as *nipae*, even though the parasitoid would not develop in it.

Some entomologists in Hawaii in the early part of this century also expressed the opinion that more than one species was being confused under the name *Nipaecoccus nipae*. Zimmerman (1948) discussed the problem and stated that "some considered the yellow form, occurring principally on palms, to be *Pseudococcus pseudonipae* (Cockerell) (1897: 302), whereas the white form has been known here as *nipae*." Ferris (1950) also discussed the problem, but concluded that there were no demonstrable differences between the yellowish and the white forms, and treated *pseudonipae* as a junior synonym of *nipae*.

However, biological evidence suggests that there are two species present in Hawaii. Despite Zimmerman's statement (1948) that "Several local observers say that they have not seen white *nipae* in many years", both forms still exist in Hawaii, and I have collected the white species on Oahu and on Molokai on several occasions since about 1960, although it is much less common than the species with buff-coloured wax. In some areas (e.g., Bird Park, Hawaii Volcanoes National Park), the latter has at times been very abundant.

## BIOLOGICAL DIFFERENCES

Strong biological evidence for the distinctness of the two "*nipae*-complex" species present in Hawaii is provided by the behaviour of the introduced encyrtid parasitoid *Pseudaphycus utilis*. Wherever I have found the white-wax species, I have reared this parasitoid from the confined mealybugs. However, I have never found any evidence of this or any other parasitoid attacking the buff-wax species. The failure of *P. utilis* to parasitize *N. nipae* in southern California, where apparently only the buff-wax species occurs, also has been noted (Flanders, personal communication).

Zimmerman (1948) stated that the specific name *pseudonipae* was generally applied in Hawaii to the "yellow forms occurring principally on palms", whereas *nipae* was applied to the white forms. When I first became interested in the *nipae*-sibling species problem during the 1960's, I established colonies of both species on potted palms (*Pritchardia* sp.) in the laboratory, and found that both would develop equally well on these palms and on guava (*Psidium guajava*), indicating that the host separation suggested by Zimmerman was untrue. This finding was also supported by host data from field collections.

Both the white- and the buff-wax species in Hawaii are bisexual, and a study of the adult males revealed that there is a consistent difference in the length of the tarsal claws of males from the two populations (Fig. 2). The claws of the buff-wax species are ca. 40µm long, greater than one-half the length of the distal tarsomere. Those of the white-wax species are ca. 32µm long; one-half, or slightly less, as long as the distal tarsomere. Approximately 25 males of each species were examined. This difference, coupled with the difference in the colour of the external wax of the females and the failure of the parasitoid of the white-wax form to develop in the buff-wax form, provides strong evidence that these two forms represent two distinct species.

Other minor morphological differences that were noted in both sexes of these two forms in Hawaii include apparent differences in the structure of the external wax coverings and the distribution of the multilocular disc-pores on the females, but these may prove not to be significant characters when populations from other areas are studied.

## NOMENCLATURE

The problem of the proper application of the names *Dactylopius nipae* Maskell and *Dactylopius pseudonipae* Cockerell required the examination of the appropriate type material for resolution. In 1974, I arranged the loan of Maskell's unmounted type-lot material of *D. nipae* from the collection of the DSIRO, Auckland, New Zealand. This material, from nipa palm, included a few mealybugs and, from these, it was possible to determine that the colour of the external wax covering was apparently buff (yellowish). Furthermore, the length of the tarsal claw on a somewhat fragmentary adult male also matched that of the males associated with the buff-wax species in Hawaii. I therefore concluded that the name *Dactylopius nipae* Maskell should be applied to the buff-wax species present in Hawaii and southern California, and probably also to other buff-wax populations outside of tropical America, although males of these are unknown to me.

The possibility that *D. pseudonipae* Cockerell might be a valid species in this complex necessitated an examination of the type material of that species. Cockerell's (1896) brief, unillustrated description of *pseudonipae* did not specify a type locality, but he did state that originally he saw specimens from a "Michigan hothouse" which he at first assigned to *nipae*, but later, after receipt of additional specimens from California, he changed his mind and named it as a new species, *pseudonipae*. Ferris (1950), after consulting with Harold Morrison (who stated that specimens collected in a California greenhouse and sent to Cockerell by Alexander Craw "do not exist in the National Collection and specimens from another source have been erroneously indicated as the types"), apparently assumed that California was the type locality. However, the "specimens from another source" that Morrison referred to are in fact labelled "*Dact. pseudonipae* / Palm. / Agr. College Mich. / July 30 '94 / (Davis)" and "Type." The label originally read "*Dact. nipae*", but someone, in the same handwriting (?Cockerell) inserted "*pseudo-*" above the line. This suggests to me that these slides contain the original Michigan hothouse material that Cockerell first identified as *nipae* but which he later changed to *pseudonipae* and are, therefore, the true cotypes of *D. pseudonipae* Cockerell. Eight female specimens on three slides that were part of this material were remounted, one specimen to a slide. One specimen was designated as a lectotype and the remainder paralectotypes of *Dactylopius pseudonipae* Cockerell. The slides, except one paralectotype retained by the writer, were returned to the U.S. National Collection.

On the basis of the described wax colour and female morphology (Cockerell's material included no males), these specimens appear to be conspecific with *D. nipae* Maskell, and Ferris's placement of *D. pseudonipae* as a junior synonym of *D. nipae* appears to be valid.

Although I am not entirely satisfied with the extent of the data available, I doubt that I will be able to do further work on the resolution of the *N. nipae* species complex, and wish to place on record the information that I now possess. I believe that, in the future, the application of molecular techniques will confirm the existence of a complex of sibling species, but I do not possess the resources needed to accomplish this.

## TENTATIVE KEY TO SOME SPECIES OF THE *NIPAECOCCUS NIPAE* COMPLEX

1. Female with ca. 100 or more multilocular disc-pores; conical setae on all abdominal cerarii relatively close together, their bases separated by less than a seta length; circulus relatively large, ca. 125µm long, more or less dumb-bell shaped; Florida. ........................................................................ *floridensis* n. sp.

- Female with 10-50 multilocular disc-pores; conical setae on anterior abdominal cerarii relatively widely separated, the distance between their bases greater than the length of one seta; circulus smaller, usually less than 80µm long, usually circular or nearly so ............................................................2

2. Adult male with middle and hind tarsal claws ca. 40µm long; adult female with buff-coloured external wax; widespread................*nipae* (Maskell)

- Adult male with middle and hind tarsal claws ca. 32µm long; adult female with largely white external wax; Mexico, Hawaii .....................*paranipae* n. sp.

Note: although *N. floridensis* runs to *N. nipae* in the key of Williams & Granara de Willink, it appears to differ markedly from the other species here placed in the *nipae*-complex, and may not be very closely related to true *nipae*.

## DESCRIPTIONS

### ***Nipaecoccus floridensis*** Beardsley, n. sp. (Fig. l).

ADULT FEMALE.

Mounted material: oval; ca. 1.4mm long; anal lobes moderately well developed, each with an apical seta ca. 160µm long. Antenna ca. 270-280µm long, 7-segmented. Legs well developed, hind trochanter + femur ca. 200µm long; hind tibia + tarsus ca 200µm long; hind tarsal claw ca. 25µm long. Hind coxa with numerous, fairly large translucent micropores, these absent on all other segments. Labium ca. 105µm long; distinctly shorter than clypeo-labial shield. Circulus conspicuous, about 110-120µm long by 110-115µm maximum width, constricted medially at intersegmental boundary, unsclerotized. Two pairs of dorsal ostioles present, rims not sclerotized. Anal ring ca. 70-75µm wide, with 6 ring setae 80-100µm long.

Anal lobe cerarii each with 2 conical setae ca. 20-26µm long, several auxillary setae, a few trilocular pores and 1-3 circular discoidal pores slightly larger than triloculars, on margin of a irregular sclerotized area that extends onto venter but is confined to apical part of lobe. Anterior abdominal cerarii each with 2 or 3 conical setae, often as long as anal lobe pair or nearly so, with bases separated by less than length of one seta; plus a few trilocular pores; usually with a few auxillary setae; surrounding derm unsclerotized. Metathoracic cerarii similar, with 2 or 3 conical setae; but anterior cerarii represented by more or less irregularly scattered marginal conical setae. Interantennal cerarii fairly well-defined, each containing a loose group of 4 or 5 conical setae.

Dorsal surface of most abdominal segments each with a transverse mesal row of 3 conical setae of variable size, mostly ca. 15-20µm long, a few such setae scattered on dorsum of head and thorax; small, spiniform setae, 10-14µm long, scattered sparsely on dorsum. Trilocular pores scattered evenly over dorsum; no dorsal ducts discernible.

Venter of abdominal segments behind circulus with 100 or more multilocular disc-pores, arranged in bands near posterior segment margins as illustrated; no such disc-pores noted anterior to circulus, on lateral margins or on dorsum. Ventral setae sparsely scattered, slender, more elongate than dorsal setae, up to ca. 30µm long on head and around vulva. Trilocular pores sparsely scattered on venter; 20-30 very small tubular ducts, without discernible rims or collars, present on venter between legs; small discoidal pores, most slightly larger than triloculars, very sparsely scattered on venter.

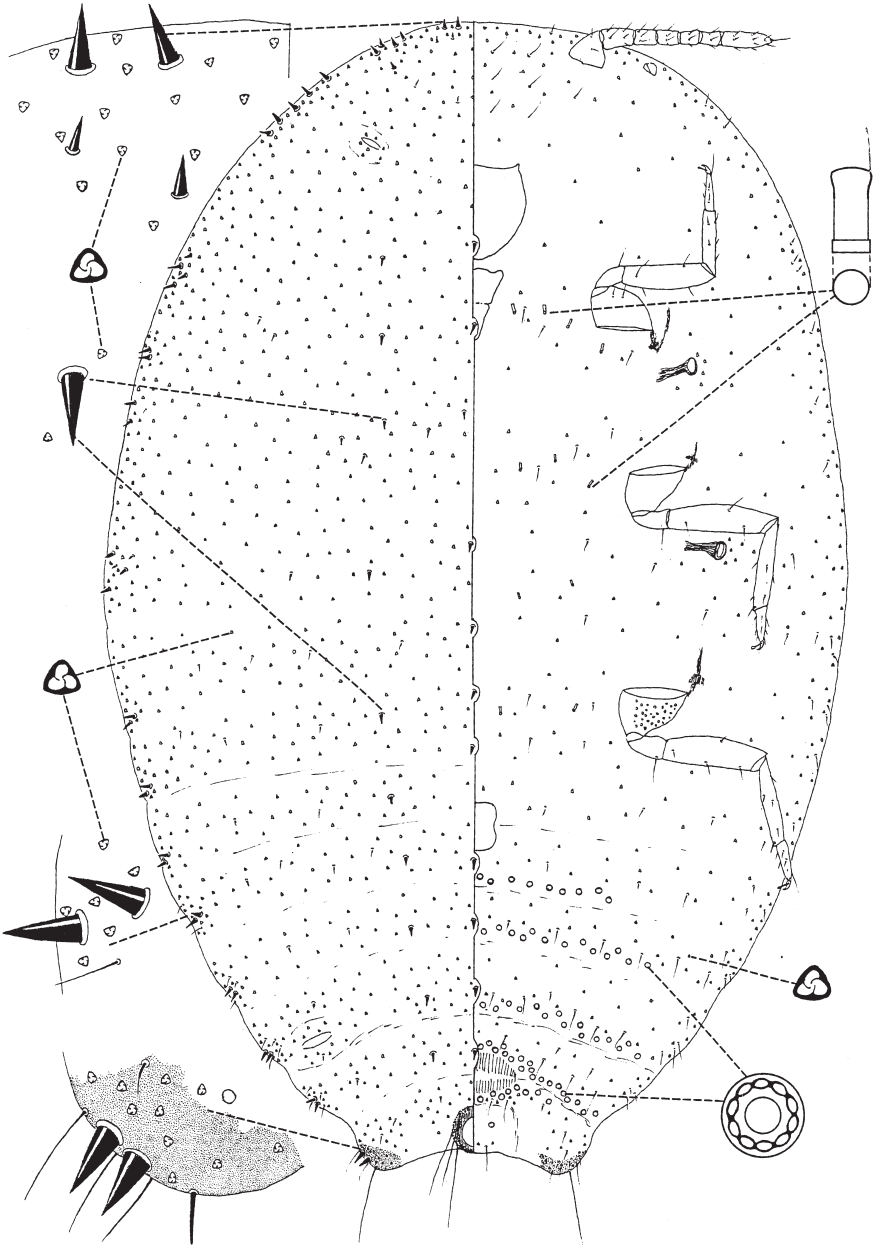

Figure l. *Nipaecoccus floridensis* **n.sp**., dorsal and ventral aspects and details.

**Material examined:** Holotype ♀ and allotype ♂ on one slide: Florida, Daytona Beach, 20.IV.1967, John N. Pott, coll., on *Acoelorrhaphe wrightii* (saw palmetto) (Palmae) (USNM). One ♀ paratype and one ♂ paratype on one slide: data as holotype (USNM).

**Remarks:** Females of *N. floridensis* run to *N. nipae* in all available keys, including that of Williams & Granara de Willink (1992). It differs from *N. nipae* in possessing: (i) a much larger number of ventral multilocular disc-pores, (ii) a larger circulus, and (iii) the conical setae of the abdominal cerarii all with their bases relatively close together.

Adult males associated with the females described above have relatively short tarsal claws, ca. 32µm long, and are similar to *N. paranipae* n. sp. from Hawaii.

I have not seen *in situ* material of this species, and do not know the colour or form of the external wax covering.

### ***Nipaecoccus paranipae*** Beardsley, ***n. sp.*** (Fig. 2).

ADULT FEMALE.

Mounted material: virtually identical to females of *N. nipae*, except in distribution of ventral multilocular disc-pores, with at least 2 to 4 such disc-pores present near posterior margin of abdominal segment IV (segment bearing posterior half of circulus) (multilocular disc-pores are usually absent on this segment on *N. nipae*, although a few specimens have one or two).

Adult male mounted on microscope slide very similar to that of *N. nipae*, but with tarsal claws ca. 32µm long (vs. ca. 40µm long in *N. nipae*).

**Material examined:** holotype ♀, allotype ♂ and paratype ♂ on one slide: Hawaiian Is., Oahu I., Punahou, Honolulu, 31.iii,1966, S. H. Au, coll., on *Areca* sp., prob. *lutescens* (Palmae) (USNM). Twenty ♀♀ and 30 ♂♂ paratypes mounted on 11 slides: data as holotype (USNM; Bishop Museum, Honolulu).

**Remarks:** the slide-mounted females of *N. nipae* and *N. paranipae* are almost indistinguishable, and the slight difference in the distribution of the multilocular disc-pores noted in Hawaiian populations may not hold when additional extra-Hawaiian populations are studied. In the field, the two species are easily recognized by the colour of the external wax covering, as discussed previously. The obvious difference in the lengths of the tarsal claws of the adult males appears to be the best morphological character available to separate slide-mounted specimens of these two species.

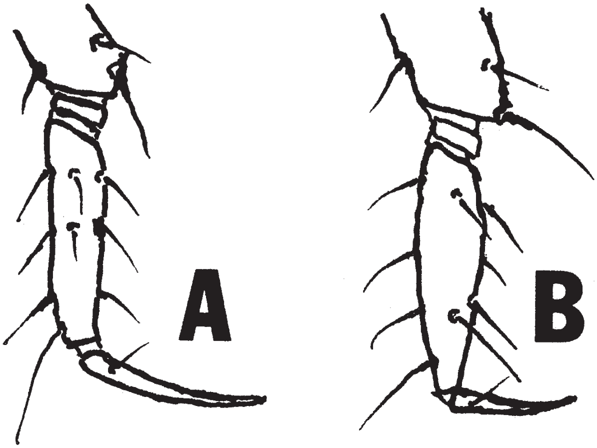

Figure 2. Middle tarsus and tarsal claw of adult male: A, *Nipaecoccus nipae* (Maskell) (specimen from San Diego, California); B, *Nipaecoccus paranipae* **n.sp**. (specimen from Honolulu, Hawaii).

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COOK, L.; GULLAN, P.G.
*Division of Botany and Zoology, The Australian National University,*
*Canberra, ACT, 0200, Australia.*

# ARE THE ENLARGED DUCTS OF *ERIOCOCCUS* (HEMIPTERA: COCCOIDEA: ERIOCOCCIDAE) PLESIOMORPHIC?

## ABSTRACT

ARE THE ENLARGED DUCTS OF *ERIOCOCCUS* (HEMIPTERA: COCCOIDEA: ERIOCOCCIDAE) PLESIOMORPHIC?

Borchsenius (1948) separated the genus *Eriococcus* Targioni-Tozzetti (Eriococcidae) from *Acanthococcus* Signoret and *Gossyparia* Signoret on the basis of the occurrence of enlarged ducts in the adult female of the type-species, *E. buxi* (Fonscolombe). Enlarged ducts are found also in another Palaearctic species, a Chilean eriococcid and several Australian species of *Eriococcus*. The enlarged ducts of *Eriococcus* are similar in appearance and distribution to the large oral rim ducts of *Ferrisia* Fullaway (Pseudococcidae) and the dorsal tubercle ducts of *Ceronema* Maskell and some species of *Pulvinaria* Targioni-Tozzetti (Coccidae). It is argued that the enlarged ducts in taxa from each of these three families are homologous and therefore may be plesiomorphic for the Eriococcidae. If so, the possession of enlarged ducts is not of itself sufficient to justify the separation of *Eriococcus* as defined by Borchsenius.

Key words: macrotubular ducts, microtubular ducts, Aclerdidae, Cerococcidae, Coccidae, Kermesidae, Lecanodiaspididae, Putoidae, *Acanthococcus aceris*, *Ceronema banksii*, *C. dryandrae*, *Eriococcus buxi*, *E. eucalypti*, *E. williamsi*, *Exallococcus laureliae*, *Ferrisia virgata*, *Greenisca*, *Kaweckia*, *Lagosinia strachani*, *Pulvinaria dodonaeae*, *Rhizococcus*, phylogeny, morphology, wax.

## INTRODUCTION

Several scale insect families are defined on plesiomorphic characters. The Margarodidae are defined by symplesiomorphies: characters that occur in sister groups to the scale insects and are therefore not shared derived characters unique to the margarodids (Miller, 1984). As a result, the Margarodidae have thus far resisted rigorous testing of monophyly (Miller, 1984; Foldi, 1997). The Eriococcidae also are problematic. Cox & Williams (1988) argued that the Eriococcidae are primarily separated from other coccoid families by the absence of the characters that help define other families rather than by the possession of unique characters (autapomorphies) that define the Eriococcidae as a monophyletic group. For example, all of the characters used by Ferris (1957) and Hoy (1962) to define the Eriococcidae (anal lobes, well-developed antennae, well-developed legs, tubular ducts, sessile pores and anal ring) are found also in other scale insect families. It appears likely that the anal lobes of eriococcids are homologous with those of coccids (Cox & Williams, 1988; Hodgson, 1995). The macrotubular ducts with cupped inner ends found in eriococcids are also common in the Aclerdidae, Cerococcidae, Lecanodiaspididae, Coccidae (Williams, 1985b; Cox & Williams, 1988), Kermesidae and Putoidae. Microtubular ducts are found in many coccoid taxa, including the Pseudococcidae, and their morphology often differs even among eriococcid taxa. The anal ring structure is common to many of the neococcoid families and quinquelocular and multilocular pores are shared with most scale insect families. If these structures are homologous among the Eriococcidae and the other scale insect families in which they occur, then either the structures are plesiomorphic for the eriococcids (occurred in a common ancestor of eriococcids and the other taxa in which they are found), or the Eriococcidae are not monophyletic.

A lack of morphological synapomorphies also is a problem in respect of some genera within the Eriococcidae. One feature which has been used for generic diagnosis is the presence of enlarged ducts in adult females of Eriococcus *sensu* Borchsenius (1948), although not all authors accept this delineation. The most important characters for separating *Eriococcus* Targioni-Tozzetti from *Acanthococcus* Signoret are the absence of enlarged ducts in *Acanthococcus* and the presence in *Acanthococcus* of two ventral setae on each anal lobe (one in *Eriococcus*) and two pairs of setae on the basal labial segment (one pair in *Eriococcus*) (Williams, 1985b). Williams (1985b) considered these characters insufficient to warrant separation of the two genera. More recently, however, Miller & Gimpel (1996) restricted *Eriococcus* to those species with enlarged ducts and assigned the remaining species to *Acanthococcus. Eriococcus* has precedence over *Acanthococcus* whenever the two names are held to denote a single taxon (Melville, 1982). *Eriococcus buxi* (Fonscolombe) has been designated the type species of *Eriococcus* and *Acanthococcus aceris* Signoret is the designated type species of *Acanthococcus* whenever the two genera are considered different taxa (Melville, 1982).

There are several implications of treating the presence of enlarged ducts as diagnostic for a genus. Firstly, both *Eriococcus* (with enlarged ducts) and *Acanthococcus* (no enlarged ducts) should be recognised. Secondly, not all eriococcid species with enlarged ducts, such as *Exallococcus laureliae* Miller and González, clearly fit into either of these two genera. Thirdly, *Eriococcus sensu lato* is the most speciose eriococcid genus and, until recently, this generic name has been used for most species worldwide; delineation of *Eriococcus* based on the presence of enlarged ducts would restrict the application of this name to just a few species.

Williams (1985b) advocated the use of *Eriococcus sensu lato*, synonymising

*Eriococcus*, *Gossyparia* Signoret, *Acanthococcus*, *Rhizococcus* Signoret, *Greenisca* Borchsenius and *Kaweckia* Koteja & Zak-Ogaza, "until the world fauna is better understood". For nomenclatural stability, it is important to determine whether the occurrence of enlarged ducts warrants the separation of *Eriococcus*. Here it is argued that the enlarged ducts of eriococcids are homologous to those of some pseudococcids and coccids and therefore their mere presence or absence cannot be used to justify a distinction between *Eriococcus* and *Acanthococcus*.

## MORPHOLOGY AND DISTRIBUTION OF ENLARGED DUCTS

### 1. **Eriococcidae**

In all eriococcids in which enlarged ducts are present, the enlarged ducts are cylindrical, sometimes longitudinally ridged, and about 35 to 45µm long (Fig. 1A-C) with a blunt inner end from which a fine inner ductule arises. The external rim of the duct is circular and sclerotised. In *E. buxi*, there are no setae near the rim but in *E. williamsi* Danzig (referred to as *E.* sp. near *buxi* in Williams, 1985b) and the Australian *E. eucalypti* species-group, the enlarged duct is sometimes surrounded by enlarged (broadly lanceolate) setae. The enlarged ducts of the *E. eucalypti* species-group produce very long glassy wax filaments. The rim of the enlarged ducts of *Exallococcus laureliae* has been described as similar to that of oral-rim ducts of some pseudococcids (Miller & González, 1975).

The distribution of enlarged ducts varies slightly among eriococcid taxa. *Eriococcus buxi* has one or two pairs of enlarged ducts submarginally on the dorsum of the head (Williams, 1985b), whereas the *E. eucalypti* species-group has up to six pairs submarginally on the posterior abdominal segments and, in some specimens, several on the head and thorax. Enlarged ducts are totally absent in some individuals of some populations of the *E. eucalypti* species-group. *Eriococcus williamsi* has up to 17 pairs of enlarged ducts submarginally around the entire dorsum with others sometimes also present near the midline of the dorsum (Williams, 1985b). The pattern in *Exallococcus laureliae* is similar to that in *E. williamsi* although there are about 23 pairs present submarginally (Miller & González, 1975). In those eriococcid species for which crawlers have been examined (*E. buxi*, the *E. eucalypti* species-group and *Exallococcus laureliae*), enlarged ducts are expressed only in adult females.

There is variation in the appearance of the enlarged ducts among eriococcid species. For example, the blunt inner end of the enlarged duct of *E. buxi* has a quinquelocular appearance and that of *E. eucalypti* sp. 1 is flower-shaped.

### 2. **Coccidae**

In adult females of *Ceronema banksiae* Maskell, the enlarged ducts are about 50µm long with a blunt inner end (Fig. 1D & E) with a fine ductule. They sometimes appear to be longitudinally ridged (Hodgson, 1994). The rim is sclerotised and has several setae and numerous tubular ducts associated with it. There are about 27 pairs of enlarged setae submarginally around the dorsum. The enlarged ducts of *Ceronema dryandrae* Fuller appear to produce long glassy wax filaments which are most noticeable in young adult females and later become incorporated in the waxy test of the mature adult female. About 5 pairs of enlarged ducts are present submarginally in crawlers of *C. banksiae*, although they are smaller (about 20µm long) than those of adult females and there are no setae or tubular ducts associated with the sclerotised rim (Fig. 1F).

The adult female of *Pulvinaria* sp. near *dodonaeae* has approximately the same number and distribution of enlarged ducts as *Ceronema*. Each enlarged duct is about 35µm long and the sclerotised rim has several setae but only two smaller ducts associated with it (Fig. 1G & H). The smaller ducts are very similar in appearance to the microtubular ducts of some eriococcids. The blunt inner end of the enlarged tubular ducts in *C. banksiae* and *P.* sp. near *dodonaeae* has the appearance of a figure-of-eight-shaped pore.

Enlarged ducts are present also in some other coccids, such as *Lagosinia strachani* (Cockerell), in which there are about five pairs submarginally on the head and one to three pairs posteriorly on the abdomen (Hodgson, 1994).

### 3. **Pseudococcidae**

Enlarged ducts are present in *Ferrisia* Fullaway (McKenzie, 1967; Williams, 1985a) and numerous other mealybug genera (McKenzie, 1967). In *Ferrisia virgata* (Cockerell), the enlarged ducts (Fig. 1I) are about 35µm long and sometimes appear to be longitudinally ridged. They have a blunt inner end which has a quinquelocular appearance and a fine inner ductule. The rim is sclerotised and has several associated setae. There are up to 40 or more pairs of enlarged ducts submarginally around the dorsum and others present medially or scattered elsewhere on the dorsum. The dorsum of *F. virgata* has numerous glassy waxen rods (McKenzie, 1967) and it appears from their number and distribution that they are produced by the enlarged ducts. Crawlers of *F. virgata* do not possess enlarged ducts.

## DISCUSSION

The enlarged ducts of representatives of the Eriococcidae, Pseudococcidae and Coccidae are very similar in morphology. All are cylindrical, between 35

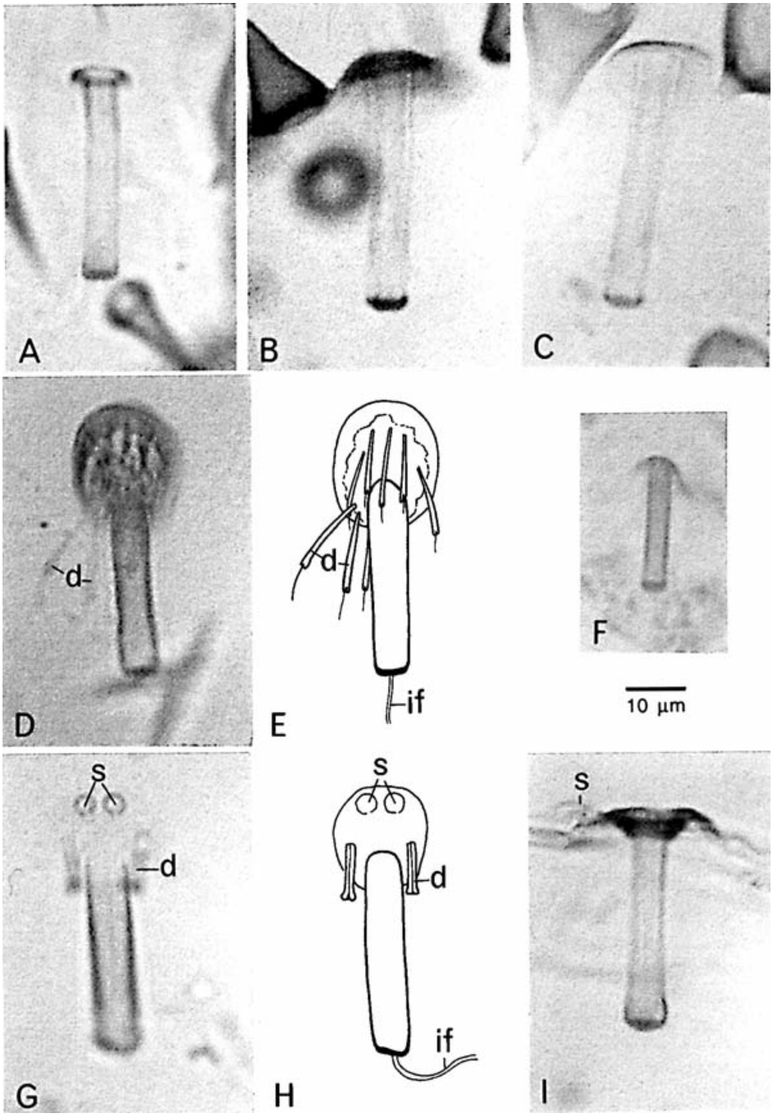

Figure 1. The enlarged duct of (A) *Eriococcus buxi* (Eriococcidae), (B) *Eriococcus eucalypti* group sp. 1 (Eriococcidae), (C) *Eriococcus eucalypti* group sp. 2 (Eriococcidae), (D) *Ceronema banksii* (Coccidae), (E) *Ceronema banksii* showing associated ducts (Coccidae), (F) *Ceronema banksii* (Coccidae) (crawler), (G) *Pulvinaria* sp. near *dodonaeae* (Coccidae), (H) *Pulvinaria* sp. near *dodonaeae* (Coccidae) showing associated ducts, (I) *Ferrisia virgata* (Pseudococcidae).
Associated ducts (d), inner filament (if) and setae associated with the rim (s) are indicated. The scale bar is the same for each figure.

and 50µm in length in the adult female, sometimes longitudinally ridged and have a blunt inner end with inner ductule. All have a sclerotised rim although the degree of sclerotisation varies among species. In at least some representatives of each of the three families, the enlarged ducts have associated setae. In addition, the appearance of the wax produced by the enlarged ducts appears to be similar in those species for which it has been observed.

The enlarged ducts display the same distributions in each of the three families. In *E. williamsi*, *Ex. laureliae*, *C. banksiae*, *P.* sp. near *dodonaeae* and *F. virgata*, enlarged ducts are located submarginally around the dorsum. In *E. williamsi*, *Ex. laureliae* and *F. virgata*, some enlarged ducts are also present medially on the dorsum. However, in *E. buxi* and the *E. eucalypti* species-group, *L. strachani* and crawlers of *C. banksiae*, the ducts are restricted to only a part of the distribution found in adult females of the other species.

It is unlikely that the morphology and distribution of enlarged ducts would be so similar in representatives of each of these families if they had evolved independently. The most parsimonious explanation is that a common ancestor of the Eriococcidae, Pseudococcidae and Coccidae possessed enlarged ducts with a sclerotised rim and associated setae and, possibly, ducts and/or pores. Under such a scenario, enlarged ducts are plesiomorphic for these families. If plesiomorphic, the presence of enlarged ducts in only a few representatives of each of the three families implies:

- that those taxa possessing enlarged ducts are basal within their respective families and the ducts have been lost in other more derived lineages, or
- that these taxa are not basal and the ducts have been lost many times, or
- that the expression of the ducts is plastic and they are not consistently expressed.

The first two possibilities cannot be addressed at present because there are no robust phylogenetic estimates available. The third alternative, however, is supported by the observation that, within populations of *E. eucalypti*, there is differential expression of enlarged ducts. Some adult females have enlarged ducts while others from the same host stem do not (Gullan & Cook, unpublished). Additionally, in those species discussed in this study, enlarged ducts of eriococcids and pseudococcids are expressed only in adult females whereas they are expressed in adult females and crawlers of *C. banksiae*. The enlarged ducts in crawlers of *C. banksiae* are more similar to those of adult female eriococcids and *Ferrisia* than are those of adult females of *C. banksiae*. Perhaps the enlarged ducts of crawlers of *C. banksiae* reflect better the homology of coccid enlarged ducts with those of eriococcids and pseudococcids than do those of adult female coccids.

If enlarged ducts are plesiomorphic for the three families discussed here, there are major implications for the inclusion of enlarged ducts as a character in systematic studies. The presence or absence of enlarged ducts should not be used as character states in data sets containing representatives with enlarged ducts from only one family since the presence of such ducts may be interpreted as a shared derived character state. A group of plesiomorphic character states may be mistakenly interpreted as shared derived character states if such features are not represented among the outgroups chosen. The result may be an inverted tree topology relative to interpretation as plesiomorphy.

The loss and reduction of features in adult female scale insects is a problem for the phylogenetic study of coccoids. Enlarged ducts may be only one of a number of characters that may be interpreted incorrectly as derived for a particular group, primarily because of loss or non-expression in other taxa or a failure to recognise homology in other groups. Studies of ontogeny, ultrastructure and physiology have the potential to help elucidate the evolution of structures which are commonly described in adult female scale insects and for which homology is otherwise difficult to assess. Thus, a more thorough knowledge of the comparative morphology and function of the cuticular structures of coccoids is essential to the development of a phylogenetically-based classification.

Clearly, the morphology of enlarged ducts is not identical among all taxa discussed since the enlarged ducts of adult females of eriococcids, coccids and pseudococcids are distinguishable. In addition, the setae, ducts and pores surrounding the enlarged duct contribute to the final appearance of the insect's waxy covering and this varies among taxa. Thus, some distinguishing features of the enlarged ducts, such as the shape of the inner end and differences in the sclerotised rims seen in the coccids *C. banksiae* and *P.* sp. near *dodonaeae* may provide informative characters for systematic studies.

Although enlarged ducts may not be useful for distinguishing between *Eriococcus* and *Acanthococcus*, other morphological characters such as the labial features described by Koteja (1974) may prove to be informative at the genus level. This cannot be addressed fully until robust phylogenies, preferably using independent data such as nucleotide sequences, are available to support morphological studies.

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FONTANA, P.; PELLIZZARI, G.
*Università di Padova, Istituto di Entomologia Agraria*
*Agripolis, via Romea 16 - 35020 Legnaro PD, Italy*

# ON THE IDENTITY OF THE GENUS *LECANOPSIS* TARGIONI TOZZETTI.

## ABSTRACT

ON THE IDENTITY OF THE GENUS *LECANOPSIS* TARGIONI TOZZETTI.

The genus *Lecanopsis* Targioni Tozzetti was generally accepted by coccidologists until 1994. In that year, on the basis that the exact facies of the genus was not known and that there was no type material, it was proposed that all the species previously included in *Lecanopsis* be transferred to the genus *Paralecanopsis* (synonymised with *Lecanopsis* in 1980) and that only the type species, *L. rhyzophila* Targioni Tozzetti, be retained in *Lecanopsis,* thus allowing a proper diagnosis of this group. In order to clarify the identity of the genus *Lecanopsis,* we have carefully checked the original descriptions of the genus and of its type species by Targioni Tozzetti and by Signoret. This work has highlighted some small mistakes in the translation of the original description from Italian or Latin to French and also some omissions, and these could have led to the conclusion that the real facies of this genus was not known and that the type species, *L. rhyzophila,* could not be congeneric with the other species currently included in *Lecanopsis.* However, some original drawings of *Lecanopsis* by Targioni Tozzetti, which he sent to Signoret in 1872, have been discovered in the Museum Nationale d'Histoire Naturelle, Paris. On the basis of this new information, and with the support of the authoritative opinion of two members of the International Commission of Zoological Nomenclature, we consider that (i) the genus *Lecanopsis* is a valid genus and propose (ii) that the species of *Lecanopsis* recently transferred to the genus *Paralecanopsis* Bodenheimer be re-assigned to the genus *Lecanopsis* Targioni Tozzetti.

Key words: host plants, *Asperula*, *Rhizobium*, *Rhyzobium*, *Agropyrum*, *Aclerda subterranea*, *Paralecanopsis turcica*, *Lecanopsis formicarum*, history, illustrations, behaviour.

## INTRODUCTION

Prior to 1994, the identity of the genus *Lecanopsis* Targioni Tozzetti (Coccidae) (Targioni Tozzetti, 1868) was generally accepted by all coccidologists (Borchsenius, 1957; Danzig, 1980; Tereznikova, 1981; Martin Mateo, 1984; Kosztarab & Kozár, 1988; Tang, 1991; Ben-Dov, 1993). Up to that time, no coccidologists had doubted the identity of the genus even though some authors had indicated that the genus was in need of revision, mainly because of the poor description of several species and of insufficient knowledge of the nymphal stages (Danzig, 1980; Kosztarab & Kozár, 1988; Longo *et al.*, 1994).

In 1994, Hodgson, during his valuable redescription of the type species of the genera in the Family Coccidae, pointed out the difficulty of clearly identifying the facies of the genus *Lecanopsis* and of its type species, *L. rhyzophila* Targioni Tozzetti. He proposed transferring all the species previously included in *Lecanopsis* (with the exception of the type species) to the genus *Paralecanopsis* Bodenheimer (synonymised with *Lecanopsis* by Ben-Dov, 1980) in order to allow a proper diagnosis of this group. The main arguments to support this proposal were the following:

1) That the meagre description given by Targioni Tozzetti (1867) together with the short description by Signoret (1874) did not allow for the clear identification of either the genus *Lecanopsis* or the species, *L. rhyzophila.* Because the original material had quite likely been lost, the real identity of the type species could never be clarified.

2) Signoret's statement that the type species of the genus, *Lecanopsis rhyzophila,* had been collected "off the roots of its host *Asperula* (Fam. Rubiaceae)". It is known that all other species currently placed in the genus *Lecanopsis* live on the underground parts of Gramineae.

3) The oldest known slides labelled "*Lecanopsis*" refer in fact to *Aclerda subterranea* Signoret (Fam. Aclerdidae).

For the above mentioned reasons, it was hypothesised that the species currently placed in the genus *Lecanopsis* could not be congeneric with *L. rhyzophila* and so it was suggested that all the species currently placed in *Lecanopsis,* apart from *L. rhyzophila*, should be transferred to the genus *Paralecanopsis* Bodenheimer, so that a proper diagnosis of the former group could be attempted. As previously reported, the genus *Paralecanopsis* was synonymised with *Lecanopsis* (Ben-Dov, 1980) and the type series of *P. turcica* (the type species) is preserved in the Department of Agriculture, Rehovot, Israel.

In 1995, we started a revision of the genus *Lecanopsis*, at that time consisting of 18 species (including *Paralecanopsis turcica* Bodenheimer), mainly distributed in the Palaearctic region. The first question to be answered was to establish the identity of the type species of the genus. A thorough investigation and comparison with the original descriptions by Targioni Tozzetti and Signoret, and those of other authors who have dealt with this genus, has been carried out. The Targioni Tozzetti material preserved in Florence has been checked and, thanks to the help of Evelina Danzig and Daniele Matile-Ferrero, the Signoret collection in the Natural History Museum in Vienna has also been checked for type material but none was found. Moreover, we had the opportunity of seeing an original unpublished drawing by Targioni Tozzetti of the genus *Lecanopsis*, discovered by Daniele Matile-Ferrero in the library of the Société Entomologique de France in Paris. In addition, the availability of living specimens of *Lecanopsis* collected in different Italian localities allowed a comparison of these with the drawings published by Signoret and by Targioni Tozzetti in his unpublished paper. Evelina Danzig, a well-known coccidologist, and two members of the International Commission of Zoological Nomenclature, were asked for their opinions on the conclusions of this study and completely agreed with them.

## HISTORY OF GENUS AND DISCUSSION

1. In 1867, Targioni Tozzetti mentioned a *Rhizobium* sp., briefly described the pores of the derm and also provided a figure with a caption of the derm of this genus. In a footnote to his paper, he wrote: "to this genus belongs a large species that I found **near** the roots of an *Asperula*". In 1868, he made *Rhizobium* (amended to *Rhyzobium*) a synonym of the new genus *Lecanopsis* and assigned *Lecanopsis rhyzophila* n. sp. to it. In 1874, Signoret, on the basis of notes sent to him by Targioni Tozzetti, published the first formal description of the genus *Lecanopsis* and of the species *L. rhyzophila*. He included the Latin description of the genus sent to him by Targioni Tozzetti and then briefly described the species *L. rhyzophila*. In the same paper, Signoret also provided drawings of an adult female and the antenna of *L. rhyzophila*. Since Signoret states in his description that he had never seen this species, we wondered how Signoret could have drawn a species he had never seen. This question was solved with the help of Daniele Matile-Ferrero, who discovered among the drawings of Signoret, a page with the drawings of *Lecanopsis* which Signoret had been sent in 1872 by Targioni Tozzetti. The two drawings of *Lecanopsis* (adult living female and antenna) published by Signoret in 1874 are identical. Two other drawings, of an adult female from the venter and an anterior leg, are still unpublished.

The illustrations by Targioni Tozzetti (published and unpublished) and the short descriptions provided in 1867 and 1874 allow for the identification of the genus: if we compare the drawings by Targioni Tozzetti with some features of a living adult female *Lecanopsis*, we can see that they are surprisingly similar. For instance, the drawing of the derm with pores provided in 1867 agrees with the dorsal derm with preopercular pores present in all *Lecanopsis* species.

The second species to be included in the genus *Lecanopsis* was *L. formicarum* (Newstead, 1893). In assigning his new species to the genus *Lecanopsis*, on the basis of the description presented by Signoret, Newstead wrote "I have not the least hesitation in placing it in this genus". Actually *L. formicarum* is one of the most common and best known species in the genus *Lecanopsis*.

2. One of the main objections to the fact that the species described by Targioni Tozzetti could not belong to the genus *Lecanopsis* is that it was collected on the roots of a species of *Asperula* (Rubiaceae), whereas it is well known that the species currently assigned to *Lecanopsis* live on the underground parts of Gramineae. In reality, Targioni Tozzetti (1867) clearly wrote that the species was collected **near** the roots of an *Asperula* plant. In translating Targioni's notes from Italian to French, Signoret made a mistake and reported that the species was found **on** the roots of an *Asperula*. From the biology of the genus *Lecanopsis*, we know that the adult females have no connection with the host plant, because, just after emergence, they leave the host plant (a Gramineae) and wander on the ground, stopping and laying eggs near different plants which are not the host plant of the species. This behaviour was observed by Boratynski *et al.* (1983) with *L. formicarum* Newstead and by us with *L. clodiensis* (Pellizzari) (see Pellizzari & Fontana, this volume). So, the fact that an adult female *Lecanopsis* has been collected near the roots of an *Asperula* does not mean it is the host plant but does fit the wandering habit of this genus.

3. The oldest known slides labelled "*Lecanopsis*" refer in fact to *Aclerda subterranea* Signoret. These slides were sent to Comstock by Signoret, arriving in 1882 (Hodgson, 1994) and were deposited in the United States National Museum, Washington. In 1872, Signoret told the members of the Société Entomologique de France about the scale insects that he had collected during a trip to Southern France and Italy. In his lecture, published in the "Séances de l'Année 1872" (Annales de la Société Entomologique de France, p. XXXVI), he reported that he had collected many specimens of *Lecanopsis rhyzophila* on *Agropyrum* (Gramineae). In the same year, he received from Targioni Tozzetti the page with the drawings of *Lecanopsis rhyzophila*. Two years later (1874), Signoret published the descriptions of both *Lecanopsis rhyzophila* Targioni Tozzetti and *Aclerda subterranea* Signoret. It is important to note that Signoret himself, in his description of the genus *Aclerda*, reported that he had thought that this species was a *Lecanopsis* at first but, when describing *A. subterranea* two pages later, he indicates that he had been wrong when he had thought he had found *L. rhyzophila* in 1872. Therefore, it appears that, after having received the description and the drawings of *Lecanopsis* from Targioni Tozzetti in 1872, Signoret was able to discriminate between the two species and consequently described *Aclerda subterranea* as a new species.

The slides labelled "*Lecanopsis*", pertinent to *Aclerda subterranea*, preserved in the USNM may refer to the first error in identification of the species reported in 1872 and admitted by Signoret himself in 1874. No confusion between the two species can be credited to Signoret after 1874.

## CONCLUSIONS

1. Although the original description of *Lecanopsis* is brief, it does fulfil the requirements of the ICZN to validate a generic name.

2. The description and the drawings by Targioni Tozzetti (both those published by Signoret and the unpublished ones) allow for the identification of the genus *Lecanopsis* and, therefore, it can be concluded that it is a valid genus. Moreover, the name *Lecanopsis* has been uniformly accepted and widely used by all specialists and should be conserved.

3. The type species, *Lecanopsis rhyzophila*, has definitely been lost. Attempts to locate the original material of Targioni Tozzetti, both in Florence and in the Signoret collection in Vienna, were unsuccessful. Attempts to find specimens of *Lecanopsis* in the type locality (Monte Morello, Florence) in order to designate a topotype have also failed to-date. Currently, *Lecanopsis rhyzophila* is an unrecognisable species or a *species inquirenda.*

4. The authors propose that the species of *Lecanopsis*, recently transferred to the genus *Paralecanopsis* Bodenheimer, be re-assigned to the genus *Lecanopsis* Targioni Tozzetti.

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GHABBOUR, M.W.
*Plant Protection Research Institute, Agricultural Research*
*Center, Ministry of Agriculture, Dokki, Egypt.*

# DESCRIPTIONS OF THE FIRST-INSTAR NYMPHS OF THREE SPECIES OF *LEPIDOSAPHES* SHIMER AND A SPECIES OF *INSULASPIS* MAMET (HEMIPTERA: DIASPIDIDAE).

## ABSTRACT

DESCRIPTIONS OF THE FIRST-INSTAR NYMPHS OF THREE SPECIES OF *LEPIDOSAPHES* SHIMER AND A SPECIES OF *INSULASPIS* MAMET (HEMIPTERA; DIASPIDIDAE).

The first-instar nymphs of two species of the genus *Lepidosaphes* (namely *L. beckii* (Newman) and *L. ficus* (Signoret)) are described and illustrated and compared with the first-instar nymph of *L. ulmi*. The first-instar nymph of *Insulaspis tapleyi* (Williams) is also described and illustrated, and the differences between *I. tapleyi* and *I. pallidula* (Green) are discussed. Keys are provided for the separation of the first-instar nymphs of these five species.

Key words: Egypt, *Citrus*, *Ficus*, *Mangifera indica*, *Psidium*, *Juniperus*.

## INTRODUCTION

The first-instar nymphs of several species of diaspidid have been described and their importance in species and generic diagnoses has been emphasised by several authors. Thus, Takagi (1969) provided excellent descriptions of the first instars of seven diaspidid tribes, Howell & Tippins (1975) described the first instars of *Haliaspis* and then (1976) the nominal type species of eight diaspidid tribes, including the Lepidosaphidini, while Ghabbour (1995) described the first instars of three species of *Aonidiella* Berlese & Leonardi.

The genus *Lepidosaphes* Shimer is quite large and contains a number of species of considerable economic importance, particularly *L. beckii* (Newman), *L. ficus* (Signoret) and *L. ulmi* (Linnaeus). The description of the first-instar nymphs of these three species is, therefore, important for a proper understanding of this genus. The first-instar nymphs of *L. beckii* and *L. ficus* are described and illustrated below and compared with the first-instar of *L. ulmi*, previously described by Howell & Tippins (1976). In addition, because the genus *Insulaspis* Mamet is close to *Lepidosaphes*, the 1st-instar nymph of *Insulaspis tapleyi* (Williams) is also described and illustrated and compared with the first-instar nymph of the very similar to *I. pallidula* (Green). Borchsenius (1963) assigned 32 species to the genus *Insulaspis* but there is very little information on the first instars of this genus. The nymphs of

*Lepidosaphes* and *Insulaspis* are compared and keys are provided for the separation of the five species discussed in this paper.

All specimens are deposited in the Collection of the Ministry of Agriculture, Plant Protection Research Institute, Department of Scale Insects, Nadi El-Said Str., Dokki-Giza, Egypt.

### *LEPIDOSAPHES* Shimer

*Lepidosaphes* Shimer, 1868: 372.

Type species: *Lepidosaphes ulmi* L.

### ***Lepidosaphes beckii*** (Newman) (Figs 1,4a,5a)

**First-instar nymph**.

*Body*: elliptical, about 310µm long and 150µm wide; derm membranous except for sclerotised areas on pygidial margin. Verrucose structures present on cephalic region between eyespots and on prepygidial region. Caudal setae long and slender; length about 75µm. Anus minute, removed about 2x to 3x its diameter from pygidial apex.

*Pygidial margin*: median pair of lobes reduced to small projections; second pair of lobes well developed, about 20µm long, 8µm wide, with 2 notches on both sides; third pair of lobes reduced to sclerotised projections. Gland spines and setae present (see under venter).

**Dorsal surface**:

*Ducts*: a single pair of large, one-barred 8-shaped ducts present anteriorly on cephalic region.

*Setae*: on head: two pairs of long setae present on margin anteriorly and two setae submedially posterior to each 8-shaped duct. On thorax and abdomen: with a row of submarginal setae present, one on each of posterior six abdominal segments, and with a row of seven pairs of submedian setae on metathoracic and abdominal segments.

**Margin & ventral surface**:

*Antennae*: six-segmented, all segments annulated except segment I. Segment VI subequal in length to segments II to V inclusive. Segments I and II each with a long seta; segment V with a stout seta; segment VI with 5 stout setae and 2 flagellate setae terminally.

*Legs*: well developed, posterior legs slightly larger. All digitules knobbed and exceeding claw in length (tarsal digitules about 21µm long). Trochanter of each leg with two sensoria on ventral surface and one long slender seta. Femur well developed, 3x as long as wide. Coxae each with a minute seta.

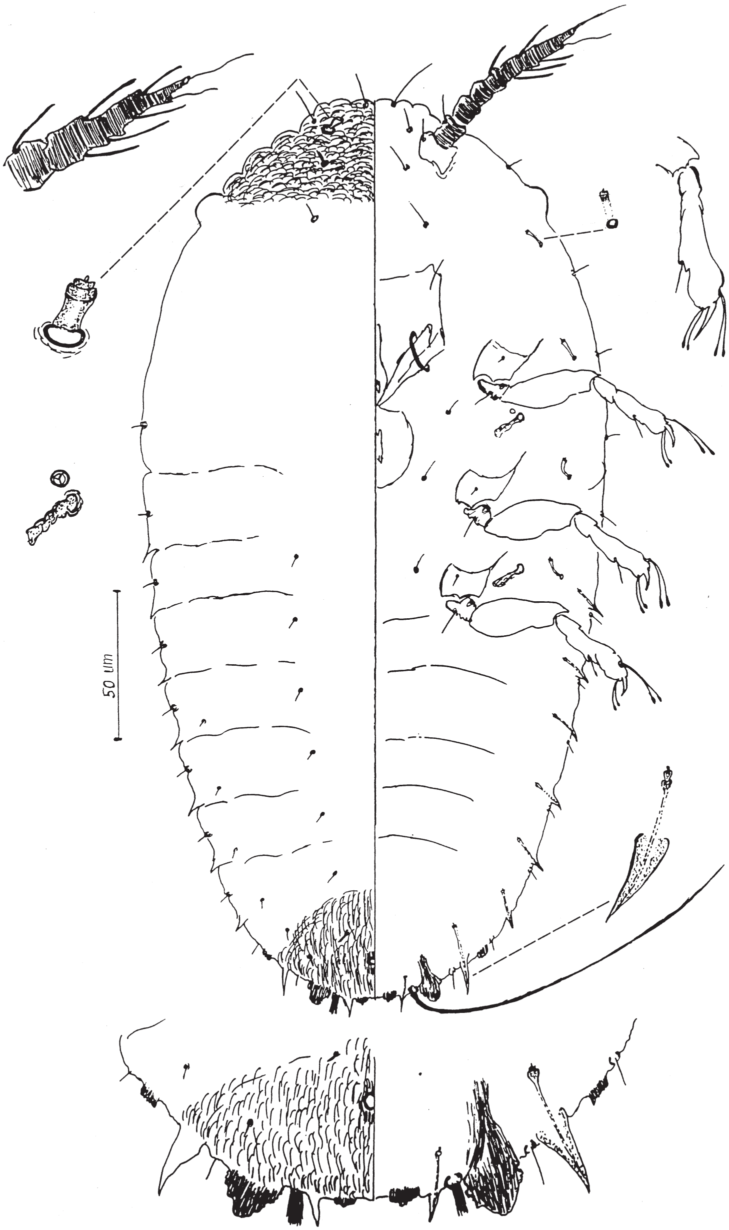

**Fig. (1) : *Lepidosaphes beckii* 1*st* instar nymph**

Fig. 1. *Lepidosaphes beckii* (Newman). 1st-instar nymph.

*Spiracles*: with a single trilocular pore associated with each anterior spiracle only.

*Setae*: with one pair of long setae on margin of head and three pairs submedially on head; with no setae submarginally or submedially on abdomen; with short setae present marginally on each segment, totalling 12 on each side posterior to eyespots. With a pair medially on each thoracic segment.

*Ducts*: with 4 pairs of submarginal microducts present, one near each eye and in pairs on each thoracic segment.

*Gland spines*: with eight pairs of marginal gland spines present, one pair laterally on metathoracic segment and one pair on each abdominal segment, each associated with a one-barred microduct. Gland behind second pygidial lobe about 2x size of other glands.

*Material examined*: Egypt, Tanta, ex *Citrus* sp., 11.III.1997, M.W. Ghabbour; Giza, El-Saff, ex *Citrus* spp, 27.IV.1998, M.W. Ghabbour. 9 slides.

### ***Lepidosaphes ficus*** (Signoret) (Figs 2,4b,5b)

**First-instar nymph**.

*Body*: oval, about 290µm long and 125µm wide; derm membranous except for sclerotised areas on pygidial margin and a verrucose structure between eyespots. Caudal setae long and slender; length about 90µm. Anus minute, removed about 3x to 4x its diameter from pygidial apex.

*Pygidial margin*: median pair of lobes absent; second pair of lobes well developed, about 14µm long and 5µm wide, with one notch on outer margin only; third pair of lobes reduced to sclerotised projections. Gland spines and setae present (see under venter).

**Dorsal surface**:

*Ducts*: a single pair of large, one-barred 8-shaped ducts present anteriorly on cephalic region.

*Setae*: on head: two pairs of long setae present on margin anteriorly and two setae submedially posterior to each 8-shaped duct on verrucose sclerotisation. On thorax and abdomen: without submarginal setae on abdominal segments, but with a row of ten submedian setae on thoracic and abdominal segments.

**Margin & ventral surface**:

*Antennae*: six-segmented, not annulated. Segment VI subequal in length to segments II to V inclusive. Segments I and II each with a long seta; segment V with a stout seta; segment VI with 4 stout setae and 2 flagellate setae terminally.

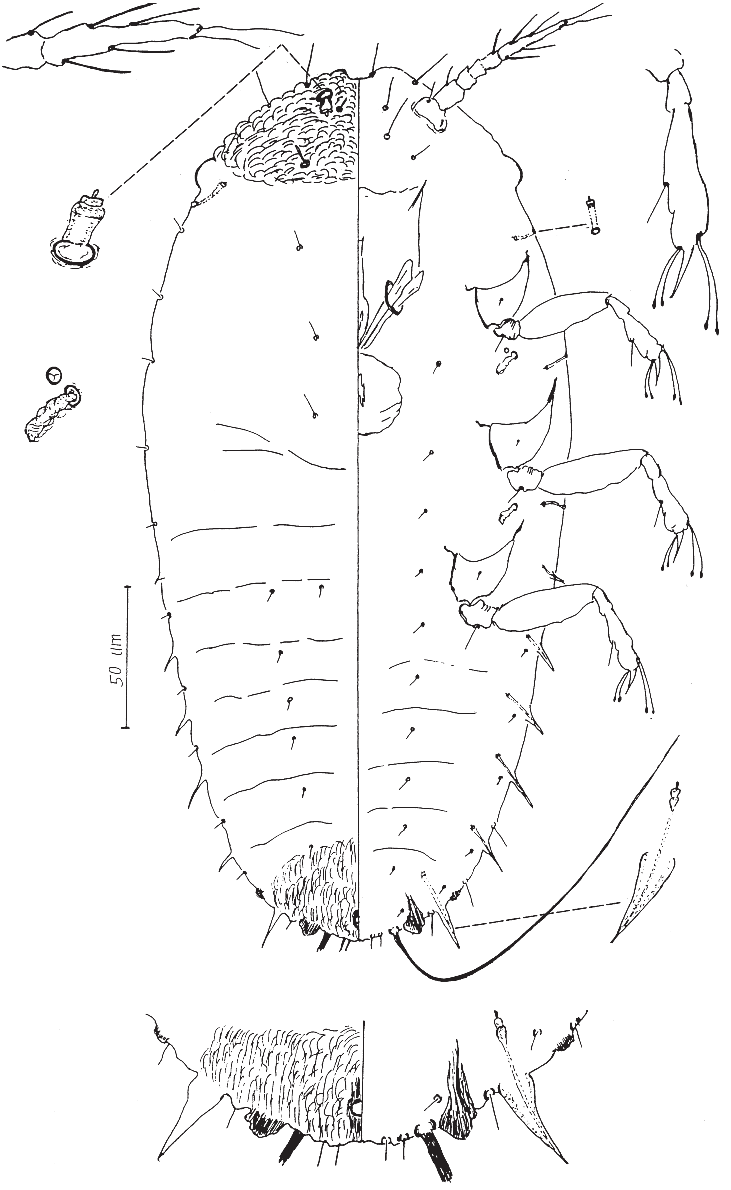

Fig. 2. *Lepidosaphes ficus* (Signoret). 1st-instar nymph.

*Legs*: well developed, posterior legs slightly larger. All digitules knobbed and exceeding claw in length (tarsal digitules about 23µm long). Femur well developed, 2.5x as long as wide. Trochanter triangular, each with two sensoria on ventral surface and one long slender seta. Coxae each with a minute seta.

*Spiracles*: with a single trilocular pore associated with each anterior spiracle only.

*Setae*: on head: with four pairs of long setae (about 12µm long) and one pair of short setae submedially. On thorax and abdomen: submarginal setae six, one per segment on abdomen; submedian setae in a row of ten, one per segment on each thoracic and abdominal segment; marginal setae short, one on each thoracic segment posterior to eyespot and on more anterior abdominal segments, totalling 10; in addition, with five pairs of long setae in pygidial area, of which two pairs between caudal setae.

*Ducts*: with 4 pairs of submarginal microducts present, two pairs just posterior to each eyespot and a pair laterad to each spiracle.

*Gland spines*: with six pairs of marginal gland spines present, each associated with a one-barred microduct: one small pair marginally on metathoracic segment and one pair on abdominal segments II to VI; more posterior gland spines larger, particularly that just anterior to second pair of pygidial lobes.

*Material examined*: Egypt: El-Arish, on leaves and branches of *Ficus* sp., 21.VIII.1997, M.W. Ghabbour; as previous but at Matrouth, 15.VI.1998. 12 slides.

**Key to first-instar nymphs of three species of *Lepidosaphes*:**

1. Antennae annulated; with eight pairs of marginal gland spines; setae absent ventrally on abdomen . ............................................*L. beckii* (Newman)

- Antennae not annulated; with six or seven pairs of marginal gland spines; setae present ventrally on abdomen..................................................................2

2. Verrucose area present between eyespots; median pygidial lobes absent; with four pairs of stout setae on VIth antennal segment; with six pairs of marginal gland spines ..........................................................*L. ficus* (Signoret)

- Verrucose area absent from between eyespots; median pygidial lobes reduced to small sclerotized projections; with five stout setae on VIth antennal segment; with seven pairs of marginal and submargin gland spines... ..........................................................................*L. ulmi* (L.) (Figs 4c,5c)

## INSULASPIS Mamet

*Insulaspis* Mamet, 1950: 32.

Type species: *Lepidosaphes vermiculus* Mamet.

### ***Insulaspis tapleyi*** (Williams) (Figs 3,4d,5d)

**First-instar nymph**.

*Body*: elongate, about 260µm long and 130µm wide; derm entirely membranous except for sclerotised pygidial lobes. With an unsclerotised verrucose area on cephalic region between eyespots and also dorsally on prepygidial area. Caudal setae long and slender, length about 60µm and about 1/5 body length.

*Pygidial margin*: median pair of lobes reduced to a pair of sclerotised points; second pair of lobes well developed, about 18µm long and 7µm wide, with two notches on each margin; third pair of lobes reduced to minute tooth-like projections. Anus minute, removed about 2-3x its diameter from pygidial apex. Gland spines and setae present (see under venter).

**Dorsal surface**:

*Ducts*: a single pair of large, one-barred 8-shaped ducts present anteriorly on cephalic region.

*Setae*: with four pairs of long setae present on margin of head and prothorax; with two pairs of setae submedially on head. On thorax and abdomen: submedian in a row of eight setae on meso- and metathorax and abdominal segments; submarginal also in a row of eight setae on meso- and metathorax and abdominal segments.

**Margin & ventral surface**:

*Antennae*: six-segmented, all segments annulated except segment I. Segments I and II each with a long seta; segment V with a stout seta; segment VI as long as segs II-V combined, with 4 stout setae and 2 flagellate setae apically.

*Legs*: well developed. All digitules knobbed and exceeding claw in length, tarsal digitules about 16µm long. Femur large and well developed. Trochanter triangular, each with two sensoria on ventral surface and one long slender seta. Coxae each with a minute seta.

*Spiracles*: with a single trilocular pore associated with each anterior spiracle only.

*Setae*: on head: with four pairs of long setae submedially. On thorax and abdomen: with three pairs of setae medially on prothorax; submedial setae absent; submarginal setae: six pairs, one per segment on meso- and metathorax and four anterior abdominal segments.

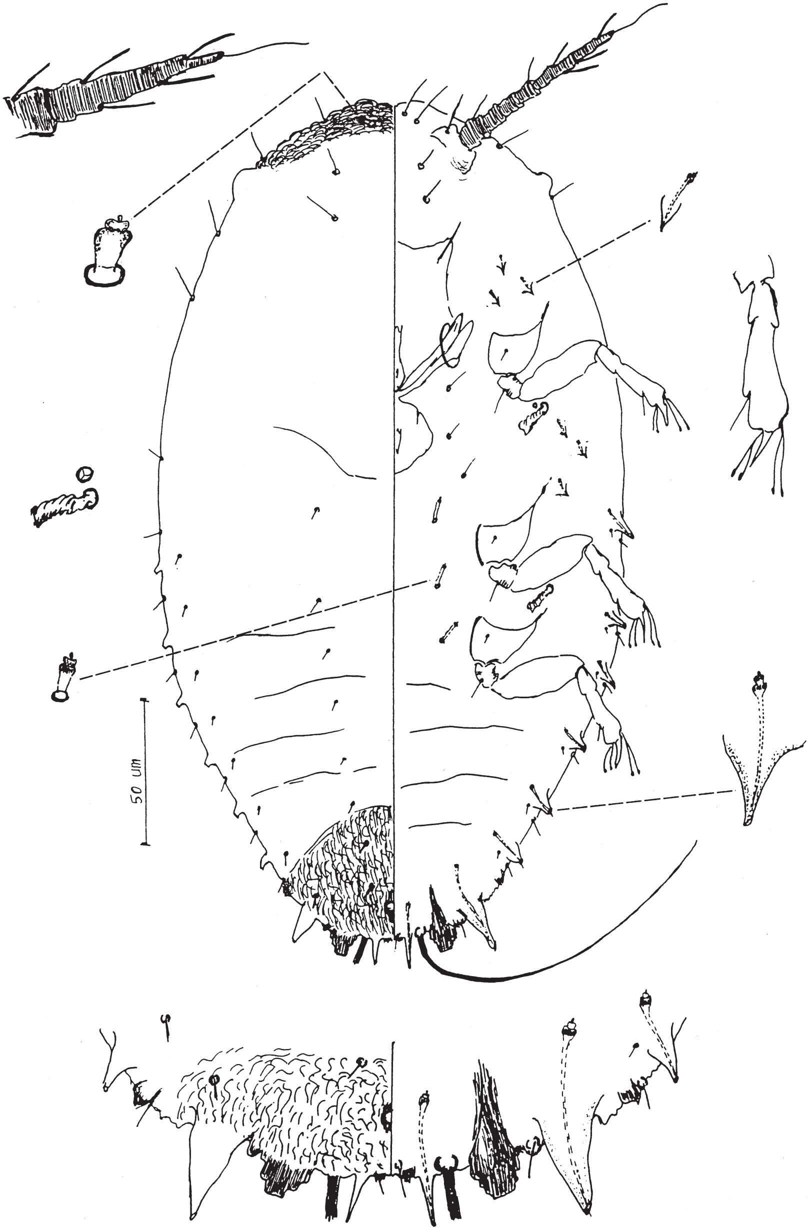

Fig. 3. *Insulaspis tapleyi* (Williams). 1st-instar nymph.

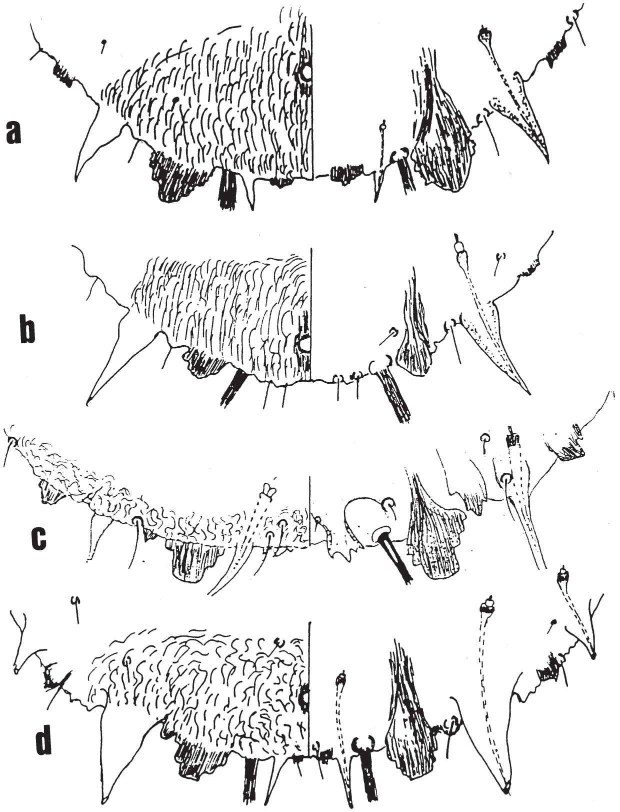

Fig. 4. Pygidium margins of **a**. *L. beckii*; **b**. *L. ficus*; **c**. *L. ulmi*; **d**. *I. tapleyi*.

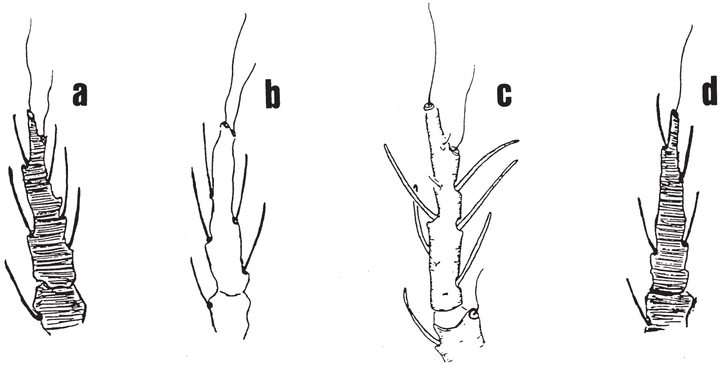

Fig. 5. Terminal antennal segments of **a**. *L. beckii*; **b**. *L. ficus*; **c**. *L. ulmi*; **d**. *I. tapleyi*.

*Ducts*: with 3 gland tubercles present just anterior to each procoxa and 3 more between each anterior spiracle and mesocoxa. With a pair of ventral microducts present just mesad to each coxa.

*Gland spines*: with eight pairs of marginal gland spines present, on metathorax and each abdominal segment, each gland spine associated with a one-barred microduct; most posterior pair of gland spines quite large.

*Material examined*: Egypt: Giza, on leaves of *Mangifera indica*, Aug. 1997, M.W. Ghabbour; as previous but Minia, May 1998; Alexandria, on leaves of *Psidium* sp., July 1997, M.W. Ghabbour; as previous but Giza, May 1998. 10 slides.

Remarks: *Insulaspis pallidula* has also been collected in Egypt (on *Citrus aurantifolia* (lime) leaves, Qualubiya (April 1997) and Alexandria (August 1997) and on *Juniperus* sp., Giza (March 1998); total 7 slides). The 1st-instar nymph of *Insulaspis tapleyi* closely resembles that of *Insulaspis pallidula.* The most important morphological differences between these two species are presented in the following key:

1 - Antennae annulated; with a quite large verrucose structure on cephalic region; with 6 pairs of gland tubercles on pro- and mesothorax; with three microducts ventrally, one on each thoracic segment.................................................................................................................*Insulaspis tapleyi* (Williams)

- Antennae not annulated; with a very narrow verrucose structure on cephalic region; with 8-10 pairs of gland tubercles on pro- and mesothorax; with five pairs of microducts ventrally, one on each thoracic segment and on abdominal segments II and III............................... *Insulaspis pallidula* (Green)

## DISCUSSION

It is clear that *Lepidosaphes* and *Insulaspis* are very closely related. Based on the material examined, the first-instar nymphs of these two genera can be separated using the following key:

1 - Apical segment of antennae with one long flagellate seta; presence of gland tubercles on prothorax; thorax with median microducts ....*Insulaspis* sp.

- Apical segment of antennae with two long flagellate setae; absence of gland tubercles on prothorax; thorax without median microducts ...........................................................................................................*Lepidosaphes* sp.

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GILIOMEE, J.H.
*Department of Entomology and Nematology, University of Stellenbosch,*
*7600 Stellenbosch, South Africa*

# THE ASTEROLECANIIDAE (HEMIPTERA: COCCOIDEA) OF SOUTH AFRICA.

## ABSTRACT

THE ASTEROLECANIIDAE (HOMOPTERA: COCCOIDEA) OF SOUTH AFRICA.

The 16 species of Asterolecaniidae known from South Africa can be tentatively placed in six genera based on the characters of the adult female. Some species do not fit into these genera as presently defined, requiring a redefinition of some genera or the creation of new ones. However, it appears that the characters on which the genera of the Asterolecaniidae are presently based are too few in number and unreliable, making a detailed study of other characters of the female and eight other stages necessary for a better understanding of the relationships within this family.

Key words: pit scales, taxonomic characters, taxonomy, *Abditococcus*, *Asterodiaspis*, *Asterolecanium*, *Bambusaspis*, *Planchonia*, *Russellaspis*, *Amorphococcus acaciae*.

The known Asterolecaniidae (pit scales) of South Africa comprise 15 species, with an additional undescribed species. This fauna is relatively rich, considering that North America has only about 27 species in four genera (Kosztarab, 1996) and Central Europe six species in two genera (Kosztarab & Kozár, 1988). Furthermore, the South African scale insect fauna is still poorly surveyed. Of the indigenous species, six were described by Brain (1918, 1920), one by Fuller (1899a, 1899b), one by Russell (1941) and one by Giliomee & Munting (1968); the others are cosmopolitan species. The species described by Fuller and Brain (except *Amorphococcus acaciae*), as well as the exotic species, were all included in the genus *Asterolecanium* by Russell (1941), who described or redescribed the species in her monumental monograph on 160 species and varieties. According to Russell (1941), the genus comprises “an extremely homogeneous array of species”, although she still divided the species into 12 “groups”. However, workers before and after Russell placed many of her species in other genera, especially Borchsenius (1960) in his comprehensive work on the Asterolecanidae of the USSR. In fact, Borchsenius (1960) recognized 11 genera for his 40 pit-scale species, which he put into the subfamily Asterolecaniinae. How, then, should the South African species in the Asterolecaniidae be classified?

It seems that, based on our existing knowledge, the species can be placed in six genera, i.e. *Abditococcus* Lambdin & Kosztarab, *Asterodiaspis* Signoret, *Asterolecanium* Targioni Tozzetti, *Bambusaspis* Cockerell, *Planchonia*

Signoret and *Russellaspis* Bodenheimer, although some species cannot be placed with confidence in these genera.

The genus *Abditococcus* was established as a monotypic genus by Lambdin & Kosztarab (1975) for the species which Brain (1918) described as *Amorphococcus acaciae*. Amongst the characters that Lambdin & Kosztarab used to distinguish this genus from other asterolecaniids were the presence of fused anal plates and a minute arched plate surrounding the anal ring, and the absence of a marginal row of quinquelocular pores and 8-shaped pore bands on the ventrum.

Four species can be placed in the genus *Asterodiaspis*, i.e. two exotic species found on oak: *A. variolosa* (Ratzeburg) and *A. quercicola* (Bouché), and two indigenous species: *A. borboniae* (Brain) and *A. brevispinum* (Brain). *Asterodiaspis* is characterized by: the reduced anal ring which has no pores and only 0-2 short setae, and anal lobes that are absent or only weakly developed (Borchsenius, 1960; Kosztarab & Kozár, 1988). Borchsenius (1961) regarded these characters as specialized. *A. borboniae* and *A. brevispinum* have been placed in *Asterodiaspis* on the basis that the anal ring is very small and without setae, as depicted by Brain (1920), although Russell (1941) indicates a bigger anal ring (without setae) for *A. borboniae* in her redescriptions of the two species. According to Russell (1941), the two species did not fit into any of her 12 “groups”. *Asterodiaspis* is the largest genus in the Asterolecaniidae in the former USSR, containing 17 of the 40 species described by Borchsenius (1960).

The genus *Asterolecanium* is represented by only one species, i.e. the new species we are describing elsewhere. It is considered to belong to this genus as it is near to *Asterolecanium machili* Russell (Russell, 1941) which, in the sense of Borchsenius (1960), belongs to *Asterolecanium sensu stricto*. Also, the anal ring (with setae and pores) is at the base of an anal tube with almost parallel walls. This character and others fit the descriptions of the genus by Borchsenius (1960) and Williams & Watson (1990). However, it also shows similarities with some *Bambusaspis* species, but lacks the characteristic dorsal tubes of this latter genus.

South Africa has three species in the genus *Bambusaspis*, namely *B. bambusae* (Boisduval), *B. miliaris* (Boisduval) and *B. pseudomiliaris* (Green). The first two species were originally described from Algeria and the third from Sri Lanka, but today all three are cosmopolitan species occurring on leaves and stems of bamboo. Cockerell (1902) erected the genus for some of these and a number of other species living on bamboo. They are all characterized by a pair of relatively large tubular ducts (dorsal tubes) near the posterior end of the body. Russell (1941) lists 47 species in this group, which is by far the largest of her 12 groups.

The species *Asterolecanium stentae* (Brain) was included by Russell (1941) in her “Group IV”, together with *A. fimbriatum* (Fonscolombe) for which Signoret (1870) established the genus *Planchonia*. Bodenheimer (1951) indicated that all the species in Russell’s Group IV should be included in *Planchonia*, so that the South African species becomes *Planchonia stentae*, as indicated by Borchsenius (1960). A double or triple row of marginal 8-shaped pores on the anterior part of the body is characteristic for this genus (Russell, 1941; Borchsenius, 1960; Kosztarab & Kozár, 1988). The arched plate anterior to the anal ring is also conspicuous in the genus.

The rest of the South African species, i.e. *brachylenae* (Brain), *conspicuum* (Brain), *euryopis* (Fuller), *euphorbiae* (Russell), *pustulans* (Cockerell) and *proteae* (Giliomee & Munting), are placed in the genus *Russellaspis*. The genus was established by Bodenheimer (1951) for the “Group XI” species of Russell (1941) with the cosmopolitan *R. pustulans* as the genotype. This was accepted by Borchsenius (1960), who suggested that the South African species *Asterolecanium conspicuum* and *A. euphorbiae* Russell should also belong in this genus. Russell (1941) included *A. conspicuum* in her “Group XI”, but could not fit *A. euphorbiae* into any of her groups.

Russell (1941) defined her “Group XI” as adult females having a row of marginal 8-shaped pores together with parallel rows of marginal quinquelocular pores and disc-pores, as well as elongate sclerotized areas ventrally on the apex of the abdomen. The characters of *A. pustulans* (genotype), *R. conspicuum* and *R. proteae* correspond with this description. However, the species *R. brachylenae*, *R. euryopis* and *R. euphorbiae* deviate in various aspects. Thus, *R. brachylenae* has a double row of marginal 8-shaped pores, although it is similar to the main group in possessing the ventral sclerotized areas. *R. euphorbiae* differs from Russell’s (1941) definition of “Group XI” in that the marginal quinquelocular pores do not extend up to the terminal marginal 8-shaped pores and it lacks a row of marginal disc-pores and the sclerotized areas ventrally near the apex. It also lacks the scattered 8-shaped pores on the dorsum as found in the genotype. In fact, it is difficult to see why Borchsenius (1960) suggested that this species belongs in *Russellaspis* and one wonders whether he did not mistake Russell’s (1941) Fig. 23C of *Asterolecanium euryopis*, showing the scattered 8-shaped pores on the dorsum, for *A. euphorbiae* which appears on the same page as Fig. 23A. However, the anal structures of *R. euphorbiae*, as depicted by Russell in Fig. 23A, do appear to be rather similar to those shown by Borchsenius

(1960) for *R. pustulans* in his Fig. 107. *R. euryopis* lacks the distinct marginal row of 8-shaped pores and the marginal quinquelocular and disc-pores, as well as the typical sclerotized areas near the apex ventrally, but resembles the genotype in possessing the scattered 8-shaped pores on the dorsum, which, in this wax secreting species, is particularly large and distinctly invaginated (Russell 1941). Like *R. euphorbiae*, it was not placed in any of Russell's (1941) groups.

It is clear that quite a number of the South African species cannot be placed with confidence in existing genera as they are presently defined (especially those in *Russellaspis*) and Russell (1941) herself was unable to fit four of them into any of her 12 groups. Placement of these species will require either that the generic characters be expanded to include these species or that new genera be created for them. However, the characters by which the genera are presently differentiated are few in number, being mostly the anal structures and particularly the distribution patterns of the various pores. The latter are variable and can be influenced by climatic factors during development (P. Lambdin, pers. comm.). There is, therefore, a great need for a careful study of other characters over a range of species for useful defining characters. In this regard, the studies on the ultrastructure of the wax glands by Foldi & Lambdin (1995) are an excellent contribution. Furthermore, the juvenile stages and the males (where present) should be described in detail, as was done by Giliomee & Munting (1968).

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GULLAN, P.J.; COOK, L.G.
*Division of Botany and Zoology, The Australian National University,*
*Canberra, ACT 0200, Australia*

# ARE COCHINEAL INSECTS ERIOCOCCIDS?

## ABSTRACT

ARE COCHINEAL INSECTS ERIOCOCCIDS?

Scale insects of the genus *Dactylopius* Costa, which all feed on cacti, are commonly called cochineal insects. Currently there are nine described species placed in their own family, the Dactylopiidae, based on a few unique morphological features. Here we review available biological, morphological and karyotype information on *Dactylopius* and report on cladistic analyses of morphological data (from first-instar nymphs plus adult females, and adult males separately) and molecular data (from the nuclear gene 18S rDNA and the mitochondrial gene cytochrome oxidase II) from *Dactylopius* and its potential relatives. We suggest that *Dactylopius* belongs with the eriococcids and we discuss the nomenclatural implications of this placement.

Key words: dye, Eriococcidae, *Apiomorpha*, *Stictococcus*, phylogeny, Aclerdidae, Asterolecaniidae, Coccidae, Diaspididae, Eriococcidae, Kermesidae, Kerriidae, Lecanodiaspididae, Phenacoleachiidae, Pseudococcidae, Putoidae, Ortheziidae, *Eriococcus*, karyology, chromosomes, life history, pigment chemistry.

## INTRODUCTION

Members of the genus *Dactylopius* Costa have attracted human attention for centuries because of the beautiful carmine dye, called cochineal, which can be extracted from their bodies and used to colour textiles and some foods (Moran, 1981; Guerra & Kosztarab, 1992). There are only nine recognised species of *Dactylopius* (De Lotto, 1974; Guerra & Kosztarab, 1992) and all are native to the New World, mostly in the deserts of south-western United States, Mexico and South America (Miller, 1991), where they feed on the stems and/or cladodes of Cactaceae.

Currently *Dactylopius* is placed in its own family, the Dactylopiidae (De Lotto, 1974; Guerra & Kosztarab, 1992), although Ferris (1955) used this family name to include all genera currently placed in the Eriococcidae, before later recognising the Eriococcidae as a distinct family that included *Dactylopius* (Ferris, 1957). Hoy (1963) later placed *Dactylopius* in the family Eriococcidae because of the presence in *Dactylopius* of 'typical eriococcid tubular ducts'. The action of Ferris and Hoy in giving priority to the name Eriococcidae is nomenclaturally invalid because, as pointed out by Williams (1969), the name Dactylopiidae is much older than the name Eriococcidae. Subsequent authors have not followed Ferris' and Hoy's recommendation: the

Dactylopiidae is recognised universally by coccidologists as a distinct, monotypic family. However, prior to 1983 (ICZN, 1983), the use of Dactylopiidae as a family-group name was unstable due to uncertainty concerning the type species of *Dactylopius* (Miller, 1974). Following the ruling by the International Commission on Zoological Nomenclature that *Dactylopius coccus* Costa be designated as the type species of *Dactylopius* (ICZN, 1983), the name Dactylopiidae was placed on the Official List of Family-Group Names in Zoology.

The main morphological features that distinguish *Dactylopius* from related genera are: (i) the presence of clusters of quinquelocular pores surrounded by a sclerotised rim (so-called "wide-rimmed pores") in the crawlers and in the second-instar and adult females and, in later instars, usually associated with one or more tubular ducts - (clusters of similar pores, but not on sclerotised plates, also occur in the eriococcid genus *Phacelococcus* Miller); (ii) the presence of truncate dorsal setae in the crawlers and in the second-instar and adult females - (truncate dorsal setae also occur in some *Eriococcus* spp.); (iii) the absence in all instars of a cellular anal ring bearing setae; and (iv) the absence of microducts in all instars (De Lotto, 1974; Hodgson, 1997). These important diagnostic features of *Dactylopius* are autapomorphies for the genus and thus provide no information of use in assessing the relationships of *Dactylopius* to other scale insect genera. Only shared derived features (synapomorphies) furnish phylogenetically informative data.

Miller (1991) stated that the relationships of cochineal insects were in need of study because, although they appear to be related to the Eriococcidae and the Kermesidae (based on female characters), some coccidologists (e.g., Boratynski & Davies, 1971) believed that their affinities lay with the Pseudococcidae. Borchsenius (1958) grouped *Dactylopius* closest to *Stictococcus* Cockerell and *Apiomorpha* Rübsaamen, whereas Koteja (1974) reported that the mouthparts of the Dactylopiidae were acanthococcid (= eriococcid) in appearance. Williams (1969) believed that a thorough study of the adult males of *Dactylopius* held the key to understanding whether the genus is distinct from the Eriococcidae. However, although morphological data on the adult males of a few *Dactylopius* species are available (Loubser, 1966), there are no explicit phylogenetic analyses based on many adult male characters from a range of coccoid families.

A recent cladistic analysis (Foldi, 1997) of combined first-instar, adult female and adult male data placed the Dactylopiidae as a more derived group than the Pseudococcidae, Eriococcidae or Kermesidae and sister to a clade containing the other lecanoid families *sensu* Boratynski & Davies (1971) and also most of the diaspidoids, but the relationships among the these families were very poorly supported (no non-homoplasious apomorphies at any of the crucial nodes). The only recent taxonomic study of *Dactylopius* (Guerra & Kosztarab, 1992) included an intuitive phylogram for the genus based on selected morphological features of adult females, but did not assess the relationships of *Dactylopius* to other genera and families. Here we review all available biological, morphological and genetic data on *Dactylopius* and provide the first comprehensive phylogenetic study of the genus and its putative relatives. We show that the relationships of *Dactylopius* clearly are with the eriococcids and we consider the implications of this postulated relationship for family-level nomenclature.

## MATERIALS AND METHODS

We performed a cladistic analysis on 84 morphological characters (49 binary and 35 multistate) of the first-instar nymphs and adult females (L.G.Cook, unpublished data) for several species of Coccidae and Pseudococcidae, one species of Kermesidae (*Allokermes kingi* (Cockerell)), one species of Kerriidae (*Austrotachardia angulata* (Froggatt)) and 28 species of Eriococcidae, selected to represent a range of potential relatives of *Dactylopius*.

We also carried out a cladistic analysis of 43 morphological characters of the macropterous adult males of *Dactylopius* and the families Aclerdidae, Asterolecaniidae, Coccidae, Diaspididae, Eriococcidae (represented by *Eriococcus sensu lato*), Kermesidae, Kerriidae, Lecanodiaspididae, Phenacoleachiidae, Pseudococcidae and Putoidae, using the Ortheziidae as an outgroup. We selected many of our characters and obtained much of our data from Afifi (1968, table A, p. 52), Koteja & Zak-Ogaza (1972, table 1) and Hodgson (1997, table 1.1.3.4.3). We used slide-mounted specimens of the adult males of *D. opuntiae* (Cockerell) and information from Loubser (1966) to score *Dactylopius*, slide-mounted specimens of an Australian *Austrotachardia* sp. to score the Kerriidae, and data from Ghauri (1962), Koteja (1986), Beardsley (1962), Theron (1962) and R.C. Henderson and T.K. Qin (pers. comm.) to score the Diaspididae, Ortheziidae, *Puto* Signoret and *Phenacoleachia* Cockerell. Phylogenetically uniformative characters were deleted from the matrix prior to analysis, leaving the final matrix with 33 binary characters and 10 multistate characters.

We obtained sequence data for a nuclear ribosomal RNA gene, 18S rDNA, for two species of *Dactylopius* (*D. austrinus* De Lotto and *D. confusus* (Cockerell)), a range of potential relatives from the Coccidae, Eriococcidae and Pseudococcidae, and *Newsteadia* sp. (Ortheziidae) as an outgroup. Nucleotide sequences for *D. confusus* and *Dymsicoccus neobrevipes* (Pseudococcidae) were obtained from Genbank (accession numbers U20402 and U20429) but all other sequences were obtained by L.G. Cook. DNA was extracted from fresh, dried or ethanol preserved specimens using the salt extraction method of Sunnucks & Hales (1996). Sequencing templates for the 5' region of 18S rDNA were generated by PCR under standard conditions using the primers 2880 and B- (von Dohlen & Moran, 1995). Templates were sequenced in both directions and analysed on an automated DNA sequencer (Applied Biosystems, Inc.). Sequences were initially aligned using Clustal W v1.6 (Thompson *et al.*, 1994) and then adjusted by eye. Regions of alignment ambiguity in the 18S rDNA data set were omitted from the phylogenetic analyses.

Taxon sampling for each of the three data sets was very different and thus all data sets were analysed separately. We used the computer program PAUP* test version 4.0d64 (Swofford, 1996) for all phylogenetic analyses. The adult male and the 18S rDNA data sets were small enough to allow use of the branch-and-bound algorithm to ensure that optimal trees were found, but the large size of the adult female + first-instar data set necessitated the use of heuristic searches using random addition sequences to overcome the possibility of converging on a single island in the data. Bootstrap support for each clade was estimated based on 500-1000 bootstrap replications. Bremer support (the Decay Index) was calculated and T-PTP tests of monophyly were carried out for important nodes in the adult-male and 18S rDNA trees.

## RESULTS

*Morphological data.* The full cladistic analysis of the morphological data set from the adult females plus first-instar nymphs is not presented here but the main findings relevant to *Dactylopius* are as follows. *Dactylopius* fell within the large eriococcid clade and, although its position was not stable (sensitive to taxon deletion), it always fell within, rather than basal to, the other eriococcids.

Cladistic analysis of the adult male data matrix produced four minimum-length trees (Fig. 1), in which *Puto* was basal and the Pseudococcidae was sister to the rest of the taxa. *Dactylopius* formed a clade with *Eriococcus s.l.* and this clade formed a trichotomy with *Phenacoleachia* and a clade containing the remainder of the taxa. The *Dactylopius-Eriococcus* clade had high bootstrap and significant T-PTP support.

*Molecular data.* Analysis of the 18S rDNA data under different assumptions produced slightly different trees but in all trees the two *Dactylopius* species were always embedded within the larger eriococcid clade (Fig. 2). The coccids formed a polytomy with multiple eriococcids whereas the pseudococcids were more basal, although the latter node had no support. The results of a phylogenetic analysis of nucleotide sequence data from a mitochondrial protein-coding gene, cytochrome oxidase II (COII) (L.G. Cook,

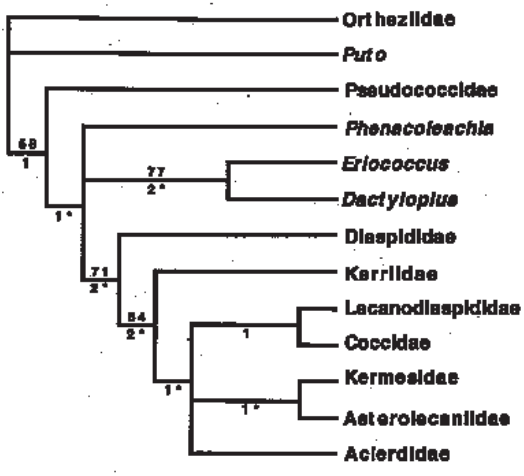

Fig. 1 - A strict consensus of the four minimum-length cladograms from morphological data of the adult males (tree length = 109; CI = 0.495; RI = 0.560). Numbers above the nodes are bootstraps (only values of 50 and above shown), below the nodes are Bremer values and the asterisks indicate nodes for which, by T-PTP tests, a prior hypothesis of monophyly is corroborated.

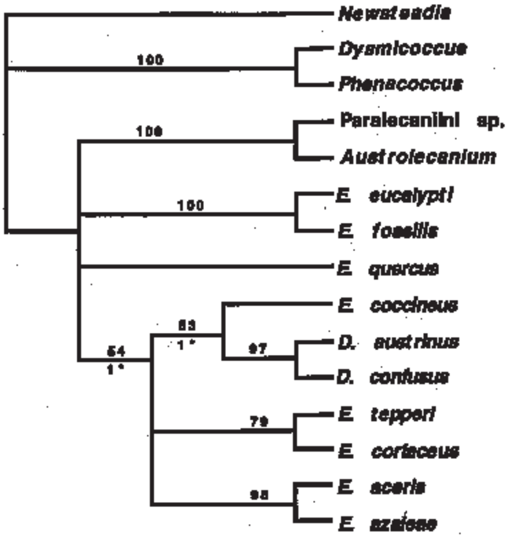

Fig. 2 - A strict consensus of the six minimum-length cladograms from nucleotide sequence data from the 18S rDNA gene (tree length = 129; CI = 0.720; RI = 0.783). Numbers above the nodes are bootstraps; Bremer support (below the node) and T-PTP significance (asterisks) were calculated only for the eriococcid (including *Dactylopius* clade) and the *Dactylopius* + *E. coccineus* clade.

unpublished data) did not contradict the above findings from the 18S rDNA analysis but were inconclusive, partly because the COII data were uninformative at the required level and also because the taxon set was smaller and did not include coccids.

## DISCUSSION

Our morphological data from first-instar nymphs plus adult females and from adult males and our molecular data from the 18S rDNA gene all show that *Dactylopius* belongs with or, at least, is more closely related to the Eriococcidae than to either the Coccidae or Pseudococcidae, as suggested by Koteja (1974) based on mouthpart morphology. Furthermore, the Pseudococcidae may be basal to both the eriococcid (including *Dactylopius*) clade and the coccid (or even the remainder of the lecanoid) clade. This is contra to the schemes suggested by Boratynski & Davies (1971), based on adult males, and by Foldi (1997), based on all life stages. The mitochondrial gene data do not contradict the relationship of *Dactylopius* suggested by the nuclear gene and the morphological data.

*Karyology and chromosome systems.* Both the Comstockiella and the lecanoid chromosome systems have been reported for *Dactylopius* (Nur, 1980, 1982). Such information is of little phylogenetic value because both of these chromosome systems and intermediates are widespread in the various lecanoid families, including the Eriococcidae (Brown, 1967; Nur, 1980). *Dactylopius* has a diploid number of 2n = 10 (Nur, 1982; Moharana, 1990), which is similar to some pseudococcids and at least one coccid species (Nur *et al.*, 1987; Moharana, 1990) and different from that of typical eriococcids (Brown, 1967). Few species of the other lecanoid families have been examined chromosomally but none have a karyotype like that of *Dactylopius*.

*Life history.* Cochineal insects have three female instars and five male instars, which is the same life-history pattern as found in eriococcids, aclerdids, asterolecaniids, kermesids and lecanodiaspidids (Miller, 1991). In contrast, the ortheziids, pseudococcids and most, but not all, coccids have four female instars (Miller, 1991), which is apparently the ancestral instar number for female neococcoids. Thus, the life-history pattern of dactylopiids is derived compared to mealybugs, but is uninformative concerning relationships with the other lecanoid families.

*Pigment chemistry.* Banks (1977) classified coccoid pigments into two chemical groups (the alpha-methyl and beta-methyl systems) and reviewed the taxonomic distribution of these pigments among coccoid families. *Dactylopius* possesses the alpha-methyl system, which is also found in representative taxa of the Coccidae, Kermesidae, Kerriidae and Margarodidae, whereas *Eriococcus* (represented by *E. confusus* Maskell and *E. coriaceus* Maskell) have the beta-methyl system typical of the Asterolecaniidae (represented only by *Callococcus acaciae* (Maskell), which L.G. Cook's unpublished molecular data suggest is an eriococcid) and the Pseudococcidae. Thus, if *Dactylopius* belongs with the eriococcids, then eriococcid taxa are heterogeneous with respect to pigment chemistry, as suggested by Banks (1977), and thus we must accept that similarities in pigments are due to convergent evolution.

In summary, neither chromosomal nor life-history data assist with the phylogenetic placement of *Dactylopius*, whereas the pigment chemistry of *Dactylopius* is more similar to that of coccids than of eriococcids. However, from analysis of available morphological and molecular data, we conclude that *Dactylopius* falls within a clade containing representatives of several undisputed eriococcid genera. In the recent past, *Dactylopius* has been set apart from other members of this clade due to its autapomorphic morphology. In addition, the cactus host association of *Dactylopius* species is unusual for eriococcids (although not for pseudococcids). Among the eriococcids, perhaps only four species, including *Eriococcus coccineus* Cockerell, feed exclusively on Cactaceae (Hoy, 1963; Miller & Miller, 1992). Interestingly, *E. coccineus* is the putative sister of *Dactylopius* in some cladograms derived from the 18S rDNA data.

If the status of Dactylopiidae as a monotypic family is to be maintained, then this would necessitate the elevation to family level of a number of other groups currently placed firmly within the Eriococcidae. Some reclassification may be warranted given that Cox & Williams (1988) argue that the Eriococcidae, as presently interpreted, cannot be regarded as a monophyletic group because it has no defining autapomorphies. Furthermore, our suggestion that *Dactylopius* belongs with the eriococcids has other serious nomenclatural implications because Dactylopiidae is an older name than Eriococcidae (Williams, 1969). However we do not support either of the potential solutions to this dilemma, i.e. either break the eriococcids into a number of smaller families (in order to maintain the Dactylopiidae as a separate taxon) or transfer all eriococcids to the Dactylopiidae. In the interests of nomenclatural stability, we instead argue that formal recognition of the valid family-group name(s) for these genera should await the completion of comprehensive phylogenetic studies. In the interim, we propose that the current usage of the names Dactylopiidae and Eriococcidae be maintained.

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GULLAN, P.J.
*Division of Botany and Zoology, The Australian National University, Canberra, ACT 0200, Australia*

# WHY THE TAXON HOMOPTERA DOES NOT EXIST.

## ABSTRACT

WHY THE TAXON HOMOPTERA DOES NOT EXIST.

Many researchers still use the name Homoptera for the higher taxon of any member of the Sternorrhyncha (Aleyrodoidea, Aphidoidea, Coccoidea and Psylloidea) or Auchenorrhyncha (Cercopoidea, Cicadoidea, Cicadelloidea and Fulgoroidea), or to refer collectively to the Sternorrhyncha plus Auchenorrhyncha. Recent work based on morphological and molecular studies provide phylogenetic evidence that the Homoptera is paraphyletic and therefore its use should be abandoned.

Key words: honeydew, ant-attended, sap-sucking, carnivory.

Traditionally the Homoptera has been regarded either as a distinct order or as a suborder of the order Hemiptera. In either classification, the Homoptera consists of the Auchenorrhyncha (Cercopoidea, Cicadoidea, Cicadelloidea and Fulgoroidea) plus the Sternorrhyncha (Coccoidea, Aphidoidea, Psylloidea and Aleyrodoidea) and usually also the Coleorrhyncha (Peloridoidea: Peloridiidae or moss bugs). Hennig (1981) recognised that the Homoptera might not be monophyletic (in the sense of not containing all descendants of the common ancestor) because the diagnostic features used to separate it from the Heteroptera are all plesiomorphies that must have been present in the common ancestors of both groups. In homopterans, the labium is inserted close to the prosternum (without the intervening gula area seen in Heteroptera), and the fore-wings, if developed, are in the form of tegmina of approximately uniform texture, i.e. without differentiation into corium and membrane (as in Heteroptera), and often are held roofwise over the abdomen (Woodward *et al.*, 1970). The insects traditionally recognised as homopterans all feed on plant saps (mostly from phloem or xylem) (Goodchild, 1966; McGavin, 1993) and a number of families, especially among the Sternorrhyncha, possess the obvious biological traits of eliminating honeydew from the anus and being ant-attended (e.g., Buckley, 1987; Bourgoin, 1997). In contrast, the Heteroptera have more diverse food habits, including plant sap-sucking and carnivory on invertebrate prey or, more rarely, vertebrate blood (Goodchild, 1966; McGavin, 1993; Schuh & Slater, 1995), and, with a few rare exceptions (e.g., Maschwitz *et al.*, 1987), the Heteroptera do not produce honeydew and are not ant-attended.

Ideally, all higher taxa should be monophyletic because natural groups provide an unambiguous representation of relationships, can be efficiently diagnosed (by one or more shared derived features), are stable to the addition of new taxa, and have maximal value in application to other studies (e.g., behavioural, biogeographic or evolutionary investigations). Polyphyletic groups, based on the misinterpretation of convergence as evidence for genealogy, are unnatural and always are rejected when detected. Paraphyletic groups also are unnatural as they do not contain all of the descendents of their ancestor, generally due to the removal of a divergent monophyletic group from the clade (e.g., the class Reptilia is rendered paraphyletic by recognition of the class Aves for the morphologically-derived reptiles that we call birds), and are difficult or impossible to uniquely diagnose due to the lack of shared derived features. Such groups appear to be common at all taxonomic levels in our existing classifications of insects and yet, in the interests of nomenclatural stability, we should not reject them without good evidence from thorough character evaluation and rigorous phylogenetic analysis. The testing of phylogenetic hypotheses, and thus classifications, using data sets that are independent of morphology (e.g., nucleotide sequence data from mitochondrial or nuclear genes) is desirable given that our existing classifications are based almost exclusively on morphology.

The phylogenetic relationships of the various higher groups of Hemiptera have been much disputed (e.g., see chapters in Schaeffer (1993) or the review in von Dohlen & Moran (1995)). Recent cladistic re-interpretations of morphological data (reviewed in Campbell *et al.*, 1995b) and particularly phylogenetic analyses of 18S rDNA nucleotide sequence data (von Dohlen & Moran, 1995; Campbell *et al.*, 1995b) do not support the monophyly of the Homoptera. Available evidence suggests that the Auchenorrhyncha are more closely related to the Heteroptera (including the Coleorrhyncha) than to the Sternorrhyncha (Wheeler et al., 1993; von Dohlen & Moran, 1995). Furthermore, the Auchenorrhyncha also may be paraphyletic because the Fulgoroidea may be more closely related to the Heteroptera than to the other auchenorrhynchan groups (Campbell *et al.*, 1995a,b; Sorensen *et al.*, 1995). The molecular data, however, strongly support the monophyly of the Sternorrhyncha (Campbell *et al.*, 1994, 1995a,b; von Dohlen & Moran, 1995) and thus validate the previous morphological evidence for the naturalness of this group (Schlee, 1969).

Despite this recent evidence for the non-monophyly of the Homoptera, the concept has been used so widely and for so long that many researchers appear loathe to discard it. However, if entomologists wish to use a phylogenetically-based higher classification, then they should abandon the use of the name Homoptera and instead refer to their favourite bug group as part of the relevant superfamily of the order Hemiptera. Several books (e.g., Carver *et al.*, 1991; McGavin, 1993; Gillott, 1995) now use a classification with three, or more rarely four, suborders, namely the Auchenorrhyncha, Sternorrhyncha, Heteroptera and sometimes with a separate Coleorrhyncha for the Peloridiidae. Using such schemes, the scale insects, for example, could be referred to as “Hemiptera: Coccoidea” or “Hemiptera: Sternorrhyncha: Coccoidea”. Sorensen *et al.* (1995) have taken the radical step of discarding the names Auchenorrhyncha, Coleorrhyncha and Heteroptera, and erecting three new hemipteran suborder names, based on relationships suggested by their 18S rDNA gene trees. This action may be premature; major nomenclatural changes should await confirmation of the postulated relationships from additional genes or other new data sources.

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LAGOWSKA, B.
*Department of Entomology, University of Agriculture*
*ul. K. Leszczyñskiego 7, 20-069 Lublin, Poland*

# MORPHOLOGICAL VARIATION IN ADULT FEMALE *COCCUS HESPERIDUM* L. (HEMIPTERA: COCCOIDEA: COCCIDAE) IN POLAND.

## ABSTRACT

MORPHOLOGICAL VARIATION IN ADULT FEMALE *COCCUS HESPERIDUM* L. (HEMIPTERA: COCCOIDEA: COCCIDAE) IN POLAND.

This paper compares the variation of ten morphological characters of adult female *C. hesperidum* L. collected off (i) five different host plants and (ii) the stems, petioles and both leaf surfaces of *Citrus*, all from glasshouses in Poland. Four measured and six meristic characters were selected for biometric study. The mean and range of each of these characters varied between host plant species and with their position on *Citrus*. The main characters which varied between host species were the size and shape of the dorsal setae and the distribution and frequency of dorsal and ventral tubular ducts. Specimens off different parts of *Citrus* varied mainly in the frequency of the dorsal tubular ducts and the spiracular disc-pores. Pocket-like sclerotisations were noted for the first time in *C. hesperidum*; when present, they were in the stigmatic areas, close to a dorsal tubercle.

Key words: brown soft scale, *Citrus limon*, *Ficus benjamina*, *Hedera helix*, *Iresine herbstii*, *Schefflera actinophylla*, dorsal tubercles, host-induced differences.

## INTRODUCTION

The brown soft scale is a cosmopolitan species, occurring outdoors in the tropics and subtropics, but more or less restricted to greenhouses in less temperate regions. In Poland, it is a serious pest of many ornamental pot plants.

Morphological variation in *C. hesperidum* has been observed by many authors but, so far, only variation in the shape and the size of the body and in parts of antennae and legs have been examined in detail (Fonseca, 1953; Blair *et al.*, 1964). Hodgson (1967) suggested that some morphological variation in this species might be correlated with its position on the host plant.

The present study was undertaken to investigate the variation of some morphological characters of adult female *C. hesperidum*, depending on (i) the host plant species and (ii) their position on the host plant.

## MATERIALS AND METHODS

Adult female *C. hesperidum* were collected from ornamental pot plants

(*Citrus limon*, *Ficus benjamina*, *Hedera helix*, *Iresine herbstii* and *Schefflera actinophylla*) reared in greenhouses. A total of 439 adult females were examined on microscopic slides: 186 off *Citrus*, 93 off *Ficus*, 30 off *Hedera*, 30 off *Iresine* and 100 off *Schefflera*. On *Citrus*, the samples from stems, petioles and the upper and lower leaf surfaces were analysed separately. The measurements of slide-mounted specimens were made using a Carl Zeiss Jenamed 2 Histology Microscope with an ocular micrometer (magnifications 10x and 400x). The characters studied, the number of measurements and the means and ranges of the values for each feature are listed in Tables 1 and 2.

## RESULTS

### VARIATION OF MORPHOLOGICAL CHARACTERS IN *C. HESPERIDUM* OFF DIFFERENT HOST PLANT SPECIES:

The means and ranges for the characters for specimens collected off the five different host plant species are presented in Table 1. The largest mean values were noted for specimens off *Ficus* (length and width of body) and off *Citrus* (length of antenna and length of trochanter + femur). In the sample off *Iresine*, the mean values of all measured characters were the smallest in comparison with those from the other host species.

Dorsal tubercles were present on all adult females examined and the mean values for this character were similar on all the samples studied, 6 and 7 being the most frequent total number present.

Pocket-like sclerotisations were also found on 92-100% of specimens collected off *Citrus*, *Ficus*, *Hedera* and *Schefflera,* where they were always present in the stigmatic areas, close to dorsal tubercles (Fig. 1). Only on a few specimens was this feature noted in the absence of dorsal tubercles. Pocket-like sclerotisations have not been previously noted on *C. hesperidum*. For further comment see under Discussion below.

Dorsal setae varied considerably in shape and size within each sample. Generally, on the samples from *Citrus*, *Hedera*, *Ficus* and *Schefflera*, the setae had bluntly pointed apices and were between 5-6µm long. However, those off *Iresine* were always sharply pointed and were 7.5-10µm long.

The dorsal and ventral tubular ducts were also highly variable in number and distribution. The greatest number of dorsal tubular ducts (19) was noted on specimens off *Schefflera*, while dorsal tubular ducts were never noted on specimens off *Iresine*. Most specimens off *Citrus* had a total of 1-3 dorsal ducts while 4-6 dorsal ducts were usually present on the other hosts. With regard to the ventral tubular ducts, the greatest number was on specimens off

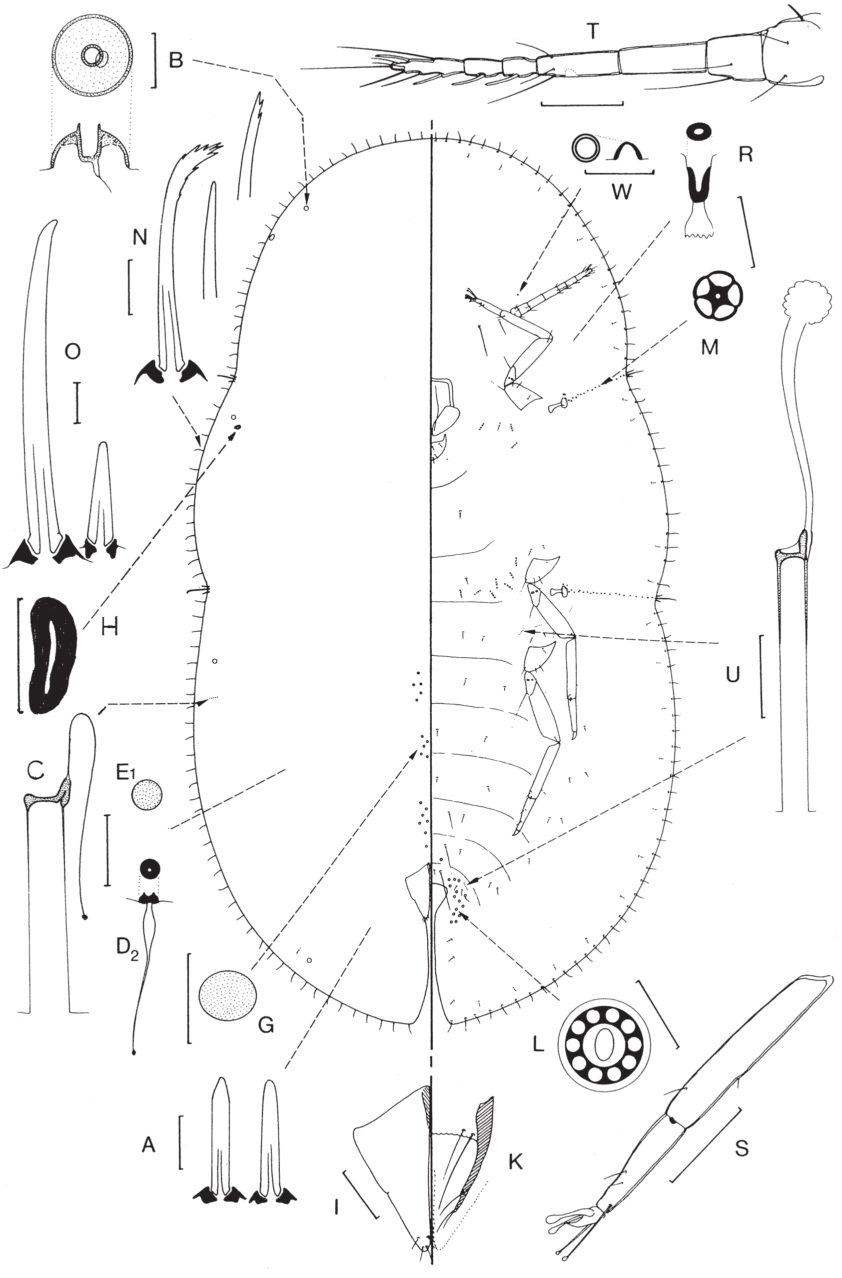

Fig. 1. Adult female *Coccus hesperidum*; showing position of pocket-like sclerotisation (H): scale line for H = 5μm.

Table 1. Means and ranges of ten characters of adult female *Coccus hesperidum* L. collected off five different host plant species

| Character | Hosts | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Citrus* | | | *Ficus* | | | *Hedera* | | | *Fraxinus* | | | *Schefflera* | | |
| | n | Mean | Range | n | Mean | Range | n | Mean | Range | n | Mean | Range | n | Mean | Range |
| Body length (μm) | 186 | 2295 | 1400-4000 | 93 | 2988 | 1230-4550 | 29 | 2747 | 1680-3800 | 30 | 1885 | 1350-3060 | 100 | 2255 | 1380-3240 |
| Body width (μm) | 188 | 1295 | 640-2300 | 93 | 1827 | 570-2550 | 30 | 1710 | 900-2520 | 30 | 944 | 600-1350 | 100 | 1289 | 510-2400 |
| Antenna length (μm) | 163 | 307 | 170-390 | 85 | 286 | 230-320 | 29 | 278 | 210-310 | 30 | 261 | 220-322 | 99 | 294 | 235-342 |
| Trochanter + femur length (μm) | 184 | 166.6 | 125-200 | 88 | 163 | 140-185 | 30 | 162 | 145-180 | 30 | 148 | 125-170 | 100 | 159 | 130-200 |
| Dors. tubular ducts: no | 155 | 4.1 | 0-14 | 84 | 4.8 | 0-17 | 29 | 4.8 | 0-11 | 30 | 0 | 0 | 97 | 6.1 | 0-19 |
| Dorsal tubercles: no | 180 | 6.5 | 2-10 | 87 | 6.6 | 3-10 | 30 | 7.3 | 6-9 | 28 | 2-9 | 2-9 | 98 | 6.6 | 2-10 |
| Spiracular disc-pores: posterior furrow: no | 180 | 23.6 | 12-33 | 87 | 23.5 | 15-31 | 30 | 24.4 | 18-31 | 29 | 17-26 | 17-26 | 100 | 24.0 | 16-39 |
| No. ventral tub. ducts: | | | | | | | | | | | | | | | |
| mesad to procoxa | 166 | 1.7 | 0-6 | 87 | 2.0 | 0-5 | 29 | 1.4 | 0-4 | 30 | 0-3 | 0-3 | 97 | 2.0 | 0-7 |
| mesad to metacoxa | 167 | 5.9 | 0-14 | 86 | 7.4 | 2-17 | 30 | 3.3 | 1-7 | 30 | 0-9 | 0-9 | 96 | 6.2 | 2-14 |
| intersegmental btwn meso- and metacoxa | 168 | 2.7 | 0-7 | 88 | 3.7 | 1-9 | 30 | 1.1 | 0-4 | 30 | 0-6 | 0-6 | 95 | 2.3 | 0-10 |

*Ficus* (usually with a group of 7-9 mesad to each mesocoxa) and the least was on the specimens off *Hedera* (60% had only 1 to 3 ducts mesad to each mesocoxa). On the remaining material, the most frequent number mesad to each mesocoxa was 4-6.

The presence of ventral tubular ducts laterad to the metacoxa and to the genital opening was highly variable; females without these ducts were dominant on specimens off *Hedera*.

VARIATION OF MORPHOLOGICAL CHARACTERS OF FEMALE *C. HESPERIDUM* OFF DIFFERENT PARTS OF *CITRUS* PLANTS:

The means and ranges for each of the characters on specimens collected off four different parts of *Citrus limon* are shown in Table 2. This shows that the largest specimens (body length and width) were off the stems and petioles rather than off the leaves, although there was much overlap.

Only two meristic characters (number of dorsal tubular ducts and number of spiracular disc-pores in the posterior stigmatic furrow) varied depending on the position on the plant. Thus, specimens off the leaves tended to have more dorsal tubular ducts than those off the stems and petioles (means of 4.6 and 5.3 off the former as compared with 3.1 and 3.2 off the latter) and similarly with spiracular disc-pores (means of 24 and 25 as compared with 22). However, on all samples, dorsal tubular ducts were sometimes absent and the most common frequency was 1-3 ducts on each side. As regards the spiracular disc-pores, specimens off the petioles tended to have the least, usually having between 16 and 20. However, there was much overlap in both characters.

The presence of ventral tubular ducts laterad to the metacoxae and laterad to the genital opening was highly variable, but a single tubular duct was generally present near the genital opening, although a few specimens had two ducts.

## DISCUSSION

This study shows that there is much variation in the structure of adult female *C. hesperidum*, depending on host plant species and on their position on the host.

Among the meristic characters studied, only the frequency of dorsal and ventral tubular ducts varied greatly between host plant species. Ventral tubular ducts were never found medially between the metathoracic legs, thus agreeing with the descriptions of this species by Hodgson (1967) and Gill *et*

Table 2. Means and ranges of ten characters of adult female *Coccus hesperidum* L. collected from four different parts of *Citrus*.

| Characters | Plant parts | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Stems | | | Petioles | | | Upper leaf surface | | | Lower leaf surface | | |
| | n | Mean | Range | n | Mean | Range | n | Mean | Range | n | Mean | Range |
| Body length (μm) | 54 | 2500 | 1700-4000 | 28 | 2373 | 1770-3250 | 42 | 2200 | 1400-2940 | 62 | 2145 | 1410-3090 |
| Body width (μm) | 53 | 1510 | 900-2300 | 29 | 1282 | 940-1650 | 45 | 1194 | 680-1980 | 61 | 1189 | 680-1780 |
| Antenna length (μm) | 50 | 308 | 255-330 | 24 | 302 | 240-340 | 36 | 299 | 262-365 | 53 | 314 | 250-390 |
| Trochanter + femur length (μm) | 54 | 166 | 140-180 | 28 | 164 | 125-185 | 42 | 163 | 150-180 | 62 | 167 | 140-200 |
| Dorsal tubular ducts: no. | 38 | 3.1 | 0-10 | 22 | 3.2 | 0-11 | 40 | 5.3 | 0-12 | 55 | 4.6 | 0-14 |
| Dorsal tubercles: no. | 53 | 6.4 | 2-10 | 26 | 6.5 | 4-9 | 41 | 6.5 | 4-10 | 60 | 6.6 | 3-10 |
| Spiracular disc-pores in posterior furrow: no. | 55 | 22.1 | 12-33 | 23 | 21.9 | 16-30 | 40 | 23.8 | 14-33 | 62 | 24.9 | 16-35 |
| Ventral tubular ducts: | | | | | | | | | | | | |
| mesad to processes: no. | 52 | 1.7 | 0-5 | 21 | 1.5 | 1-3 | 39 | 1.8 | 0-4 | 54 | 1.7 | 0-6 |
| mesad to metacoxae: no. | 48 | 5.9 | 2-11 | 21 | 5.8 | 4-9 | 40 | 5.9 | 3-9 | 58 | 5.9 | 0-14 |
| intersegmental between meso- and metacoxae: no. | 47 | 2.7 | 1-7 | 22 | 2.7 | 1-4 | 40 | 2.5 | 0-5 | 59 | 2.9 | 0-6 |

*al.* (1977). On the material from Poland, the frequency of the dorsal tubular ducts ranged from 0-19 while, on specimens from North America, it ranged between 0-21 (Gill *et al.*, 1977).

Only two meristic characters (i.e., the number of dorsal tubular ducts and the number of spiracular disc-pores) varied according to the position of females on their host plant but even these showed much overlap. The remaining meristic characters were all very similar.

The mean number of dorsal tubercles was also similar for all the samples studied, and appeared to be independent of host plant species and of the position on the host. In North America, both Williams & Kosztarab (1972) and Gill *et al.* (1977) found up to a total of 12 dorsal tubercles, but the maximum on Polish adult females was only ten.

In 1967, Hodgson suggested that the presence or absence of the dorsal tubular ducts and the ventral tubular ducts found near the genital opening might be affected by the development site of the females on the plant, and that these ducts might be absent from specimens taken from the leaves. However, on the Polish material studied here, these ducts could be present or absent.

The specimens off *Iresine herbstii* clearly differed from the other material in lacking dorsal tubular ducts and pocket-like sclerotisations, and also in the shape and size of their dorsal setae. In addition, the mean values for all measured characters and for the two meristic characters were the smallest in comparison with those off the other four host plants. More females from this host plant should be examined to confirm these results.

Although *C. hesperidum* has been redescribed many times in the last twenty or so years (Hodgson, 1967, 1994; Ezzat & Hussein, 1969; Williams & Kosztarab, 1972; Gill *et al.*, 1977; Tereznikova, 1981; Williams & Watson, 1990), pocket-like sclerotisations have never been noted before. Even within the material studied (all from Poland), pocket-like sclerotisations was absent from all specimens off *Iresine*, suggesting that this may be a host-induced difference.

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LAMBDIN, P.L.[1]; JOSHI, P.A.[2]

[1]*Department of Entomology and Plant Pathology, The University of Tennessee,*
*P. O. Box 1071, Knoxville, Tennessee 37901-1071, USA*

[2]*Priyavadan A. Joshi, Department of Plant Biology, The Royal Veterinary &*
*Agriculture University, 40 Thorvaldsensvej,*
*DK-1871 Frederiksberg C Copenhagen, Denmark*

# HAEMOCYTES OF THREE SCALE INSECT SPECIES: *PHENACOCCUS GOSSYPII* TOWNSEND & COCKERELL, *PSEUDOCOCCUS LONGISPINUS* (TARGIONI TOZZETTI) AND *DACTYLOPIUS CONFUSUS* (COCKERELL) (HEMIPTERA: COCCOIDEA).

## ABSTRACT

HAEMOCYTES OF THREE SCALE INSECT SPECIES: *PHENACOCCUS GOSSYPII* TOWNSEND & COCKERELL, *PSEUDOCOCCUS LONGISPINUS* (TARGIONI TOZZETTI) AND *DACTYLOPIUS CONFUSUS* (COCKERELL) (HEMIPTERA: COCCOIDEA).

An evaluation of the haemocytes in the cochineal scale, *Dactylopius confusus* (Cockerell), was completed and compared with those found in the mealybugs *Phenacoccus gossypii* Townsend & Cockerell and *Pseudococcus longispinus* (Targioni Tozzetti) to assess the potential sites of the dye pigment source. Four basic cell types were found in the two pseudococcids and five in the cochineal scale. The cell types common to all species included: prohaemocytes, oenocytoids, typical granulocytes and plasmatocytes. In addition, a modified granulocyte (poly-glyco-based granulocyte) was found to be specific to the cochineal scale and this produced rough endoplasmic reticulum derived granules that may be the source for the synthesis of carminic acid.

Key words: function, *Coleus*, *Philodendron*, *Opuntia*, unknown cell type, haemolymph.

## INTRODUCTION

The haemolymph in insects not only functions to transport nutrients, hormones and other components throughout the body but, in several species, also functions to protect the individual from parasites or predators. Six primary cell types are recognized in the insect species examined in the past (Gupta, 1991), with the cell types present often depending upon the taxa, stage of development and state of health of the insect. Although substantial research on the haemocytes of insects in different orders exists, only a few studies have been conducted on scale insects (Joshi & Lambdin, 1996: Poisson & Pesson, 1937: Tauber & Yeager, 1935: Yadava, 1967). Historically, the unique red dye derived from the cochineal scale was used in textile, medical and agricultural products in the United States until the mid-1960’s. Although the more permanent and more economically produced aniline dyes that eventually replaced the organic-based dyes are beneficial, concern has arisen regarding their disposal and their accumulation in streams and underground water. Attention is beginning to focus once again on organic-based materials as they might be more environmentally compatible, causing fewer allergic reactions upon contact and possibly breaking down more rapidly in the environment once materials containing the dye are discarded; however, these last two points still need clarification. Our objectives of this study were to assess the haemocytes of three scale insects to determine whether the same haemocytes were common to all three species and to investigate the potential source of the dye in the cochineal scale.

## MATERIAL AND METHODS

Populations of three scale insect species (the mealybugs *Phenacoccus gossypii* Townsend and Cockerell and *Pseudococcus longispinus* (Targioni Tozzetti), and the cochineal *Dactylopius confusus* (Cockerell)) were maintained on *Coleus* sp., *Philodendron* sp. and *Opuntia* sp., respectively. Haemocytes were obtained by bleeding adult females (20-24 per species) and processing the haemolymph to obtain sections to view under the transmission electron microscope (TEM) (Joshi & Lambdin, 1996). Histochemical tests for glycogen, mucoproteins and glycoproteins were made on 1μm thick sections and on blood smears by the Periodic acid-Schiff (PAS) reaction, with amylase and dimedone used as control treatments.

## RESULTS

We observed four typical haemocyte types (prohaemocytes, typical granulocytes, oenocytoids and plasmatocytes) in all three insects. However, in addition to these, a fifth cell type, a modified granulocyte (poly-glyco-based) was observed in *D. confusus*.

**Prohaemocytes** (Fig. 1a): round to oval stem cells, characterized by the lack of differentiation of sub-cellular material, with a large medial nucleus occupying most of the cell and containing a distinct nucleolus, and a poorly developed rough endoplasmic reticulum (RER) system. From the PAS test, these cells took on a pink colour, indicating a high cytoplasmic density possessing some glycogen components. These cells were few in number and, when found, were amassed in clusters.

**Oenocytoids** (Fig. 1b): the second most abundant haemocyte type in the haemolymph of all three species examined. Distinguished by their oval to oblong appearance, a small central or exocentric nucleus, well-developed

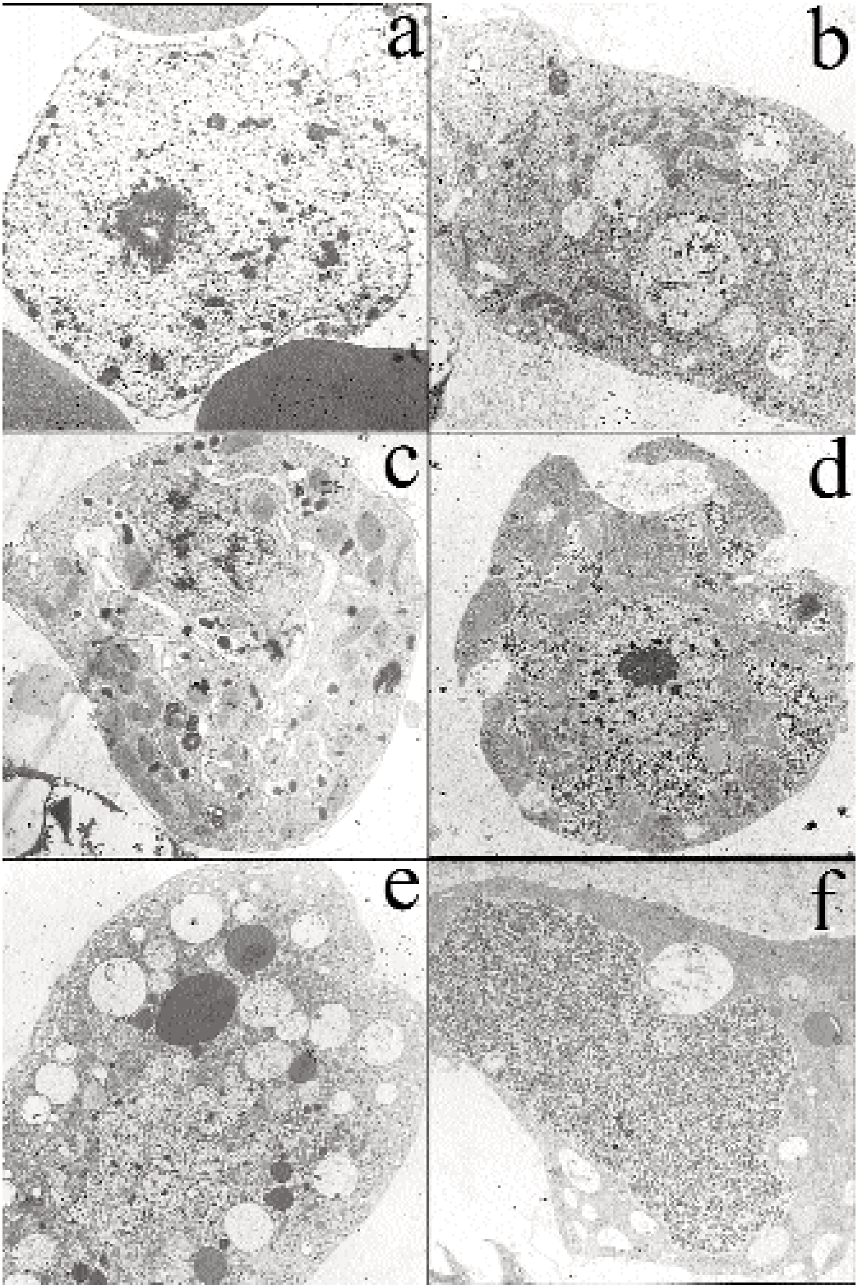

**Figure 1 a-f.** Haemocytes: a, prohaemocyte; b, oenocytoid; c, typical granulocyte; d, modified granulocyte; e, plasmatocyte; f, undetermined cell type.

mitochondria, a moderate smooth endoplasmic reticulum (SER) and RER systems, and the presence of large crystals within the vacuoles. Like the typical granulocytes, these crystals stained metachromatically with toluidine blue and are PAS-negative. As such, they have a different chemical nature and functional role to the granules observed in the modified granulocytes (i.e. storage of excretory products). Release of crystals into the haemolymph also indicates an additional role for these crystals in this species.

Histochemical tests with PAS provided a positive colour reaction within the cytoplasm of oenocytoids. The colour reaction of these granules was less than that for the modified granulocytes. The granules appeared to be synthesized on the polyribosomes on the RER membrane. The crystals aggregated within the vascular spaces of the more mature cells and were eventually deposited into the haemolymph. Numerous free crystals, which did not have a colour reaction with the PAS test, were found within the haemolymph.

**Typical Granulocytes** (Fig. 1c): observed in the two mealybug species. Subcircular, with a central nucleus, well-developed RER and SER systems, numerous mitochondria and SER-originated membrane-bounded granules. These granules stained metachromatically with toluidine blue inferring that the mode of origin and structure of the large granules was different from that of the rosette-shaped granules common to the modified granulocytes.

**Modified granulocytes** (Figs. 1d): absent in the mealybug species but by far the most abundant haemocyte population in adult female *D. confusus*. Distinguished by the numerous mitochondria and well-developed RER, producing numerous, rosette-like, fine granules within the cytoplasm. Based on histochemical data from the PAS test, a positive colour reaction occurred, ranging from a light pink in the cytoplasmic area to a high intensity pink found in the dense granules. As such, these fine granules appeared to be glycogen or glycoprotein in nature. No colour reaction occurred in the control treatment when subjected to the PAS histochemical test.

**Plasmatocytes** (Fig. 1e): the largest haemocytes observed, distinguished by their ovoid to amoeboid shape. Plasmatocytes possess a large, elongated and lobed nucleus and numerous small vesicles along the periphery of the plasma membrane. Histochemical tests with PAS did not provide a colour reaction either in the cytoplasm or vascular content, while toluidine blue heavily stained these structures. Also, the cytoplasm and vacuoles did not stain metachromatically with toluidine blue. These cells were capable of surrounding or engulfing foreign particles and probably function as one of the first lines of defense against potential disease-causing agents.

An **undetermined cell** (Fig. 1f) was observed in the haemolymph of the cochineal insect. The large nucleus occupying much of the cell and the numerous mitochondria present in the cytoplasm were the most pronounced traits of this cell and were unlike that found in the prohaemocytes.

## DISCUSSION

Based on histochemical tests and observations at the TEM level, four types of haemocyte were identified in adult female *Phenacoccus gossypii* and *Pseudococcus longispinus* and five types in the cochineal scale. It would appear that the cell types present may differ depending on the species. It is unclear why these differences exist. The selected genetic trait for this modified granulocyte may have originally developed as a result of feeding activity by species of *Dactylopius* on *Opuntia* and may now aid in protection against natural enemies and invading foreign agents. The special, modified granulocytes are believed to perform a synthetic and secretory function in the cochineal scale. That this modified granulocyte is the source of the proteins responsible for the colour of the haemolymph is supported by the production of fine particles, which are synthesized along the length of, and secreted from, the RER into vacuoles, and by the exocytosis of these particles in a mass into the haemolymph.

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LIT, I.L. JR[1]; GULLAN P.J.[2]

[1] *Museum of Natural History, University of the Philippines Los Baños (UPLB), College, Laguna 4031, Philippines.*

[2] *Division of Botany & Zoology, The Australian National University, Canberra, ACT 0200, Australia.*

# COMPARATIVE MORPHOLOGY OF THE ANAL TUBERCLE AND ASSOCIATED STRUCTURES OF SOME LAC INSECTS (HEMIPTERA: COCCOIDEA: KERRIIDAE).

## ABSTRACT

COMPARATIVE MORPHOLOGY OF THE ANAL TUBERCLE AND ASSOCIATED STRUCTURES OF SOME LAC INSECTS (HEMIPTERA: COCCOIDEA: KERRIIDAE).

Specimens of *Austrotachardia acaciae* (Maskell), *Austrotachardia* sp. ex *Cassinia* spp., *Kerria lacca* (Kerr) and *Paratachardina decorella* (Maskell) were examined under the scanning electron microscope (SEM). SEM images were compared with observations under the light microscope. The anal tubercles and associated structures of each species are described and compared. The presence of what appears to be vestiges of an anal cleft in *Paratachardina* is interpreted as suggesting the possible evolution of the lac insects from a lecanoid ancestor that possessed an anal cleft. The results provide an easier interpretation of these characters under the light microscope.

Key words: morphology, pre-anal plate, supra-anal plate, tubular plate, anal fringe, anal ring, anal collar, anal ring wax-pores, anal tube, perisetal micropores, homology, Coccidae, Pseudococcidae, *Acacia*, *Callitris*, Australia, Thailand.

## INTRODUCTION

Among the scale insects (Coccoidea), the lac insects (Kerriidae) possess very unusual morphological details. The family is probably the easiest to define as a group as it has, in addition to the anal tubercle, such unique characteristics as the dorsal spine, brachia and brachial plates, among others. Ferris (as quoted by Chamberlin, 1923) wrote that they “constitute a very peculiar and isolated group” and their unique characters “are apparently not homologous with anything found in any other” Coccoidea.

However, with the exception of the Indian lac insect (*Kerria lacca* (Kerr)), the group is one of the (if not *the*) least studied coccoid families, despite the works of Chamberlin (1923, 1925) and Varshney (1977, 1984). This neglect is probably due to the difficulty of preparing slide mounts and their relative rarity as compared to other scale insects. Furthermore, taxonomically important characters are difficult to interpret under the light microscope because, although these odd insects are generally membranous and soft-bodied, the significant characters are usually highly sclerotised.

This paper deals with the comparative morphology of the anal tubercle and associated structures of four species of lac insects. It is the first of a series of studies on the morphological characters of the Kerriidae. By studying the external appearance of lac insects under the scanning electron microscope (SEM), especially the highly sclerotised structures, this paper aims to: (1) provide a better understanding of their morphology; (2) facilitate the interpretation of characters under the light microscope, and (3) gain insights into the possible putative relationships of the Kerriidae with other groups of scale insects.

In this study, standard procedures were followed in preparing specimens for slide mounts and for SEM. For the latter, all specimens were taken from alcohol-preserved collections except for *K. lacca* which were from a dried lac stick. Slide mounts of the specimens examined are deposited in the Australian National Insect Collection (ANIC), CSIRO Entomology, Canberra, Australia, with the exception that the specimens of *K. lacca* are deposited in the Entomology Section of the UPLB Museum of Natural History.

## RESULTS AND DISCUSSION

### GENERAL MORPHOLOGY OF THE ANAL TUBERCLE

Basically, the anal tubercle is the more or less heavily sclerotised posterior prolongation of the body. In the three genera we have so far studied, this structure is held upright on the dorso-posterior area and this is probably also true for the rest of the Kerriidae. In general, the anal tubercle is composed of plates or sclerotised regions referred to as the supra-anal plate, the anal fringe and the adjacent and/or intermittent membranous areas. In some species or groups, a pre-anal plate precedes the supra-anal plate, as in two known *Austrotachardia* species. The distal end of the tubercle of all lac insects bears the anal ring with its complement of ducts, pores and anal-ring setae and often an anal tube. All Kerriidae possess 10 anal-ring setae.

The supra-anal plate is an incomplete tubular plate that covers the anal tubercle. In some groups, e.g., *Metatachardia*, a pre-anal plate is located below it or on the area of the anal tubercle, next to the body. This plate (together with the pre-anal plate when present) comprises the principal sclerotised area of the anal tubercle. In our opinion, however, the pre-anal plate represents a segment anterior to the anal ring (e.g., possibly abdominal segment VII) that, together with the anal and penultimate segments, forms the anal tubercle, at least for *Austrotachardia* species. As such, the pre-anal plate is never really “absent” but is either in a membranous or a sclerotised state. Further studies of other lac insects will probably reveal intermediate states such as slightly sclerotised and highly sclerotised.

Both Chamberlin (1923) and Varshney (1977) described the anal fringe as some sort of apron possessing a median cleft and several irregular lobes that project posteriorly. In live specimens and under SEM, the boundaries and details of the sclerotised plates (pre-anal and supra-anal plates), as well as the anal fringe, are not easily discernible. Under SEM, however, these regions are bounded by areas of depression or varying degrees of wrinkling or folding, the latter indicating its membranous nature and thus indicating that it is likely to be affected by drying and/or fixing. Under the light microscope, the boundaries of these plates are better seen when slides have been prepared so that the anal tubercle is expanded or extended.

## BRIEF DESCRIPTIONS OF ANAL TUBERCLES:

### ***Austrotachardia acaciae*** (Maskell) (Fig. 1)

Anal tubercle large and elongate, broadly dome-shaped, with vulva at base of posterior side; supra-anal plate strongly sclerotised, with fine sculpturing (i.e. micropapillose) distally; pre-anal plate absent or probably membranous and not evident; anal fringe apparently entire, without an obvious median cleft or line of filaments, somewhat broadly spatulate on longer (medial) end and bearing 1-2 marginal setae on each apex; anal ring 4-sectored, surrounded by a circular structure here referred to as the collar; anterior anal-ring sectors each with 3 anal-ring setae, posterior each with 2 setae; anal-ring setae longer than anal fringe; anal tube cylindrical, very prominent.

*Material examined*. SEM & slide mounts: AUSTRALIA: Northern Territory (NT): Alice Springs, 23°43’S, 133°53’E, ex stem of *Acacia aneura* (mulga) (Leguminosae), P.J. Gullan coll., 01.VI.1992. NT: N’Dhala Gorge, 23°29’S, 134°27’38”E, ex stem of *A. aneura* group, P.J. Gullan coll., 25.V.1992. Other slide mounts: South Australia: 75km N of Coober Pedy, ex *Acacia* sp., F.D.M. coll., 28.VIII.1976. NT: Haast’s Bluff Reserve, ex *Acacia aneura*, J.B. Cleland coll., VIII.1957.

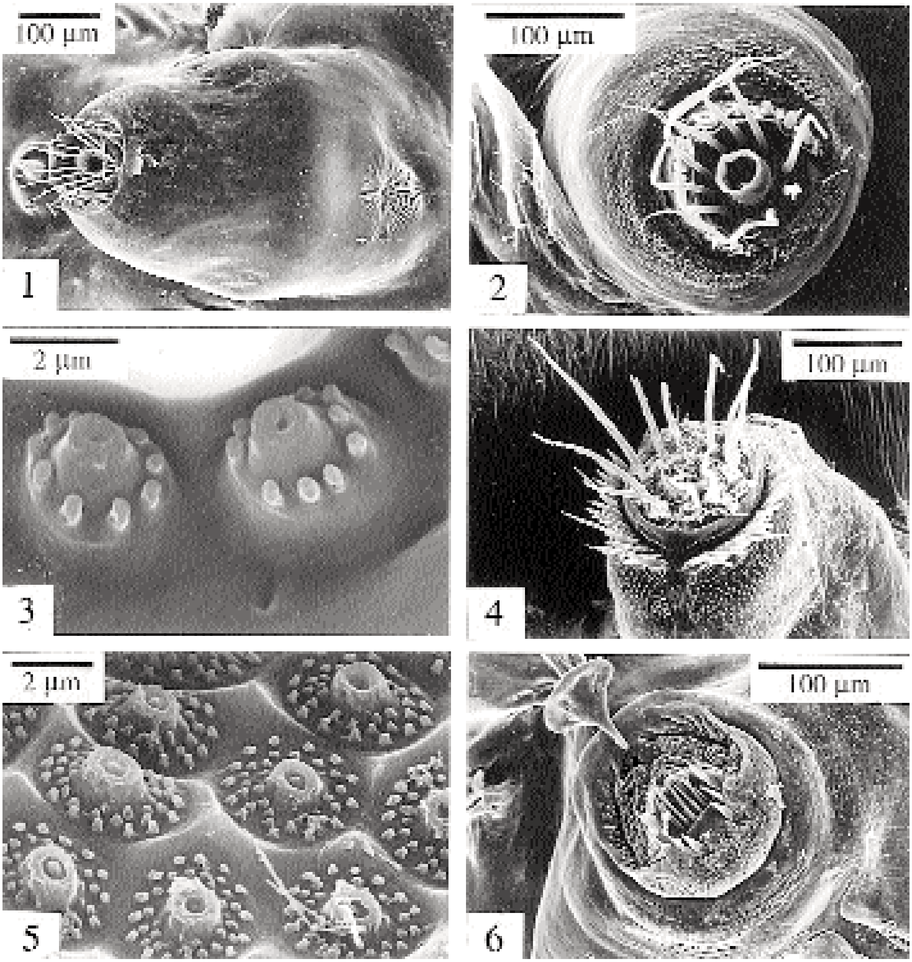
*Remarks*. Chamberlin (1923) did not have sufficient material “to permit working out the anal fringe” of this species. He also remarked that “the anal tubercle of this species requires more careful study to determine whether or not there is a truly essential difference between it and the type found in other species of the genus." We now believe that the anal fringe of this species is entire and that the pair of ligulate lobes known in other *Austrotachardia* species is absent. This is probably a case of secondary fusion of the lobes, since some slide-mounted specimens reveal a faint membranous line in the medial area of the anal fringe. Thus, the anal fringe may not be typical of the genus *Austrotachardia*. Chamberlin (1923) described the anal ring as being "retracted far under a heavy chitinous projection entirely different in character from the typical fringe", and this projection is here interpreted to be the anal collar (as shown by our SEM observations), which has not previously been recorded.

### ***Austrotachardia*** sp. ex ***Cassinia*** (Figs 2, 3)

Anal tubercle large, elongate and broadly dome-shaped but relatively smaller than that of *A. acaciae*; supra-anal plate strongly sclerotised and tuberculate around tip; pre-anal plate present as thin subcircular or subcylindrical patch below much larger supra-anal plate; anal fringe consisting of fairly broadly ligulate lobes on either side of a median cleft, each lobe bearing 5-6 fimbriate, bluntly spinose or digitate setae on the margins and 1-2 shorter but conical setae approximately apically; anal ring 4-sectored, each anterior sector embracing 3 anal-ring setae, each posterior sector with 2 setae; anal-ring setae at least 3 times as long as anal fringe, each surrounded by about eight perisetal micropores (Fig. 3) and each micropore surrounded by 10-12 or more minute tubercles; anal collar narrow; anal tube prominent but not as obvious as that of *A. acaciae*.

*Material examined*. SEM: AUSTRALIA: New South Wales (NSW): Orange, from culture on *Cassinia* (Compositae), M.H. Campbell coll., 08.II.1995. Slide mounts: same locality but from property of P. Wykes, Kerr's Creek, ex *Cassinia arcuata,* M.H. Campbell coll., -.XII.1990.

*Remarks*. This possibly undescribed species appears to be morphologically close to *A. melaleucae* in possessing a thin pre-anal plate and in a few other characters. The differences between the two species will be covered in a future revision of the genus. Based on our observations under SEM and the light microscope, as well as the descriptions provided by Chamberlin (1923), the anal fringe of this species may be said to be typical (as defined by Chamberlin) of *Austrotachardia*. The existence of minute structures surrounding each anal-ring seta is hitherto unknown in any lac insect species. They are possibly also secretory in function and might also be present in other *Austrotachardia* species at least, although we have so far been unable to observe them on *A. acaciae*.



**Figures 1-6.** SEM images of anal tubercles and associated structures of some lac insects (Kerriidae): **1.** *Austrotachardia acaciae*, posterior view showing vulva at the base; **2-3.** *Austrotachardia* sp. ex *Cassinia*: 2. Dorsal view; 3. Details of perisetal micropores; **4-5.** *Kerria lacca*: 4. Posterodorsal aspect; 5. Details of perisetal micropores; **6.** *Paratachardina decorella*, dorsal view, showing flap-like structures

### ***Kerria lacca*** (Kerr) (Figs 4, 5)

Anal tubercle large, elongate (longer than widest width) but relatively narrower or thinner than that of *A. acaciae,* except for the setae and fringe, conical but almost truncate at tip; supra-anal plate strongly sclerotised and papillose; no pre-anal plate visible; anal fringe sharply acute, consisting of fairly short but wide lobes on either side of a median cleft, each lobe bearing about 3 ligulate setae, as well as variously digitate or fimbriate fringes on margins and with 1-2 small conical setae at apex; anal ring 4-sectored, bordered by a fairly narrow collar; sectoral divisions not as well defined as those of *Austrotachardia*; anal-ring setae longer than anal fringe; perisetal micropores scattered around each sector, more numerous than those of *Austrotachardia*; each micropore surrounded by at least 40 minute tubercles (Fig. 5); anal tube prominent but only about 1/6 as long as anal-ring setae.

*Material examined.* SEM: THAILAND: Bangkok?, in cultivation, no host data, F.M. Laigo coll., 02.X.1960.

*Remarks. Kerria lacca* is the most well-known and most frequently described lac insect. Even so, the anal collar that borders the anal ring and the micropores surrounding the anal-ring setae have not previously been described. These micropores probably correspond to the anal-ring wax-pores observed under the light microscope in other coccoid families, e.g., in the Pseudococcidae. In *K. lacca*, the anal fringe also possesses fringes in the form of long, variously digitate or fimbriate extensions of the major lobes, in addition to the definable setae.

### ***Paratachardina decorella*** (Maskell) (Fig. 6)

Anal tubercle short, broader than long, not as prominent as in other genera; lateral profile quite convex; supra-anal plate strongly sclerotised, top portion tuberculate, apparently eversible/depressible, with posterior portion papillose; pre-anal plate visible in slide-mounted specimens as a very thin slightly sclerotised semicircular bar that runs around base of supra-anal plate and fades or blends with surrounding membranous area; anal fringe consisting of a pair of angular, fairly long, ligulate lobes on either side of a median cleft; lobes of anal fringe bearing 1-2 marginal setae and 1-2 smaller conical setae at posterior apex; anal ring entire, not sectored; anal-ring setae longer than anal fringe; anal tube not obvious. With a pair of flap-like structures present on posterior side at the base of anal tubercle, these not obvious under light microscope.

*Material examined.* SEM and slide mounts: AUSTRALIA: NT: Watarrka National Park, Stokes Creek, 24°21’S, 131°45’E, ex stem of *Callitris* *columellaris* (Cupressaceae), P.J. Gullan, coll., 04.VI.1992. Slide mounts: NSW: 20km E of Temora, 1km E of Springdale, ex *Callitris glaucophylla*, P.J. Gullan coll., 30.X.1993.

*Remarks*. The pair of flap-like structures on the posterior side of the anal tubercle are most probably the terminal ends of the pre-anal or supra-anal plate that have not fused fully with the rest of the tubercle integument. From many angles, these flaps appear to be vestiges of an anal cleft.

### COMPARATIVE NOTES AND HYPOTHESES:

The presence of what appears to be vestiges of an anal cleft in *Paratachardina* suggests that the lac insect group may have evolved from an ancestor that bears such a structure. At the same time, the pair of flap-like structures on the posterior side of the anal tubercle suggests that the supra-anal plate is homologous to the anal cleft of coccids and related cleft-bearing families. In addition, the structure of the anal fringe, especially its possession of a median cleft and its position in the anal tubercle (i.e. just above or anterior to the anal ring) suggests an homology with the anal plates of the Coccidae. In *A. acaciae*, however, there seems to have been some secondary fusion of the lobes of the anal fringe. Furthermore, the presence of an anal tube (which is very prominent in *A. acaciae*) suggests and confirms an earlier hypothesis that lac insects belong to the lecanoid family-group. Thus, the whole morphological structure of the anal tubercle, as complex as it is in the adult female Kerriidae and probably involving fusion and sclerotisation, appears to represent a highly derived character that is homologous to the anal structures of coccids – e.g., the anal cleft, anal plates, anal tube, anal ring and its complement of setae and wax pores. Indeed, the Kerriidae (as the Tachardiidae) was the sister group to the Coccidae in one of Miller & Hodgson's (1997 - Fig. 1.1.3.7.5) cladograms.

These hypotheses may be supported in the future by further evidence from an on-going study of first-instar nymphs of some *Austrotachardia* species. Hodgson's (1995) study of plate-like structures associated with anal areas of lecanoid Coccoidea did not discuss the ontogeny of these structures in Kerriidae and 2 other families, due to lack of information on first-instar nymphs. However, an earlier work by Miller (1991) included an illustration of a first-instar lac insect and so did Chamberlin (1923). There are some differences between our interpretation and that of Miller (1991) and Chamberlin (1923) with regard to the structure they labelled as the "supra-anal plate". We do not intend to discuss this matter in detail here but we tentatively propose that Miller's and Chamberlin's "supra-anal plate" on first-instar nymphs might actually be the precursor of the anal fringe.

The difficulty of interpreting highly sclerotised characters under the light microscope has not only been experienced by the present authors but also reported by other students of Coccoidea, such as Chamberlin (1923). SEM studies have not only helped to interpret these characters under the light microscope but have also revealed previously unknown details of kerriid morphology, such as the anal collar, the perisetal micropores and their accompanying minute tubercles, and the actual configuration of the anal fringe of *A. acaciae*. Further SEM studies, covering other difficult groups or species, will probably bring out more interesting data that will improve our understanding of the relationships and classification of the Kerriidae.

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MAROTTA, S.[1]; FRANCO, J.C.[2]

[1]*Dipartimento di Biologia, Difesa e Biotecnologie Agro-forestali, Università della Basilicata, via N. Sauro 85, 85100 Potenza, Italy*

[2]*Departamento de Protecção das Plantas e de Fitoecologia, Secção de Protecção Integrada, Instituto Superior de Agronomia, 1399 Lisboa Codex, Portugal*

# IS THE GENUS *LUSITANOCOCCUS* NEVES A JUNIOR SYNONYM OF *CUCULLOCOCCUS* FERRIS (HEMIPTERA: COCCOIDEA: PSEUDOCOCCIDAE)?

## ABSTRACT

Is the genus *Lusitanococcus* Neves a junior synonym of *Cucullococcus* Ferris (Hemiptera: Coccoidea: Pseudococcidae)?

The genus *Lusitanococcus* was established by Neves in 1954 to include *arrabidensis*, a new species of mealybug collected in Portugal on *Erica arborea* and *E. lusitanica*. Later, on the basis of the original illustration and description, some workers considered that *Lusitanococcus* was a subjective synonym of *Cucullococcus* Ferris, 1941, while others considered it a valid genus.

Specimens were collected in the topotypic locality in Portugal off the same species of host plant and compared with the type specimens of *Lusitanococcus arrabidensis* Neves and with *C. vaccinii* Ferris, the type species of *Cucullococcus*. From this study, we have concluded that: (i) the genus *Lusitanococcus* is a junior subjective synonym of *Cucullococcus*, and that (ii) *arrabidensis* is a valid species. Some points with regard to generic characters of *Cucullococcus* are discussed.

Key words: Portugal, Spain, California, generic description, morphology, type, *Erica*, *Vaccinium*.

## INTRODUCTION

The family Pseudococcidae includes more than 260 valid genera, of which about 40% are monotypic (Ben-Dov, 1994). Only a few monotypic genera are present in Europe and, among them, *Lusitanococcus* Neves stands out because of its' peculiar morphology. The validity of *Lusitanococcus* has been doubtful since its original designation and currently its' status is controversial. In fact, on the basis of the original illustration and description, *Lusitanococcus* has been considered to be a subjective synonym of *Cucullococcus* Ferris (1941) by some workers while others have considered it a valid genus.

The purpose of this paper is to discuss the systematic status of the genus *Lusitanococcus* and its type species *arrabidensis*.

### A BRIEF HISTORY

Neves (1954) established the genus *Lusitanococcus* to include *arrabidensis*, a new species of mealybug collected in 1943 in Portugal (Serra da Arrábida) on *Erica arborea* and *E. lusitanica*. In a footnote (p. 238) he wrote: "In 1943, when this paper was written, I was not aware of the publication of Prof. G.F. Ferris with the description of the genus *Cucullococcus*. The genus *Cucullococcus* is very similar to *Lusitanococcus* but it seems that there are some characteristics that are not shared by both genera. However, in 1946, Ferris told me that, according to him, it is the same genus" (translation from Portuguese). Neves (1954) also gave information regarding the first-instar nymph and the biology of *L. arrabidensis*. Subsequently, specimens have been collected in two other Portuguese localities: at Serra da Estrela, on *Erica* sp. in 1948 and at Mata de Leiria on *E. scoparia* in 1954.

The species was also recorded from Spain by Gomez-Menor Ortega (1957), who redescribed and illustrated the adult female and the 1st-, 2nd- and 3rd-instar female nymphs and the pupa, based on the Spanish specimens. He considered *Lusitanococcus* to be a valid genus. The views of other workers have been as follows: Morrison & Morrison (1966) regarded the genus as a subjective synonym of *Cucullococcus* Ferris without any comment or suggestions; McKenzie (1967), in his report of *Cucullococcus vaccinii* in California, did not mention *Lusitanococcus*; Kozár & Walter (1985) listed *Lusitanococcus* as a valid genus, but also quoted the Morrison & Morrison (1966) synonymy; Martin-Mateo (1985) included *arabidensis* (sic!) in the genus *Cucullococcus* for the Spanish fauna; Tang (1992) redescribed the adult female of *arrabidensis* and, following Morrison & Morrison (1966), regarded *Lusitanococcus* as a subjective synonym of *Cucullococcus* but considered *arrabidensis* a valid species; Ben-Dov (1994) wrote, in the Remarks for *Cucullococcus*: " Tang's (1992) interpretation that *Lusitanococcus* Gomez-Menor Ortega (sic!) is a subjective synonym of this genus is not accepted in this catalogue"; and for *Lusitanococcus*, he wrote: "Morrison & Morrison (1966) and Tang (1992) regarded this genus as a subjective synonym of *Cucullococcus* Ferris, but this interpretation is not accepted in this catalogue".

As far as we know, none of the authors studied Neves syntype series or other Portuguese specimens and even Gomez-Menor Ortega (1957) based his observations on Spanish specimens of *arrabidensis*.

## MATERIALS AND METHODS

Several fresh specimens of *arrabidensis* were collected on *Erica arborea* at the topotype site in February 1995 during a working visit to Portugal by the first author. These specimens have been studied and compared with both the syntype series of Neves and with specimens of *vaccinii*, the type species of *Cucullococcus* Ferris, including four paratype specimens.

The terminology for the adult female morphology follows McKenzie (1967). Abbreviations of depositories are as follows: Direcção Geral de Protecção da Produção das Culturas, Lisboa, Portugal (DPCL); Dipartimento di Biologia, Difesa e Biotecnologie Agro-forestali, University of Basilicata, Potenza, Italy (DBP); United States National Museum of Natural History, Beltsville, Maryland (USNM).

## RESULTS

From this study, we have concluded that: (i) the genus *Lusitanococcus* is a junior subjective synonym of *Cucullococcus*, and that (ii) *arrabidensis* is a valid species. The taxonomic redescription of *arrabidensis* will be presented in a future paper.

## TAXONOMY

*Cucullococcus* Ferris, 1941: 25; 1953: 312; McKenzie, 1967: 134; Tang, 1992: 588. Type species: *Cucullococcus vaccinii* Ferris, 1941, by original designation and monotypy.

*Lusitanococcus* Neves, 1954: 238; Gomez-Menor Ortega, 1957: 72. Type species: *Lusitanococcus arrabidensis* Neves, 1954, by original designation and monotypy. Synonymised by Morrison & Morrison, 1966: 112.

*Derivatio nominis*

The name *Cucullococcus* is derived from the Latin '*cucullus*', meaning 'hood', and refers to the sclerotised and enlarged anterior extremity.

### DESCRIPTION OF GENUS

Body of adult females subcircular or very broadly oval, with distinct segmentation and anterior extremity extended forwards and sclerotised. Mounted specimens less than 2mm long and 1.5mm wide. Antennae 5- or 6-segmented. Legs short and stout; claw with or without a small denticle on plantar surface; translucent pores present or absent. Dorsal ostioles absent. Cerarii of usual type absent, represented only by a pair of small setae on each anal lobe area. Four to six dark-rimmed circuli present. Anal ring simple, entirely without pores, bearing six small setae along its extreme anterior border. Anal lobes absent or poorly developed. Trilocular pores of normal size and form on both sides, replaced on posterior region of abdominal venter by 5-10 locular pores. Quinquelocular pores on venter only. Tubular ducts on both sides, moderately large, more or less sclerotised, with slightly convex internal termination.

### COMMENTS

The peculiar morphological characters of *Cucullococcus* are: (i) absence of dorsal ostioles and cerarii, (ii) presence of four to six dark-rimmed circuli, (iii) anal ring simple and without pores, (iv) the shape of the tubular ducts, (v) the extension and sclerotisation of the anterior extremity body, and (v) presence of quinquelocular pores ventrally.

The main differences in the adult females of *arrabidensis* and *vaccinii* are the structure of the legs and, in particular, the hind legs. In *vaccinii*, they are short and stout, normally developed, with distinct segments, without translucent pores and with a small denticle on the claw; in *arrabidensis*, the legs are short, stout and squat, sometimes distorted, with trochanter and femur fused and swollen (even globose in some specimens), with tibia and tarsus also fused or without free articulation, and with numerous, large and irregular translucent pores on all segments except the claw, which may or may not have a denticle.

However, these remarkable differences in the structure of the hind legs do not seem sufficient to justify the separation of these two genera, considering that they share many other morphological characters.

According to Ferris (1941) and McKenzie (1967), the “aberrant” genus *Cucullococcus* resembles certain species of *Ehrhornia* Ferris, *Discococcus* Ferris and *Rhodania* Goux, but the above combination of characters should preclude confusion.

Tang (1992) includes *Cucullococcus* in the sub-family Phenacoccinae, tribe Ritsemini, together with *Ritsemia* Lichtenstein and *Polystomophora* Borchsenius. This interpretation requires further studies to evaluate the suprageneric group assignment.

### MATERIAL EXAMINED

*Lusitanococcus arrabidensis* Neves.

**Syntype ♀♀**. Fifty-five adult females mounted on 12 slides, labelled as follows: *Lusitanococcus arrabidensis* n.sp., s/*Erica arborea*, Serra da Arrábida (right label); Leg. M. Neves, Id. e Prep.: M. Neves, 4/IX/943 (left label). Forty-three of the specimens are mounted on 9 slides in Canada Balsam; twelve are mounted on 3 slides in Hoyer fluid (DPCL).

**Non-type material**. Forty-four specimens on 29 slides, labelled: *Lusitanococcus arrabidensis* Neves, det. S. Marotta, Serra da Arrábida, Portugal, on *Erica arborea*, 4/II/1995, leg. S. Marotta & J.C. Franco (DBP).

*Cucullococcus vaccinii* Ferris.

**Paratype ♀♀**. Four adult females on one slide, labelled: *Cucullococcus vaccinii* n.sp., on *Vaccinium parvifolium* Sm, Castle Lake Rd., Siskiyou Co. California, 8H, Stanford University Natural History Museum (USNM), without date or collector.

**Non-type material**. Three adult females on one slide: *Cucullococcus vaccinii* Ferris, det. by D.F. Wilkey, 14/II/1962, 500 feet north Gasquet Dump, Del Norte Co., California, 10/II/1962, ex. *Vaccinium parvifolium*, L.J. Garret coll. (USNM). Three adult females on one slide, labelled: *Cucullococcus vaccinii* Ferris, on *Vaccinium* sp., Grants Pass, Oregon, 30/III/1970, J.B. Gianell colr. (USNM).

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MAROTTA, S.; TRANFAGLIA, A.
*Dipartimento di Biologia, Difesa e Biotecnologie Agro-forestali,*
*Università della Basilicata, via N. Sauro 85, 85100 Potenza, Italy*

# A NEW MORPHOLOGICAL STRUCTURE ON *KERMES VERMILIO* (PLANCHON) (HEMIPTERA: COCCOIDEA: KERMESIDAE).

## ABSTRACT

A new morphological structure on *Kermes vermilio* (Planchon)
(Hemiptera: Coccoidea: Kermesidae).

*Kermes vermilio* (Planchon) is a common scale insect living on *Quercus ilex* L. in urban environments in Southern Italy. Morphological studies on the nymphs and prepupae showed the presence of a pair of membranous ventral frontal lobes, situated just antero-medially to each basal antennal segment. Similar lobes are only currently known in the family Eriococcidae. These structures are therefore here recorded in the Kermesidae for the first time, although it is thought probable that they are present on other species of the family. Their function is unknown.

Key words: phylogenetic relationships, Pseudococcidae, Dactylopiidae, Coccidae, Lecanodiaspididae.

## INTRODUCTION

*Kermes vermilio* (Planchon) is a rather common Mediterranean gall-like scale insect living mainly on *Quercus ilex* L. on which it does not cause damage. However, since 1987, it has been reported as a pest on ornamental *Q. ilex* trees in some Central and Southern Italy urban environments, and heavy infestations have recently been recorded in Tuscany, Emilia and Basilicata regions (Belcari & Minnocci, 1989; Belcari, 1991; Del Bene & Landi, 1992; Andreatta, 1996; Marotta *et al.*, 1998).

*K. vermilio* has one generation per year, overwintering as the 1st-instar nymph. Females develop through three nymphal stages, while males develop through four. Morphological characters have previously only been studied on the crawler, 3rd-instar nymph and adult female (Balachowsky, 1950; Borchsenius, 1960).

During the present investigations on the biology of this species, all instars of both sexes were studied taxonomically and it was found that large, ventral frontal lobes were present on male and female nymphs and on the prepupa. These structures are here recorded for the first time in the family Kermesidae, although it is considered likely that they are also present on other species of the family.

## MATERIALS AND METHODS

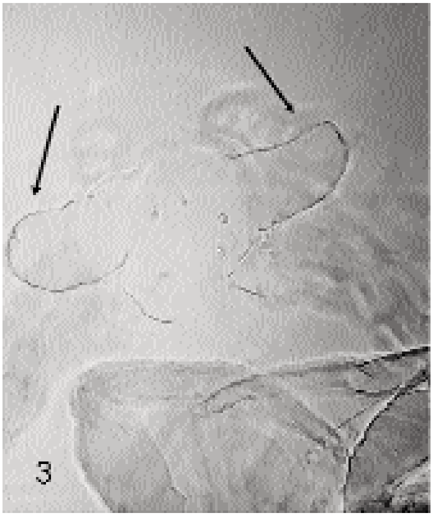
Specimens for light microscopy were collected during April and May between 1993 and 1995 at Rapolla (PZ), Basilicata region, Southern Italy. All suitable specimens were mounted on glass slides, using the permanent mounting procedure described in Bullington & Kosztarab (1985). Observations and photos were made under phase contrast, using a Zeiss Axiophot Microscope.

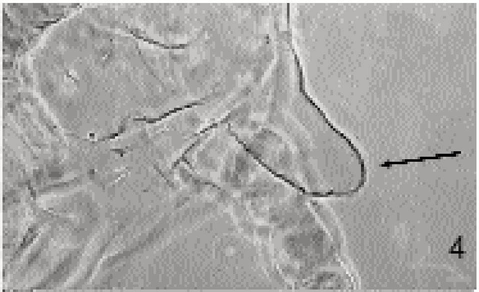
## RESULTS

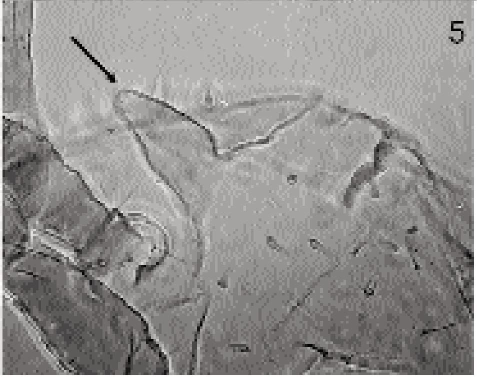
Pairs of ventral frontal lobes were observed on 2nd-instar males and females, and on 3rd-instar females and prepupal males. Each lobe arises laterally on a swollen area, here referred to as the frontal swelling, which is situated between the base of the antennae and the upper part of clypeolabral shield. The lobes appear membranous but vary considerably in size and length depending on the instar and the degree of body growth in each stage. They are much more pronounced and recognisable on newly-moulted specimens, when they stick out from the ventral surface. On 2nd-instar (Fig. 1) and 3rd-instar (Fig. 2) females, the “frontal swelling” is not very pronounced and the frontal lobes are sausage-shaped and about as long as the antennae. On 2nd-instar males (Figs 3, 4, 5), the “frontal swelling” and the frontal lobes are together T- or handlebar-shaped and the lobes are shorter than the antennae. On the male prepupa, the frontal lobes resemble those of third-instar female but are shorter. Their function is unknown.

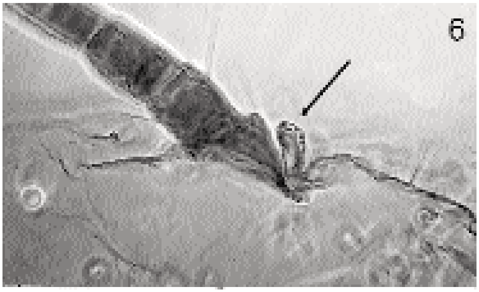
## DISCUSSION AND CONCLUSION

Frontal lobes have been recorded previously only in the family Eriococcidae and even then Williams (1985) commented: “These structure seem to have been ignored in most other works but Dr J.M. Cox and the present writer have observed them in numerous species from all zoogeographical regions” (see Williams, 1985, for further details; those found in *Acanthococcus aceris* (Signoret) are shown in Figs 6 and 7). There is no mention of these structures on the Kermesidae in any of the available morphological descriptions or illustrations (Nearctic (Hamon *et al.*, 1976; Bullington & Kosztarab, 1985; Baer & Kosztarab, 1985; Miller & Miller, 1993a); Palaearctic (Borchsenius, 1960; Sternlicht, 1969, 1972; Koteja & Zag-Ogaza, 1972; Saakyan-Baranova & Muzafarov, 1972)).









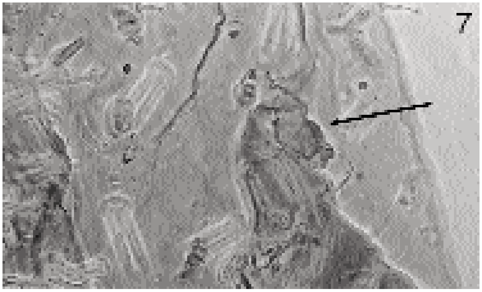


Fig. 1. Frontal lobes on *Kermes vermilio* (Planchon), second-instar female.

Fig. 2. Frontal lobes on *Kermes vermilio* (Planchon), third-instar female.

Figs 3, 4, 5. Frontal lobes on *Kermes vermilio* (Planchon), second-instar male.

Figs 6, 7. Frontal lobes on *Acanthococcus aceris* (Signoret), adult female.

The family Kermesidae Signoret includes about 70 species in 9 genera, but the taxonomic status of several species and the relationships between some genera in this family and others in the Coccoidea remains controversial. In the past, the genus *Kermes* Boitard has been placed in the Pseudococcidae, Eriococcidae, Dactylopiidae and Coccidae. Balachowsky included it in the Eriococcidae (1942) and Pseudococcidae (1948), while Goux (1946), Ferris (1955, 1957) and Borchsenius (1960) suggested a close relationship between *Kermes* and the family Eriococcidae. From a study of the males, Giliomee (1968) concluded that the genus was closest to the Coccidae and Lecanodiaspididae, while Koteja & Zag-Ogaza (1972) considered that the Kermesidae had probably evolved from the Eriococcidae at an early stage. Boratynski & Davies (1971) and Miller & Kosztarab (1979) stated that the Kermesidae and Eriococcidae were closely related, while Baer & Kosztarab (1985) and Kosztarab & Bullington (1987) concluded that Kermesidae had arisen from an eriococcid-like ancestor.

The cladistic studies of Miller & Miller (1993a) when studying *Eriokermes* suggested that the Kermesidae were closest to the Coccidae and that the Eriococcidae were closest to the Pseudococcidae, although in another paper on *Puto* (Miller & Miller, 1993b), the Eriococcidae were found to be closer to the Kermesidae than to the Pseudococcidae. More recent phylogenetic analyses suggest that the Kermesidae and Eriococcidae are closely related (Miller & Williams, 1995; Miller & Hodgson, 1997).

The frontal lobes observed in *Kermes vermilio* might be further evidence for the close relationship between the Kermesidae and the Eriococcidae. Their real taxonomic and phylogenetic importance can be tested only when new morphological studies have been made on other species.

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PODSIADLO, E.
*Department of Zoology, Warsaw Agricultural University, Warsaw, Poland*

# SEXUAL DIMORPHISM IN THE FIRST- AND SECOND-NYMPHAL INSTARS OF *QUADRASPIDIOTUS ZONATUS* (FRAUENFELD) (HEMIPTERA: COCCINEA: DIASPIDIDAE).

## ABSTRACT

Sexual dimorphism in the first- and second-nymphal instars of *Quadraspidiotus zonatus* (Frauenfeld) (Hemiptera: Coccinea: Diaspididae).

Morphological characters separating male and female 1st- and 2nd-instar nymphs of *Quadraspidiotus zonatus* are discussed. In the 1st instar, male nymphs possess a campaniform sensillum on each tarsus and dorsal submedian setae on the 1st abdominal segment; these characters are absent on the female. There is also a slight difference in the body shape.

In the 2nd-instar nymphs, the differences are greater. In the male nymph, the number of glandular ducts is much greater than in the female and there is a pair of setae present on the 1st abdominal segment and three pairs of ventral submedian setae on the head (absent on the female). There is also a greater difference in body shape than in the 1st-instar nymphs.

Key words: macroducts, setal distribution, Aspidiotini, scale cover.

## RESULTS

*Quadraspidiotus zonatus* (Frauenfeld) belongs to the tribe Aspidiotini. The 1st-instar nymphs differ from the other known 1st-instar nymphs of the Aspidiotini in lacking the ventral submedian series of setae on the abdomen. However, as in all species of Diaspididae, they do have only a single pair of short submedian setae on the venter of abdominal segment VII.

The 1st- and 2nd-instar nymphs of *Q. zonatus* are sexually dimorphic and are described in detail in Podsiadlo (1997) and Podsiadlo (2000).

*First instar nymphs*: sexual dimorphism is shown by the presence in the male of: (a) a campaniform sensillum on the dorsal side of each tarsus and (b) a pair of dorsal submedian setae in the 1st abdominal segment; these two characters are absent in the female. There is also a slight difference in the shape of the thorax which, in newly hatched males, tends to be widest in the mesothorax but is widest in the metathorax in the female. Fully-grown specimens are rather variable in shape, although males tend to be somewhat longer and narrower than females, and their abdomen tends to be triangular rather than rounded as in the female. However, many individuals are intermediate in the shape, some even showing the characteristics of the opposite sex, and so determination of the sex based on body shape is unreliable.

*Second instar nymphs*: sexual dimorphism is more obvious than in the 1st instar, with differences in (a) the colour and structure of scale cover, (b) the shape of the body, (c) the glandular system and (d) the distribution of the setae.

a. Scale cover: 2nd-instar male nymphs of *Q. zonatus* settle on the underside of oak leaves and, because the scale cover is white, they are conspicuous against the green leaf. However, the females, which settle almost entirely on the trunks and branches of the oaks, have a thinner, semitransparent scale cover which is usually darker and brownish and, as a result, are rather difficult to see.

b. Body shape: this changes with age. Newly-moulted males are broadly oval, usually with a triangular-shaped abdomen although this later becomes more elongate. Newly-moulted females are nearly circular, usually with a rounded abdomen and, as they age, they barely change shape, the body just becoming slightly more pyriform.

c. Glandular system: males have 8-12 short macroducts on each side of the body, arranged in a marginal series extending from the mesothorax to Ist abdominal segment; these are absent in females. The males also have 11-13 long macroducts on each side of the pygidium, beginning on the Vth abdominal segment, while the females only have 4-6 long macroducts on the pygidium. In addition, the males have a marginal, dorsal and ventral series of microducts on thorax and abdomen, whereas only the marginal series are present in the female. No macroducts are present on the IVth abdominal segment on either sex.

d. Setal distribution: the males possess a pair of short dorsal submedian setae on the Ist abdominal segment and three pairs of ventral submedian setae on the head. These setae are absent on the female.

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PORCELLI, F.
*Istituto di Entomologia Agraria, Università di Bari, Italy*

# FINE MORPHOLOGY OF THE ANTENNAE OF *DIASPIS ECHINOCACTI* (BOUCHÉ) 1833 (HEMIPTERA: DIASPIDIDAE).

## ABSTRACT

FINE MORPHOLOGY OF THE ANTENNAE OF *DIASPIS ECHINOCACTI* (BOUCHÉ) 1833 (HEMIPTERA: DIASPIDIDAE).

The antennae in the Diaspididae are reduced to minute appendages composed of one antennomere called the “antennal tubercle”. Few or no setae can be found on the antennal tubercle, although some small pegs in cuticular invaginations can be seen. In *Diaspis echinocacti*, the single antennal seta arises from two fused sensilla at its base. The chemoreceptive (olfactory) function of these multiporous sensilla was demonstrated using crystal violet and Transmission Electron Microscopy (TEM), while further information was obtained using light microscopy (LM), confocal laser scanning microscopy (CLSM) and Scanning Electron Microscopy (SEM). Some hypotheses on the possible function of these sensilla are discussed: (a) a feedback system to regulate the production of the female pheromone; (b) for detecting a male pheromone (postulated), or (c) for detecting a pheromone (postulated) produced by the crawlers. The possible evolutionary reduction in the number of antennal sensilla by fusion is evaluated. The lowest number of setae is accepted as the derived status for the character.

Key words: host-plant kairomones; mass-rearing; *Opuntia ficus-indica*, prickly pear, morphology.

## INTRODUCTION

The antennae of adult female Diaspididae have received little attention by researchers working on this group. Berlese (1896) described the antennae of adult female Diaspididae as being “ridotte ad un semplice tubercolo, ai lati del quale sorge un lungo pelo semplice” but, on the other hand, he drew an antennal nerve from *Aonidiella aurantii* (Maskell). From an evolutionary point of view, Brown & McKenzie (1962) and Takagi (1969) considered that the number of setae may have gone on decreasing with each reduction in antennal size, eventually giving the highly reduced structure found today. This reduced structure has been variously described as: “reduced to an unsegmented tubercle, bearing one or more setae” (Kosztarab, 1963), a “simple tubercle with 1 or more setae” (Williams & Watson, 1988) and “a tubercle without joints but with setae at the apex” or “reduced to the size of a small tubercle” (Danzig, 1990).

In the Diaspididae, the number of antennal setae (in conjunction with other characters) is considered to be of taxonomic value at the tribal level

(Ben-Dov, 1990) and has also sometimes been used by taxonomists as a generic character, as, for instance, in separating the genera *Rugaspidiotinus* Balachowsky and *Poliaspoides* MacGillivray (now *Natalaspis* MacGillivray (Ben-Dov & Takagi, 1974)) (Takagi, 1969).

Apart from the morphological and taxonomic aspects, the function of the sensillae is uncertain. Ferris (1942) commented that "(the antennae) bear setae, which at times are somewhat 'fleshy' and are perhaps of a sensory nature". This was also the view of McKenzie (1956), Koteja (1980), Rosciszewka (1989) and Bielenin *et al.* (1995), although only the latter provided evidence by reporting the presence of a nerve cell associated with the antenna of female *Quadraspidiotus ostreaeformis* (Curtis).

Due to this confusion and uncertainty, the aims of the present study were to clarify the sensillary nature of the antennal seta of *Diaspis echinocacti* (Bouché) and to discuss its possible function in connection with the general biology of the Diaspididae. In addition, the possible evolutionary trends in the morphology of these sensillae and their use as experimental systems are also discussed.

## MATERIALS AND METHODS

These observation were made on more than 100 ovipositing adult females of *D. echinocacti* mass-reared on cladodes of prickly pear (*Opuntia ficus-indica* (L.) Mill.) maintained on turf under laboratory conditions (18-20°C and 65% RH). The culture was started from a few females collected in the field.

*Light microscopy*: the general morphology was studied on specimens mounted in Canada balsam using the methodology suggested by Wilkey (1990), although the inset picture in Fig. 1d was taken from a fresh, water-mounted, specimen. Observations and pictures were obtained using an Olympus BX 50 microscope equipped with bright field and phase-contrast at 400 and 1000 enlargement. Confocal laser scanning microscopy (CLSM) was performed using an Olympus BX 50 on the same slides, with the natural green fluorescence of the cuticle being collected by a CCD camera and elaborated on a Personal Computer.

The presence of pores in the cuticular wall of the sensilla was detected by using crystal violet, as suggested from Slifer (1960) and later modified by Porcelli (1995). A drop of the wetting agents Tween 80 or Triton X was added to 100cc of the staining solution to improve the results. More than 75 specimens have been observed over the past four years.

*Scanning Electron Microscopy (SEM)*: specimens were observed "in vivo" or macerated in 10% potash in water, rinsed in 75% EtOH, repeatedly washed in chloroform (Mazzoni 1996), gold-palladium coated and observed at 5KV.

*Transmission Electron Microscopy (TEM)*: specimens were fixed in Karnovsky (1965), post-fixed in Osmium tetroxide, dehydrated in EtOH, and embedded in araldite 502. Serial sections were obtained using a diamond knife and counter-stained with uranyl acetate (Robinson *et al.*, 1987) and lead citrate (Reynolds, 1963).

The terminology and interpretation are based on Berlese (1909), Snodgrass (1935), Schneider (1964), Zacharuk (1980, 1985), Altner & Prillinger (1980), Keil (1982) and Keil & Steinbrecht (1987).

The following abbreviations are used:

| | In English | in Italian |
|---|---|---|
| Ant | antennomere | antennomero |
| AS | antennal seta/ae | setola antennale |
| asr | antennal seta roots | radici della setola antennale |
| cha | chamber of the seta/sensillum | vano all "interno della setola" |
| CS | ciliary sinus | seno ciliare |
| CU | cuticle | cuticola |
| DB | dentritic branches | terminazioni dendritiche |
| DS | dendritic sheath | guaina dendritica |
| Fa | fovea antennalis | fovea antennalis |
| Mf | foveal muscle | muscolo della fovea |
| MV | microvilli | microvilli |
| NC | nerve cell | cellula sensoriale |
| NU | nucleus | nucleo |
| oD | outer dendritic seg(s) | tratto (i) distale del dedrite |
| P | pore(s) | poro(i) |
| Pe | peg | sensillo basiconico |
| Pt | pore tubules | tubuli del poro |
| RL | receptor lymph | secreto linfatico |
| SC | sheath cell(s) | cellule della guaina |
| SJ | septate junctions | giunzioni settate |
| SS | sensillar sinus | seno sensillare |
| stu | arch at base of seta | varco della setola |

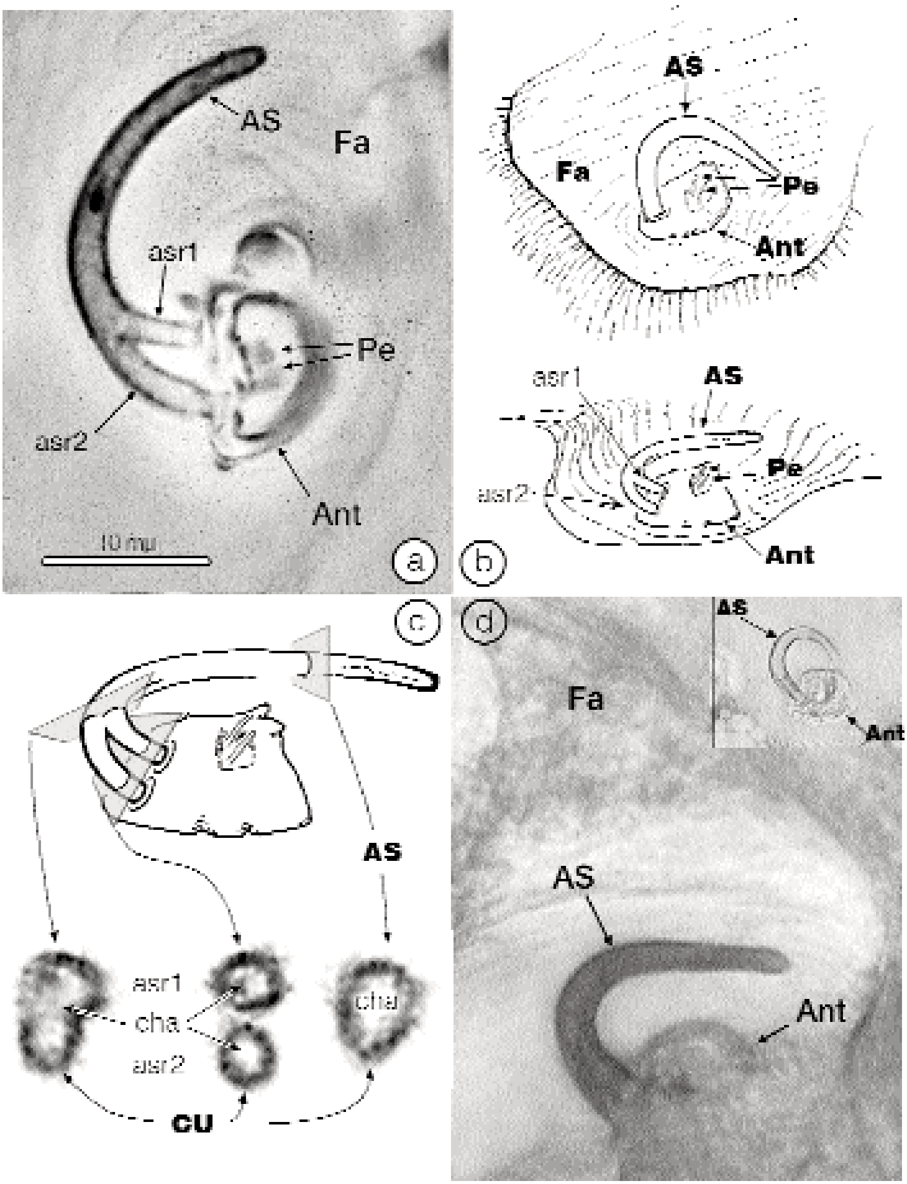

Fig. 1. *Diaspis echinocacti*: adult female antenna: a) light microscopy - phase contrast; b) schematic drawing of the antenna; c) Confocal Laser Scanning Microscope sections; d) crystal violet stained antennal seta (inset: natural coloured seta).

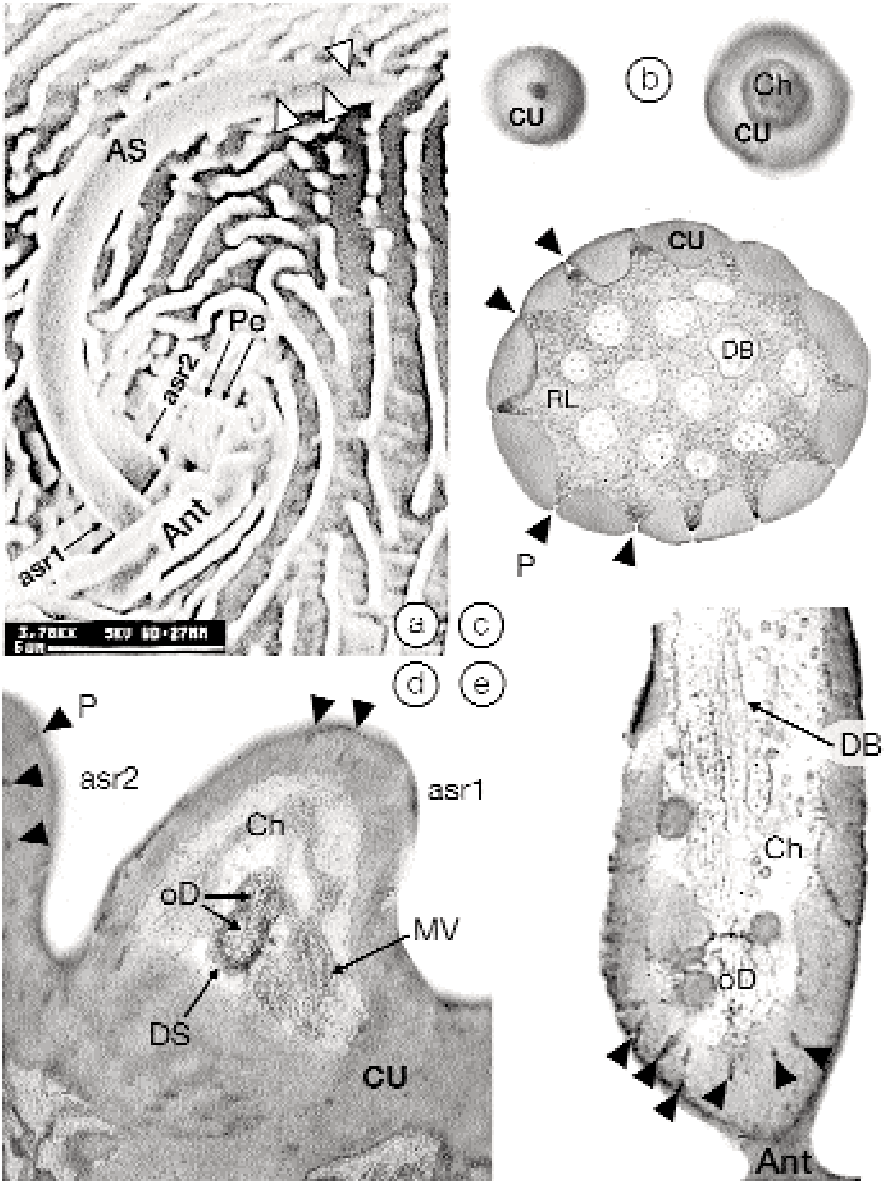

Fig. 2. *Diaspis echinocacti*: adult female antenna: a) SEM picture; b) transverse section of the pegs; c) transverse section of the antennal seta; d) tangential section of the roots; e) longitudinal section of one root.

## RESULTS

*Phase contrast light microscopy* (Fig. 1a,b): the antennae (Ant) of *Diaspis echinocacti* are located on the “ventral” surface of the prosoma relatively far from the body margin and are encased in the antennal fovea (Fa).

The antennae are monomeric and each bears a stout, arch-shaped seta (AS) about 15µm long. The basal end of each antenna is composed of two distinctly separate roots (asr1 & asr2) which form an arch (stu), but which fuse distally to form the antenna. The antennomere is also provided with two small pegs (Pe) arising from a small invagination in the cuticle. The longitudinal (dorso-ventral) plane of the antennal seta is more or less parallel to the dorso-ventral plane of the insect. Some specimens have their antennal setae split almost to the apex or at least forming an arch-shaped seta.

These structures are best observed in very flat, clear specimens mounted in Canada balsam and observed at about 1000 enlargement under oil immersion.

*Confocal Scanning Laser Microscope* (Fig. 1c): optical sections showed two single and independent setal elements (roots = asr1 & asr2) arising from the antenna (Ant), which then joined together to form the antennal seta (AS).

All optical sections showed a dense peripheral cuticular wall surrounding a large chamber, with the arch (stu) between the two roots being delimited by the external surface of the cuticular wall. Sections through the seta at the point where the roots join show the confluence of the root chambers into the chamber of the antennal seta.

*Crystal violet* (Fig. 1d): in the natural position, only the side of one of the roots can be seen and the general morphology of the roots (asr) and of the setal arch can only be guessed by modifying the focus.

All crystal-violet treated antennae show a deep-blue stained seta (AS) in contrast to the clear seta of untreated specimens (Fig. 1d: inset). The antennomere and the pegs are unstained, as are all the other parts of the body. Rarely, in some specimens, some glandular ducts in the pygidium and part of the salivary ducts may become stained violet but this only occurs after several days in the staining solution.

*Scanning Electron Microscope* (Fig. 2a): the photograph shows the antennomere (Ant), the two pegs (Pe), the two roots (asr1 & 2) and the antennal seta (AS). At the distal end of the antennal seta, there is a scar (bordered arrows).

*Transmission Electron Microscope*: *Pegs* (Fig. 2b): the pegs are two similar, thick-walled, cuticular spurs. The cuticular wall (CU) is devoid of pores but a small, electron-dense area can be seen in sub-apical sections, while, in the

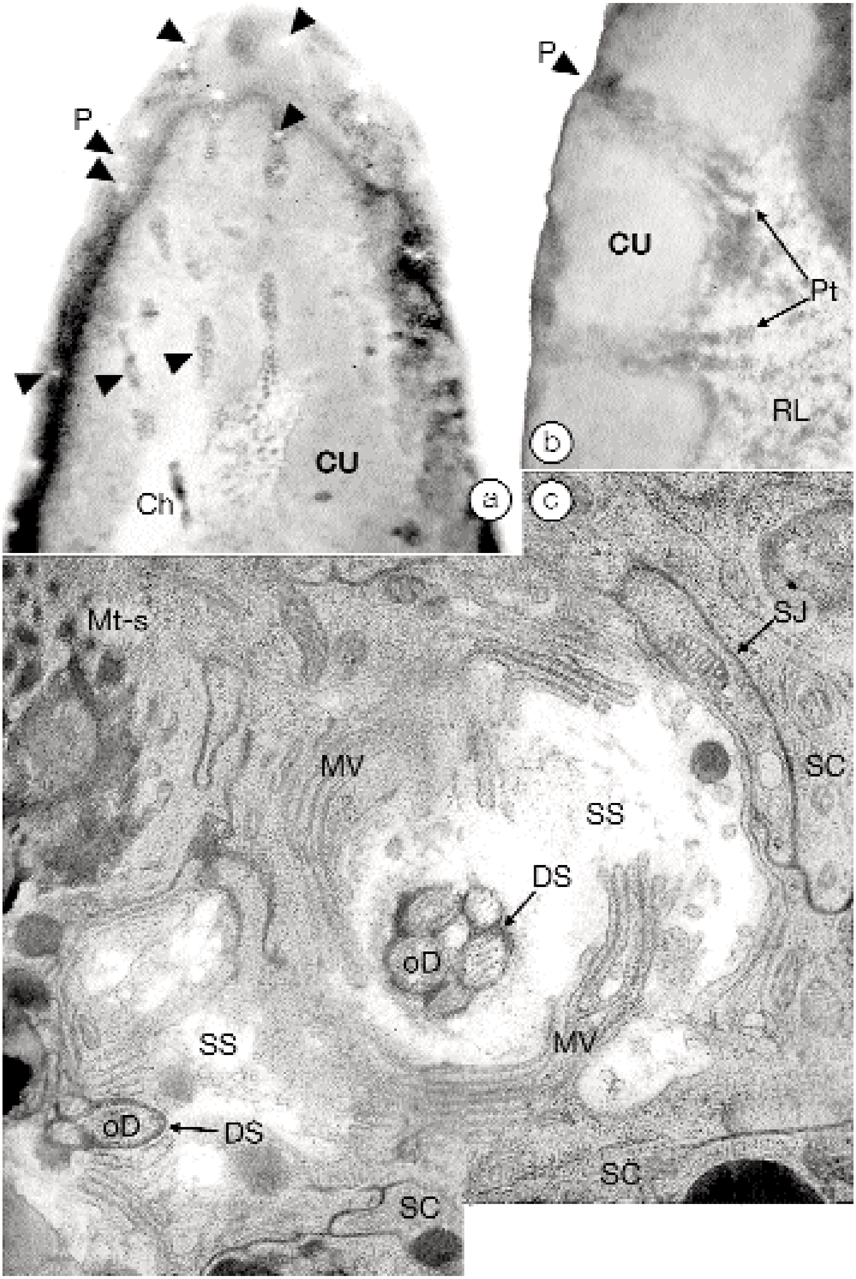

Fig. 3. *Diaspis echinocacti*: adult female sections: a) cuticular wall of the antennal seta; b) pores in the cuticular wall of the seta ▲; c) section at the level of sensillar sinus.

more proximal sections, a large chamber (cha) filled with moderately electron-dense matter with some membranes is visible. The two outer dendritic segments reach to the base of each peg. Neither a joint membrane nor any tubular bodies are found at the base of the pegs.

*Setae* (Fig. 2c,d,e; 3a,b): each seta has a single cuticular wall (CU) which is very rich in pores (P) with pore tubules. The large inner chamber of the seta is filled with receptor lymph (RL) which has several dendritic branches (DB) lying within it. The dendritic branches extend into the outer dendritic segments in the chamber of each root, where some microvilli (MV) are also found. Within the roots, an electron-dense dendritic sheath (DS) is found. Pores are present right to the base of each root.

Just beneath each antenna, within the body of the female, two distinct sensillary sinus (SS) are found (Fig. 3c). Each sinus is bordered with microvilli (MV) and contains up to five outer dendritic segments protected by a dendritic sheath (DS). Also present are sheath cells (SC) and related junctions (SJ), and a foveal muscle (Fig. 4b, Mf) connecting the fovea antennalis (Fig. 4b, Fa) with the dorsum of the insect. Each group of outer dendritic segments innervates one setal root. Neither a joint membrane nor any tubular bodies were present at the base of the roots.

## DISCUSSION (FIG. 4)

Both light microscopy and confocal laser scanning microscopy showed that the antennal seta is composed of two joined elements and, on the basis of general morphology of setae among insects, it is proposed that the primitive status was two discrete elements and that the fused structure noted here is the derived state.

With regard to function, these antennal setae show all the features of chemoreceptors, i.e. the presence of pores in the cuticular wall, the large chamber filled with receptor lymph and provided with dendritic branches, and the connection of the sheltered dendritic branches with sensory neurons equipped with sensillary sinus and sheath cells. Some features are also of special interest with regard to the olfactory function of the antennal seta, i.e. the lack of a basal joint membrane and tubular bodies, and the position of the antenna itself in connection with a foveal muscle able to move the antenna (Fig. 4). The two pegs are possibly thermo-hygro-receptors, whose function is to tune the reaction of chemoreceptors.

Beyond the somewhat obvious presence of chemoreceptors and associated thermo-hygro-receptors, some aspects are of interest in connection with the

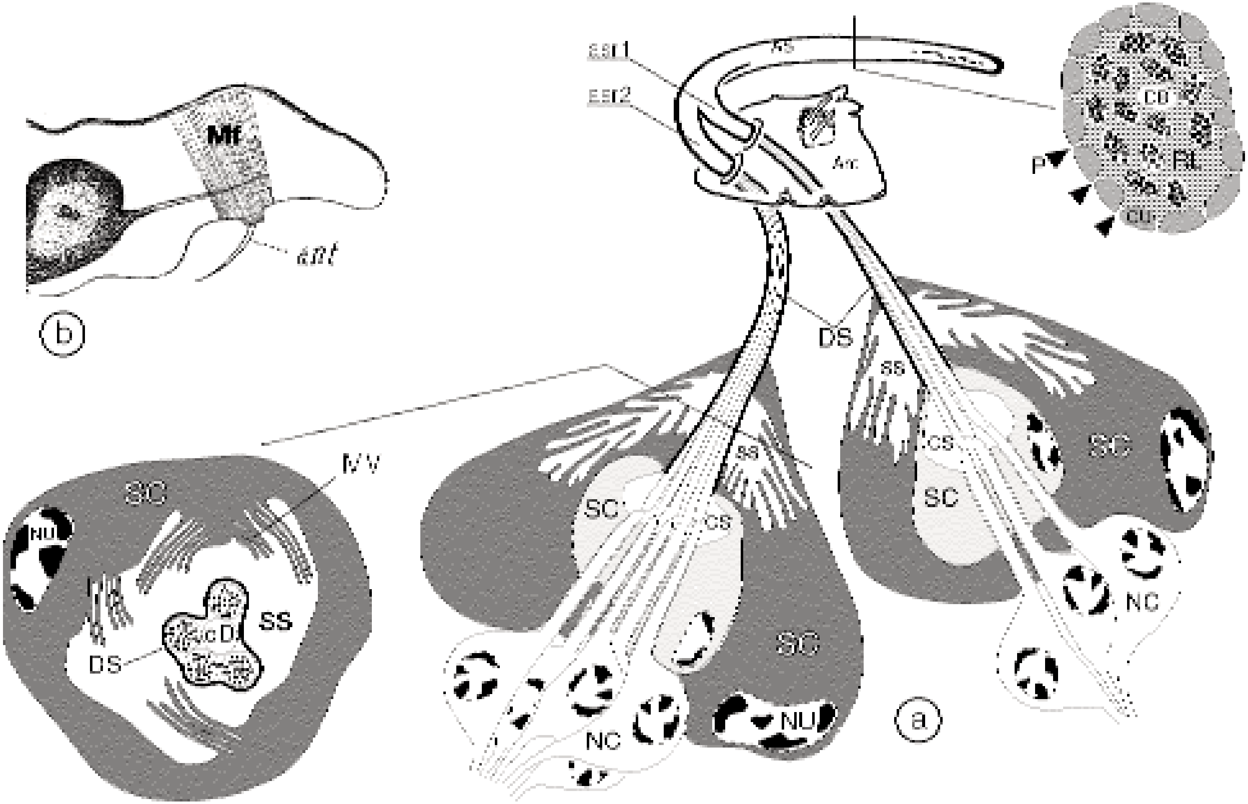

Fig. 4. *Diaspis echinocacti*: a) adult female antenna schematic drawing; b) schematic drawing of a section at the level of the foveal muscle (partly redrawn from Berlese, 1896).

special life-style of *D. echinocacti.* As armoured scales are fixed in position on their host plant, protected inside a self-produced protein-wax cover, one can hypothesise about what use the adult female can make with this chemosensory unit. Acceptable hypotheses regarding the antennal chemoreceptor are: (a) that it is part of a feedback system to regulate the secretion of the female sex pheromone that is absorbed by the scale cover from the anus; (b) that it is for the perception of a possible male pheromone (not yet discovered), or (c) it is for the perception of a pheromone (not yet identified) produced by the crawlers inside the scale cover, for instance, to avoid overcrowding.

Two further aspects of the antennal chemoreceptor of *D. echinocacti* are worthy of note. The first is the derived state of the joined setae as compared with the primitive state of two independent setae, and that the actual numerical reduction is by fusion. The second is to draw attention to the possible use of this experimental system to locate the site of selectivity or the redundance of a sensory unit. In fact, when the semiochemicals involved in intraspecific relationships have been identified, it will be possible to test these substances using these different types of antennal setae.

## CONCLUSION

The finding of chemoreceptors on the antennae of adult female diaspid scales will allow some interesting new perspectives on armoured scale biology to be studied. In particular: (a) the use of the special morphology of the antennal seta in experimental systems for testing possible pheromones, and also (b) phylogenetically, as the trend for reduction in antennal structures recalls the fusion of abdominal segments to form the pygidium. Other interesting aspects might be in relation to agricultural entomology if, for instance, either male or crawler pheromones were found or if it became possible to interfere with the secretion of the female pheromone.

The next step in this study will be to test the electrophysiological response of the antennal seta to several substances in order to identify the most promising classes of semiochemicals to search for in nature.

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STUMPF, F.C.; LAMBDIN, P.L.
*The University of Tennessee, Dept. of Entomology and Plant Pathology, Knoxville, TN 37901-1071*

# A COMPARISON OF THE PIT SCALE GENERA OF NORTH AND SOUTH AMERICA (HEMIPTERA: COCCOIDEA: ASTEROLECANIIDAE).

## ABSTRACT

A comparison of the pit scale genera of North and South America
(Hemiptera: Coccoidea: Asterolecaniidae).

Of the 12 asterolecaniid genera known from the New World, six are believed to have been introduced from other faunal regions. The distinctive morphological characters and generic relationships of the New World species are discussed, along with their biogeography and host plant affinities.

Key Words: *Asterodiaspis*, *Asterolecanium*, *Bambusaspis*, *Grammococcus*, *Mycetococcus*, *Mycococcus*, *Neoasterodiaspis*, *Palmaspis*, *Planchonia*, *Pollinia*, *Russellaspis*, *Sclerosococcus*.

## INTRODUCTION

The pit scales (Asterolecaniidae) constitute one of the largest and more economically important groups of scale insects worldwide. The fauna is rich and diversified, with its members occurring in all major zoogeographical regions of the world. The taxonomy of the pit scales is poorly known on a world-wide basis. Indeed, a significant lack of knowledge of the lesser known asterolecaniid taxa exists, and the relationships between many species or species-groups are not well defined.

The genus *Asterolecanium* was established by Targioni-Tozzetti in 1868. Ferris elevated the subfamily Asterolecaniinae to family rank in 1937 and Russell (1941) described and catalogued the 156 species that had been described between 1758 and 1940 and which she put into 12 groups; these have since been raised to generic status. The only other significant changes which have been made since Russell's work have been the separation from the Asterolecaniidae of the families Lecanodiaspididae (Borchsenius, 1959) and the Cerococcidae (Koteja, 1974).

In North and South America, the family Asterolecaniidae currently consists of 12 genera: *Asterodiaspis* Signoret, *Asterolecanium* Targioni Tozzetti, *Bambusaspis* Cockerell, *Grammococcus* Miller & Lambdin, *Mycetococcus* Ferris, *Mycococcus* Ferris, *Neoasterodiaspis* Borchsenius, *Palmaspis* Bodenheimer, *Planchonia* Signoret, *Pollinia* Targioni Tozzetti, *Russellaspis*

Bodenheimer and *Sclerosococcus* McKenzie. The objective of this study was to define the New World genera and to help clarifying the status of the family.

## RESULTS

The subfamily Asterolecaniinae in the New World includes the seven genera: *Asterodiaspis*, *Asterolecanium*, *Bambusaspis*, *Neoasterodiaspis*, *Palmaspis*, *Planchonia* and *Russellaspis*. The main distinctive character of species in these genera is the presence of a marginal row or band of both 8-shaped pores and multilocular pores, which can be either trilocular, quadrilocular or quinquelocular.

The oak feeding genera *Asterodiaspis* and *Neoasterodiaspis* were both introduced from the Palaearctic region. *Asterodiaspis* may be widespread in both continents, but *Neoasterodiaspis* is only known in North America from an infestation on *Quercus hemisphaerica* in the New York Botanical Gardens. Species in these two genera are very similar and share a shield-like, fused, anal ring with one pair of setae, but differ in that *Neoasterodiaspis* has prominent sclerotized projections from the marginal 8-shaped pores which are absent in *Asterodiaspis*.

The anal area of some species of the palm feeding genus *Palmaspis* appears similar to that of *Asterodiaspis*, although it is never shield-like. *Palmaspis* is believed to have originated in the Neotropical region but is also frequent in other zoogeographic regions. It has not so far been recorded from the USA, although suitable hosts are available. The interspecific morphological characters of species in this genus are rather variable and the genus may not represent a monophyletic taxon. Most species possess trilocular pores (sometimes also quadrilocular pores) together with (or instead of) quinquelocular pores in the marginal row and in the spiracular furrows. There is also a tendency to reduce the length of the arms of the clypeolabral shield and the length of the spiracular arm in some species. In addition, the structures of the anal area vary considerably, i.e. in the number of apical setae and in the structure of the anal ring, which may be separated or fused, with one, two, or no pairs of setae. Interestingly, some species of *Palmaspis* (e.g., *P. pallida* (Russell) and *P. truncata* (Russell)) show considerable similarities to species in the non-asterolecaniine genus *Grammococcus*, both groups having trilocular pores (although these are restricted to the spiracular furrows in *Grammococcus*) and a separated anal ring with two pairs of setae. *Grammococcus* also occurs on palms and has been reported from Trinidad, Colombia and the Peruvian Amazon region. Species in this genus possess unique submarginal clusters of multilocular pores on their dorsum. It is the only non-asterolecaniine genus that has a hard translucent cover, all other genera producing whitish, waxy, non-translucent covers similar to the typical cover of male scale insects.

Members of the bamboo feeding genus *Bambusaspis* can be found wherever bamboo grows, although no reports are known from Bolivia, Ecuador, Paraguay and Uruguay. The eight species currently recognized from the New World were probably introduced from the Oriental region. Species in the genus *Bambusaspis* are characterised by the presence of dorsal tubes (a character unique to species of this genus), an interrupted row of submarginal setae and a labium without setae. It shares a closed anal ring with 3 pairs of setae and the lack of trilocular pores with the genera *Asterolecanium*, *Planchonia* and *Russellaspis*. However, these characters may be plesiomorphic and may, therefore, not be useful for defining relationships among these genera.

Two species in the genus *Planchonia*, which may have originated in the Palaearctic or Ethiopian regions, have been introduced into the Nearctic region and can now be found in Canada, in northeastern USA, Florida and in several of the western States, where they cause periodic damage on a variety of host plants. Species in the genus *Planchonia* are characterized by a double or triple row of marginal 8-shaped pores accompanied by a dorsal and a ventral row of disc pores.

The genus *Russellaspis* is probably of Oriental origin and is represented in the New World by one species, the oleander pit scale, *R. pustulans* (Cockerell), which has been recorded from more than 100 host plants in 46 plant families. It is known from the USA and most Central and South American countries. Species in this genus are characterized by a ventral marginal row of disc pores and the presence of distinctive sclerotized areas on the ventral apex of the abdomen. This genus may be closely related to the genera *Asterolecanium* and *Planchonia*.

The genus *Asterolecanium* once included all the species in the subfamily Asterolecaniinae but it now contains only ten species in North and South America, infesting a variety of plants from agavas to orchids. The habits of these species seem to suggest a New World origin. No single character can be used to define this genus but its members generally possess single marginal rows of 8-shaped pores, disc pores and quinquelocular pores, and 4-6 pairs of anal setae. A thorough analysis of the species currently remaining in *Asterolecanium* is needed to elucidate a possible polyphyletic or paraphyletic origin.

The other four genera (*Mycetococcus*, *Mycococcus*, *Pollinia* and *Sclerosococcus*) do not belong to the Asterolecaniinae and their relationship to that subfamily and to *Grammococcus* are not well studied. With the exception of *M. corticis*, none possess tubular ducts. The two species of the genus *Mycetococcus* live on oaks in Mexico, California and Arizona and are distinguished by the heavily sclerotized anal lobes. *Pollinia pollini* (Costa), which is characterized by the distribution of the quinquelocular pores on the venter and by a ventral anal lobe with 5 pairs of setae, was introduced from Europe into the olive growing areas of California and Argentina, where it is an important pest. The four species in the genus *Sclerosococcus* have characteristically-shaped tubular duct-like 8-shaped pores and quinquelocular pores on both the dorsum and venter; they are known from Florida, Mexico, Chile and Ecuador, where they feed on Bromeliaceae. *Mycococcus coperniciae* Ferris is known only from palms in Cuba and has a very unique sclerotized plate on the dorsum and a ventral band of quinquelocular pores around the mouthparts, while other characters, such as 8-shaped pores, are not expressed in the adult female. More detailed studies, including all developmental stages, are necessary to elucidate the evolutionary position of this and most other pit scale genera.

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TREMBLAY, E.[1]; PONZI, R.[2]

*[1]Dipartimento di Entomologia e Zoologia Agraria; [2]Dipartimento di Arboricoltura, Botanica, e Patologia Vegetale, Universita di Napoli "Federico II" - Via Universita 100, 80055 Portici, Italia.*

# ULTRASTRUCTURAL OBSERVATIONS ON SYMBIONT DEGENERATION IN THE MALE LINE OF *PSEUDAULACASPIS PENTAGONA* (TARGIONI TOZZETTI) (HEMIPTERA: COCCOIDEA: DIASPIDIDAE).

## ABSTRACT

Ultrastructural observations on symbiont degeneration in the male line of *Pseudaulacaspis pentagona* (Targioni Tozzetti) (Hemiptera: Coccoidea: Diaspididae).

During the development of the immature stages of male scale insects, the mouthparts become lost at the prepupal stage and this is paralleled by the degeneration of the symbiont micro-organisms inhabiting the mycetocytes. This degenerative process has been studied in the male line of the white peach scale, *Pseudaulacaspis pentagona* (Targioni Tozzetti). In the first two feeding instars, the mycetocytes appear as spherical cells, 30-40µm in diameter, filled with normal micro-organisms, round or oval in shape, 3-5µm long. In the prepupal and pupal stages, some symbionts undergo degeneration by a dissolution of the dense ribosomal granulations which characterize the microorganisms in the two feeding instars. In these symbionts, the fusing of the small vacuoles results in the appearance of larger, more centrally-placed, vacuoles. Other symbionts become loosely reticulated or, alternatively, condensed or contracted, to form regular or irregular bodies. The mycetocytes seem to undergo no reduction in size but their cytoplasm shows signs of dissolution as well. A great number of dense, crystalline-like granulations were found in their proximity. The nature and derivation of these granulations remains to be investigated.

## INTRODUCTION

The endosymbionts of Coccoidea have been very little investigated using modern technology, even though this could shed new light on their identity. Results based on the study of 16s rDNA sequences are available only for three pseudococcid species and these indicate that mealybug endosymbionts are members of the ß-subdivision of the Proteobacteria (Munson *et al*., 1992), supporting the idea that endosymbionts of all known mealybugs might be derived from a single ancestral infection, in a manner similar to that which has been demonstrated for the endosymbionts of all aphid species investigated to-date (Baumann *et al*., 1998). The endosymbionts of Diaspididae were first considered to be yeast-like micro-organisms, but subsequent studies have suggested that they might be pleomorphic bacteroids (Tremblay, 1990) and circumstantial evidence indicates that they do not belong to the pseudococcid lineage. In our opinion, this idea is consistent with the hypothesis that endosymbiont phylogeny may correspond to the phylogeny of the host insect, in small taxon groups at least, due to a single ancestral infection and a lack of endosymbiont exchanges between host lineages, as suggested by Baumann *et al.* (1998).

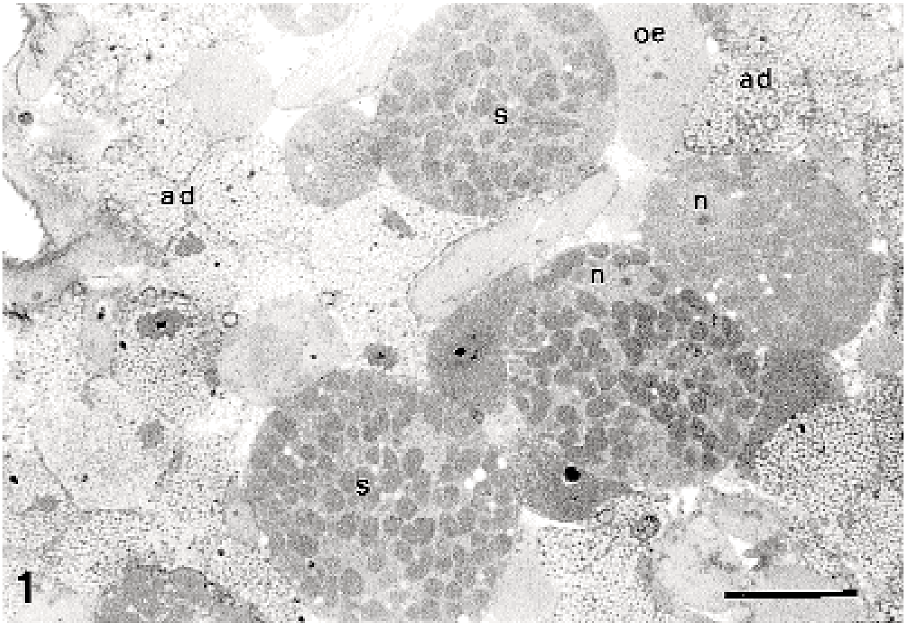
In diaspidids, the symbionts are localized in specific large cells (mycetocytes or, perhaps, bacteriocytes) dispersed throughout the body of both sexes, especially during the juvenile stages. In an early study by one of the authors (Tremblay, 1960), the mycetocytes of the white peach scale, *Pseudaulacaspis pentagona* (Targioni Tozzetti) were found to decrease in number and to degenerate during development in the male. This phenomenon was found to be correlated with the atrophication of the mouthparts of Coccoidea males. Some data on the ultrastructure of the female *P. pentagona* endosymbionts were given in a paper presented at ISSIS-V in Portici (Tremblay & Ponzi, 1987). Information on the ultrastructure of the degenerating male symbionts of this species is now provided.

## MATERIALS AND METHODS

Male nymphs and newly emerged adults of *P. pentagona* were fixed for 5 hours at room temperature in 6% glutaraldehyde I 0.05M sodium phosphate buffer at pH 7.2. Before fixation, the nymphs were punctured on the apex of the head while the adult males were decapitated after dealation. The specimens were then rinsed for 10h in the same buffer and post-fixed for a further 5h in buffered 1% OSO4. After dehydration with a graded ethanol series, the material was treated (3h) with propylene oxide and embedded in consecutive concentrations (3:1; 1:1; 1:3) of a mixture propylene oxide-Epon Araldite. Treatments with each mixture lasted 12 hours and were followed by two other 12h inclusions in pure Epon Araldite and by a final inclusion in this resin in gelatin capsules. Ultrathin and thin (1-2µm) sections were obtained with a LKB Ultratome III and stained in 5% uranyle acetate (1h) and lead citrate (5min). Thin sections were observed and photographed with a Zeiss Axiophot microscope. Ultrathin sections were examined and photographed with a Philips EM 300 electron microscope at 80kV.

## RESULTS

In the 1st- and 2nd-nymphal instars of the male, the mycetocytes were mostly localized in the peripheral part of the body and appeared as large spherical cells, 30-40µm in diameter, with a large nucleus and filled with round or oval 3-5 µm long microorganisms, characterized by dense ribosomal granulations (Fig. 1). These cells were surrounded by adipocytes (ad) and



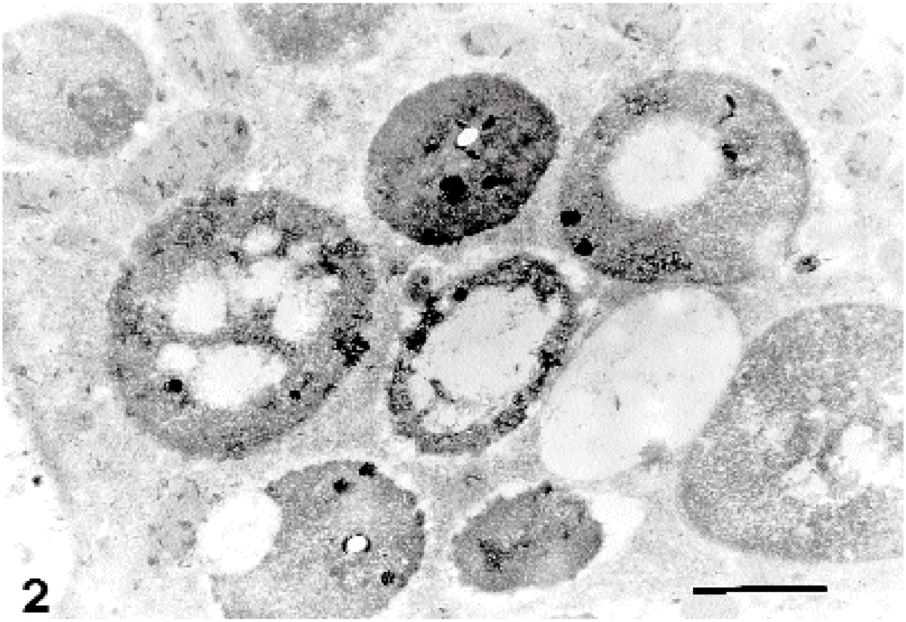
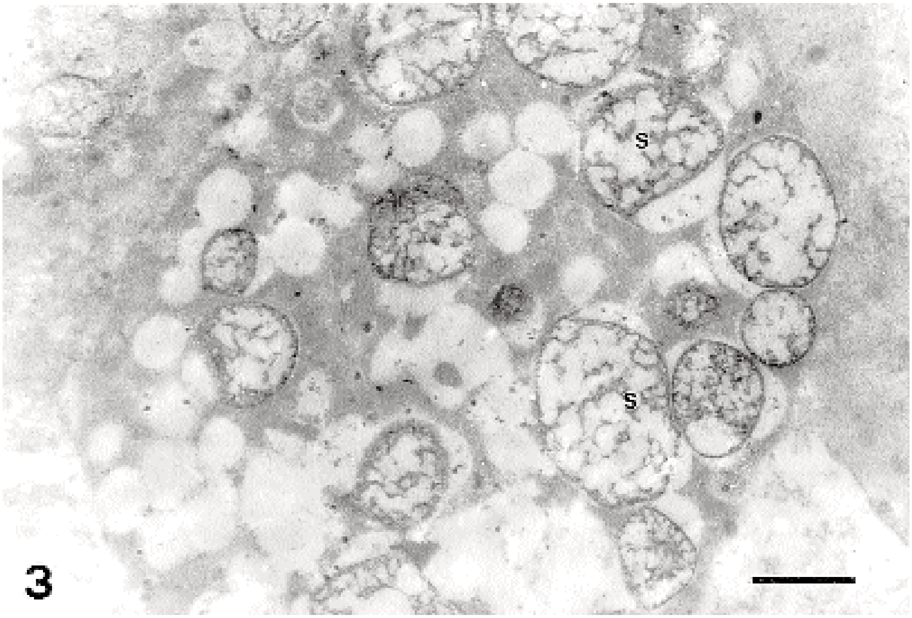


Fig.1. Section of a 2nd-instar male nymph showing some mycetocytes; ad, adipocytes; oe, oenocytes; n, mycetocyte nucleus; s, symbionts. Bar length: 20μm.
Fig. 2. Degenerating symbionts in a male pupa. Bar length: 2μm.

oenocytes (oe) in most sections. At this stage of development, their shape and localization did not differ from those observed in females. However, in the prepupae and pupae, clear signs of degeneration appeared, both in the endosymbionts and in the mycetocyte structure. Some microorganisms initially showed some dissolution of their dense ribosomal granulation followed by the formation of large, central vacuoles (Fig. 2). Other vacuoles became apparent in the mycetocyte cytoplasm as well. In addition, other symbionts became loosely reticulated or, alternatively, condensed or contracted, to form regular or irregular bodies (Fig. 3). In the adult male, the mycetocytes showed no reduction in size when compared with those of the nymphs or the adult female but their cytoplasm did show some signs of dissolving (Fig. 4). The final stage of these degenerative processes seems to be the dissolution of the internal mycetocyte structure. In the sections, a great number of dense, crystalline-like granulations (cl) were found in the proximity of the degenerating mycetocytes.

## DISCUSSION

Recently Prameelarani Kantheti *et al.* (1996), while studying the expression of an endosymbiont 16S rRNA gene in the mealybug *Planococcus lilacinus* (Cockerell), discovered that male adults of this species were free or nearly free of endosymbionts. These conclusions were confirmed by microscopic examination of adult males, which were devoid of mycetome-like structures. A study of the embryos, 1st- and 2nd-nymphal instars of both sexes, and the adult female using the same gene probe, revealed the presence of endosymbionts. In the scale insect genus *Stictococcus* Cockerell, males are dwarf, lack mouthparts and are symbiont-free from their earliest embryonic stages (Buchner, 1955) because, in the mother's ovaries, the symbionts infect only female eggs. Buchner (1955) considered that the symbionts were responsible for sex determination in this scale. In the gall-forming aphids of the genus *Pemphigus* Hartig, both the sexuales (female and male) are dwarf and without mouthparts but only the males lack symbionts. Immunodetection of symbionin, a symbiont specific protein, showed that in a group of eusocial aphids, males and soldiers lacked symbionts, which were, in contrast, regularly present in the reproductive females (Fukatsu & Ishikawa, 1992). On the other hand, the soldiers of aphids which suck phloem possess symbionts. One explanation for all these observations is the "host's selection hypothesis", which assumes that the host rejects the symbionts when these are no longer necessary because they cost energy and resources (Fukatsu & Ishikawa,



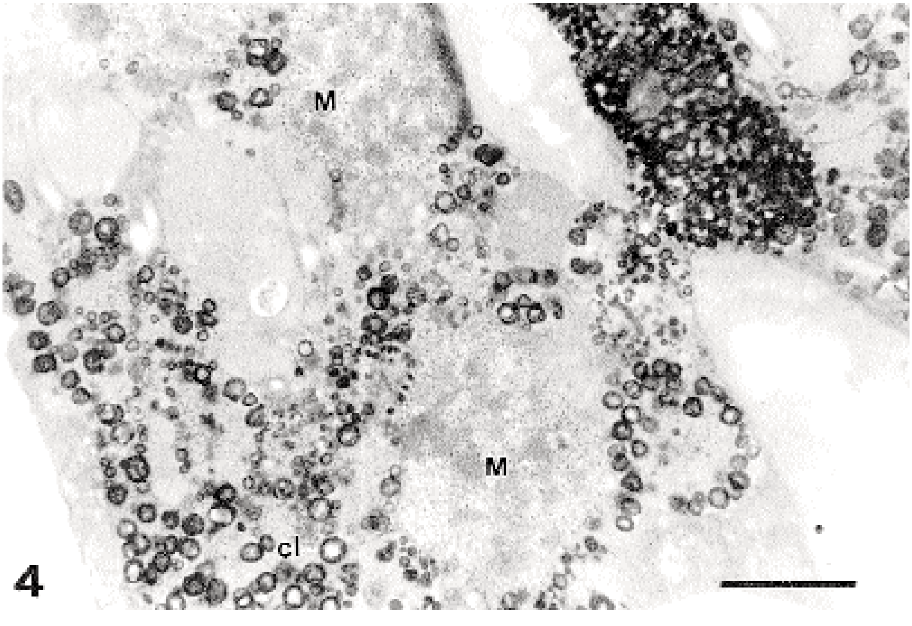


Fig. 3. Degenerating symbionts in a male adult. Bar length: 3µm.
Fig. 4. Mycetocytes (M) of an adult male; cl, crystalline-like inclusions. Bar length: 20µm.

1992). Evidence for symbiont degradation apparently controlled by the host insect was obtained by Hinde (1971) for some aphids and their symbionts. The breakdown of symbionts was attributed by Hinde to the action of insect lysosomes and is considered to be a form of regulation of symbiont number and activity by the host insect. Residual bodies in the form of dense and small myelin figures were also reported by Hinde (1971) as a result of lysosome action. These bodies showed some similarity to the crystalline-like elements found by us in *P. pentagona* males (Fig. 4). In addition, similar crystalline granulations, of a possible excretory nature, were found in the alimentary canal and malpighian tubules of both sexes of *Quadraspidiotus ostreaeformis* (Curtis) by Bielenin & Weglarska (1967). Other speculative ideas on the nature of the crystalline-like inclusions were presented by Tremblay (1960). However, at present their origin is still obscure and deserves further investigation.

## ACKNOWLEDGEMENTS

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# SYSTEMATICS AND MORPHOLOGY: Posters and Abstracts:

## THE TAXONOMIC RELATIONSHIP OF SOME COCCOIDEA (HEMIPTERA) BASED ON MALE CHARACTERISTICS.

BOHIDAR, K.
*Department of Zoology, Utkal University, Bhubaneswar - 751004, Orissa, India*
*Email: sankar@giascl01.vsnl.net.in*

Male characters of species from five different families were studied and the taxonomic status of the families are described. A key of characters was presented for adult males. The quantitative evaluation method was applied to assess the relationship between the families. All the characters included were regarded as being of equal importance and those shared by any one family exhibited some differences, justifying the recognition of the taxon as a distinct family. It was found that the Margarodidae were the most primitive group followed by Pseudococcidae. The Diaspididae showed the maximum number of specialised characters, with the Coccidae and Dactylopiidae falling between the Diaspididae and the Pseudococcidae. The Coccidae and Dactylopiidae shared an equal number of characters with the Pseudococcidae and are considered to be close to each other.

## MORPHOLOGICAL VARIATION IN THE MEALYBUGS *PSEUDOCOCCUS CALCEOLARIAE* AND *P. SIMILANS* (HEMIPTERA: COCCOIDEA: PSEUDOCOCCIDAE).

CHARLES, J.G.[1]; FROUD, K.J.[1]; HENDERSON, R.C.[2]
[1]*HortResearch, Private Bag 92 169, Auckland, New Zealand*
[2]*Landcare Research, Private Bag 92 170, Auckland, New Zealand*
*Email: jcharles@hort.cri.nz*

Examination of slide-mounted laboratory-reared daughters from isolines of *Pseudococcus calceolariae* (Maskell) and *P. similans* (Lidgett) mothers collected from two widely separated locations in the North Island of New Zealand has thrown doubt on the validity of the defining characters of the species. For *P. similans*, the number and position of oral rim tubular ducts varied widely and sometimes fell outside the defined species limits. In addition, the characteristic `stout abdominal setae' were lost in the F1 generation. The combinations of leg-length and number of oral rim tubular ducts which separate *P. calceolariae* (Maskell) from *P. similans* co-existed in cohorts of F1 sisters and both character-sets could be manipulated by changing the temperature at which the mealybugs developed. Mating studies are proposed to investigate whether the two species are valid, or whether they merely represent the phenotypic extremes of one widely polymorphic species.

## *APIOMORPHA*: AN EXTRAORDINARY SCALE INSECT GENUS.

COOK, L.
*Division of Botany and Zoology, Australian National University, Canberra, ACT, 0200, Australia*
*Email: lyn.cook@anu.edu.au*

*Apiomorpha* is a gall-inducing eriococcid genus which is endemic to Australia, where it is restricted to *Eucalyptus*. Females of most species induce large and spectacular galls which generally have species-specific morphologies. *Apiomorpha* is one of the most chromosomally diverse of all animal genera. Closely related species usually have very different karyotypes and there is extensive chromosomal variation between populations within most morphologically defined species. Some, but not all, of the karyotypic variation within morphospecies probably represents species-level differences. A phylogeny of *Apiomorpha* based on DNA sequence data has been proposed, onto which chromosomal and morphological traits have been mapped. Both fusion and fragmentation appear to be playing a role in chromosomal evolution in this genus.

## A PUTATIVE MOLECULAR PHYLOGENY OF NINE SCALE INSECT "FAMILIES" AND ITS IMPLICATIONS.

COOK, L.; GULLAN, P.; TRUEMAN, H.
*Division of Botany and Zoology, Australian National University, Canberra, ACT, 0200 Australia*
*Email: lyn.cook@anu.edu.au*

An incomplete and only partially tested molecular phylogeny of the scale insects based on 18S rDNA using sample taxa from the Margarodidae, Ortheziidae, Pseudococcidae, Coccidae, Kerriidae, Eriococcidae, Diaspididae, Dactylopiidae and Asterolecaniidae is presented. Aphids and psyllids have been included as outgroup taxa. The general topology is discussed in relation to the evolution of the scale insects. Several well-supported clades have major implications for the classification and taxonomy of the Eriococcidae. A phylogeny of the eriococcids based on sequence data from the mitochondrial gene cytochrome oxidase subunit II is in general agreement with the nuclear gene-based tree.

## SOME ASPECTS OF THE TAXONOMY OF PALAEARCTIC MEALYBUGS (HEMIPTERA: COCCINEA: PSEUDOCOCCIDAE).

DANZIG, E.M.
*Zoological Institute, Russian Academy of Sciences, St. Petersburg, Russia*
*Email: dem@zisp.spb.su*

In the group of mealybugs possessing oral rim ducts, the genera *Atrococcus* Goux, *Spilococcus* Ferris, *Chorizococcus* McKenzie and *Paracoccus* Ezzat & McConnell are discussed. The genus *Atrococcus* is a small natural group of species, sharing similar morphology, the presence of black pigment and a Palaearctic distribution. The borders between the other genera are not clear, as has been mentioned by other authors. The

genera *Spilococcus* and *Chorizococcus* are separated from each other by the number of cerarii (6-17 or fewer), while the genus *Paracoccus* is characterized by the presence of an anal lobe bar. In the fauna of the former USSR, there are 6 species: *Spilococcus furcatispinus* (Borchsenius), *S. flavus* (Borchsenius), *S. expressus* (Borchsenius), *S. erianthi* (Kiritshenko), *S. herbaceus* Danzig and *S. halli* McKenzie & Williams. These are all very similar morphologically and are associated with grasses (the other 7 known species in the genus *Spilococcus* live on dicotyledons). The placement of these species in genera based on the number of cerarii (which varies from 1 to 17 pairs) or on the presence of an anal lobe bar (*S. expressus*) is here considered to be artificial. Therefore, it is here suggested that the genus *Spilococcus* should be accepted in the wide sense (at least for the fauna in the Palaearctic region).

## THE STRUCTURE AND FUNCTION OF THE TEST OF NEW ZEALAND MALE SOFT SCALE INSECTS.

HENDERSON, R.
*Landcare Research, Private Bag 92170, Auckland, New Zealand.*
*Email: HendersonR@landcare.cri.nz*

Male scale insects (Hemiptera: Coccoidea) undergo a metamorphosis from scale-like nymph through prepupa and pupa to winged adult. The nymphal instar preceding the prepupa secretes a protective cover or test under which these complex life changes take place. Each family of scale insects is characterised by a different type of male covering, whether cocoon, cap or test. Male mealybugs make rather fluffy cocoons from cottony wax strands, eriococcids produce woven wax covers, while armoured scales incorporate their moulted skins into waxy caps. The Coccidae or soft scales construct glassy wax tests. This test, being rigid, needs a mechanism to allow for the emergence of the adult male. A suture across the posterior third of the test enables the back plate to flex at a pair of hinges (so forming something akin to an "up-and-over garage door"). The hinges are secreted by groups of tubular ducts on the dorsum of the 2nd-instar males. The rows of hexagonal wax-plates found in the male tests of most New Zealand Coccidae are apparently unique in the way they are constructed. Scanning electron micrographs show the detail and diversity of the hinge types and how the hexagonal plate structure of the test is distinct from the back plate suture. Very little research has been published on male scale insects and even less on their coverings. In comparison with North American species, only two species of New Zealand native soft scales have male tests similar to those in other parts of the world.

## SOME CHARACTERISTICS OF THE DEVELOPMENT OF THE SEX ORGANS IN MARGARODID MALES.

MKRTCHIAN, L.P.; SARKISSOV, R.N.
*Institute of Zoology, Armenian NAS, Yereven, Armenia.*
*Email: aaa@triada.armenia.su*

A comparative study of the male sex organs of three subfamilies of the Margarodidae (namely Margarodinae, Monophlebinae and Coelostomidiinae) has

shown that some morpho-functional rearrangements occur in their ontogenesis during the pre-imaginal period. These changes lead to a reduction of the testes and the formation of an evolutionarily new structure, a spermsac filled with semen bundles.

During this general process of structural transformation, two types of spermsac construction can be distinguished, which allows the males of these subfamilies to be divided into two groups:

1. A group which has a spermsac with an ejaculatory duct which penetrates the more or less long, sclerotised penis (e.g., as in species of *Porphyrophora*, *Steingelia* and *Matsucoccus*)
2. A second group where the ejaculatory duct opens into the spermsac and the penis is very short and straight. In this group, the duct is turned out during copulation and then lowered into it - as in species of *Icerya*, *Drosicha* and *Neomargarodes*.

The inner position of the ducts in the male sex organs of some scale insects (e.g., male *Neomargarodes* which retain rudiments of the testes) suggests that this is the primitive condition and that the external position of the ejaculatory duct is secondary. In addition, further study of the Margarodidae has shown that the duct has evolved differently in different groups. Thus, in the first group, the penis tube with the ejaculatory duct within it has developed progressively, while in the second group, in which the penis tube is short, the development of the ejaculatory duct seems to have occurred within the spermsac.

## PHYLOGENY OF THE MARGARODIDAE (HEMIPTERA: COCCOIDEA) USING MOLECULAR SEQUENCES.

TRUEMAN, H.E.
*Division of Botany & Zoology/Research School of Biological Sciences, Australian National University, Canberra 0200, Australia.*
*Email: Holly@rsbs.anu.edu.au*

In the past, the taxonomy of the Margarodidae has been based solely on morphological features, mainly those of adult females. However, the reduction and loss of structures makes it difficult for evolutionary relationships to be estimated from morphology alone. Morrison (1927) characterised the margarodids by their possession of abdominal spiracles in all stages and compound eyes in the adult males, two features that are clearly not shared derived features (synapomorphies) (Miller, 1984). The characters upon which the family is based are ancestral features (plesiomorphies) that margarodids share with other hemipterans. Thus, the Margarodidae may be a paraphyletic grouping of species that could not be placed in other families (Schlee, 1969), rather than a monophyletic group. A re-construction of margarodid phylogeny using molecular sequences and cladistic methodology was presented, addressing the question of monophyly.

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ABD-RABOU, S.
*Plant Protection Research Institute, Agricultural Research Center, Dokki-Giza, Egypt*

# PARASITOIDS ATTACKING THE MEDITERRANEAN BLACK SCALE, *SAISSETIA OLEAE* (HEMIPTERA: COCCIDAE) ON OLIVE IN EGYPT.

## ABSTRACT

PARASITOIDS ATTACKING THE MEDITERRANEAN BLACK SCALE, *SAISSETIA OLEAE* (HEMIPTERA: COCCIDAE) ON OLIVE IN EGYPT.

*Saissetia oleae* is an important pest of olive trees in Egypt. A survey of the parasitoids of *S. oleae* was carried out monthly between April 1995 and March 1997 in three different locations in Egypt. Five species of Encyrtidae, a species of Pteromalidae and an aphelinid hyperparasite were found. Three of these records were new for Egypt.

Key words: survey, rearing methods, percentage parasitism, *Diversinervus elegans*, *Metaphycus flavus*, *M. zebratus*, *Metaphycus* spp., *Scutellista caerulea*, *Marietta leopardina*.

## INTRODUCTION

The Mediterranean black scale, *Saissetia oleae* (Olivier) (Hemiptera: Coccidae) is a serious pest of olives in many countries and has been recorded off about 115 host plant species (Ben-Dov, 1993). Recently, *S. oleae* has become a serious pest of olive trees in Egypt and has also been recorded on 8 other host species in 10 different localities (Mohammad & Nada, 1991). *S. oleae* causes serious damage to olive trees both indirectly, through the copious accumulation of honeydew acting as a substrate for the growth of sooty mould fungi, and directly by mass feeding.

The role of parasitoids in the biological control of *S. oleae* has been previously investigated in Egypt by Priesner & Hosny (1940), in Libya by Lal & Naji (1979), in France by Panis (1983), in the USA by Lampson & Morse (1992), in Israel by Argov & Rossler (1993), in Cyprus by Orphanides (1993) and in Greece by Argyriou & De Bach (1968).

The present study was conducted to determine the species and seasonal abundance of parasitoids of *S. oleae* on olive trees in three locations in Egypt.

## MATERIALS AND METHODS

Olive trees with heavy infestations of *S. oleae* from three locations in Egypt (namely Northern coast & Matruh (about 150km and 350km west of Alexandria respectively), and El-Arish (north east Egypt)) were selected and sampled monthly between April 1995 and March 1997. No chemical control for the pest was performed on these trees during the study.

In each location, twenty trees were selected randomly and sampled by collecting 10 *S. oleae* infested twigs (15 cm long) and 30 infested leaves. These were taken back to the laboratory where each twig or leaf was stored in a well-ventilated glass tube and monitored daily for parasitoid emergence. The percentage parasitism was calculated on the basis of the number of scales in each sample, with the assumption that only a single parasitoid emerged from each scale.

## RESULTS AND DISCUSSION

Five encyrtid and a pteromalid parasitoid species were collected, plus an aphelinid hyperparasitoid:

Primary parasitoids:

**Encyrtidae**

- *Diversinervus elegans* Silvestri
- *Metaphycus flavus* (Howard)
- *Metaphycus zebratus* (Mercet)
- *Metaphycus* sp.I*
- *Metaphycus* sp.II*

**Pteromalidae**

- *Scutellista caerulea* (Fonscolombe)

Hyperparasitoid:

**Aphelinidae**

- *Marietta leopardina* Motschulsky*.

(* = new records for Egypt).

At the North Coast location, four species were recorded (*D. elegans*, *M. flavus*, *Metaphycus* sp. II and *S. caerulea*). The total percentage parasitism was greatest during the period Sept. to Feb., reaching a peak of 47% in Oct. in the first year and 51% in Nov. in the second year. The overall percentage parasitism was 20.1% (first year) and 23.8% (second year).

At the El-Arish site, three species were recorded (*D. elegans*, *Metaphycus* sp. I and *M. leopardina*). The total percentage parasitism was greatest during the period Sept/Oct. to March, reaching a peak of 55% in Jan. in the first year and 76% in Dec. in the second year. The overall percentage parasitism was

23.2% (first year) and 34.6% (second year). The relative abundance of the three species in the two years was: *D. elegans*: overall 9.2% and 20%; *Metaphycus* sp. I: overall 9.8% and 12.2% and *M. leopardina*: overall 4.3% and 2.4% each year respectively.

At the Matruh location, only two species were recorded (*D. elegans* and *M. zebratus*). In both years, the total percentage parasitism was greatest during the period Oct./Nov. to March, reaching peaks of 37% and 25% in Nov./Dec of each year. The overall percentage parasitism was 17.0% (first year) and 9.3% (second year). The relative abundance of the two species in the two years was: *M. zebratus*: overall 10.5% and 4.4% and *D. elegans*: overall 6.5% and 4.4%.

Only *M. flavus*, *Metaphycus* sp. II and *S. caerulea* were recorded from Northern Coast area, where *Metaphycus* sp. II was the most abundant parasitoid. *M. zebratus* was recorded only from Matruh region, while *Metaphycus leopardina* and *M.* sp. I were recorded only from El-Arish site (where *Metaphycus* sp. I was the most abundant parasitoid). Only *D. elegans* was collected from all three sites but only at low levels; it was reported to be the dominant parasitoid of *S. oleae* in Israel (Rosen *et al.*, 1971). The latter workers also found *M. leopardina* to be an abundant hyperparasitoid in *S. oleae*. *Metaphycus* sp. I and II are completely different morphologically and are easy to separate.

The rather low percentage parasitism of *S. oleae* found here in Egypt in the present study in comparison with the levels noted in other countries suggests a serious need for the introduction into Egypt of additional specific natural enemies and parasitoids of this important soft scale.

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ABD-RABOU, S.
*Plant Protection Research Institute, Agricultural Research Center, Dokki-Giza, Egypt*

# AN ANNOTATED LIST OF THE HYMENOPTEROUS PARASITOIDS OF THE DIASPIDIDAE (HEMIPTERA: COCCOIDEA) IN EGYPT, WITH NEW RECORDS.

## ABSTRACT

An annotated list of the hymenopterous parasitoids of the Diaspididae (Hemiptera: Coccoidea) in Egypt, with new records.

Eighteen species of hymenopterous parasitoid of armoured scale insects (Hemiptera: Diaspididae) were recorded in a survey of host plants in three locations in Egypt during 1994-1997. The 16 species of Aphelinidae and two Encyrtidae are listed, along with their diaspidid hosts and location in Egypt; ten species were new records for Egypt.

Key words: survey, geographic distribution, host range, rearing methods, *Ablerus*, *Aphytus*, *Coccophagoides*, *Encarsia*, *Marietta*, *Habrolepis*.

## INTRODUCTION

Prior to the studies of Priesner & Hosny (1940), very little was known about the parasitoids of armoured scale insects in Egypt. Priesner & Hosny recorded six aphelinid species: *Aphytis chrysomphali* (Mercet), *A. diaspidis* Howard, *A. maculicornis* (Masi), *A. mytilaspidis* (Le Baron), *Encarsia citrina* (Craw) and *E. lounsburyi* (Berlese & Paoli). Later, Abdel-Fattah & El-Saadany (1979) recorded *Aphytis lepidosaphes* Compere associated with *Lepidosaphes beckii* (Newman), while *Aphytis cohni* De Bach was recorded from *Aonidiella aurantii* (Maskell) in Alexandria by Hafez (1988). There have been no more recent records.

During the period 1994-1997, a survey was conducted throughout Egypt, the results of which are given below. Each entry gives the geographic distribution and the host range; new records are indicated by an asterisk.

## MATERIALS AND METHODS

The survey consisted of random samples of 60 host plants with 25 species of Coccoidea collected from 25 governorates in Egypt. The survey was carried out between Sept. and March in 1994-'95, 1995-'96 and 1996-'97. Scale-infested plants were transferred separately to the laboratory in a cool box and then kept in a well-ventilated container until after the emergence of any parasitoids. Each parasitoid was then either mounted on a card or on a glass slide (depending on family) for identification.

## RESULTS

List of hymenopterous parasitoids of armoured scale insects found between September and March in a three year survey in Egypt:

### Aphelinidae:

***Ablerus atomon (Walker)*.***

Host: *Chionaspis stanotophri* Cooley on *Cupressus* sp.
Distribution: Fayoum and Helwan.

***Aphytis chrysomphali (Mercet): (previously recorded by Priesner & Hosny, 1940).***

Hosts: *Aonidiella aurantii* (Maskell) on *Ficus nitida*; *Chrysomphalus ficus* (Ashmead) on *Citrus* sp.; *Mycetaspis personata* (Comstock) on *Mangifera indica*; *Parlatoria oleae* (Colveé) on *Olea* sp.; *P. ziziphi* (Lucas) on *Citrus* sp.
Distribution: Alexandria, Cairo, Giza and South Sinai.

***Aphytis coheni De Bach: (previously recorded by Hafez, 1988).***

Host: *Aonidiella aurantii* (Maskell) on *Citrus sinensis.*
Distribution: Alexandria.

***Aphytis diaspidis (Howard): (previously recorded by Priesner & Hosny, 1940).***

Host: *Parlatoria oleae* on *Olea* sp.
Distribution: Northern Coast and El-Arish.

***Aphytis lepidosaphes Compere: (previously recorded by Abdel-Fattah & El-Saadany, 1979).***

Host: *Lepidosaphes beckii* (Newman) on *Mangifera indica*
Distribution: Behira.

**Aphytis lingnanensis Compere*.**

Hosts: *Aonidiella aurantii* on *Citrus* sp.; *Aspidiotus hederae* (Vallot) on *Nerium* sp.; *Lindingaspis floridana* Ferris on *Ficus nitida.*

Distribution: Alexandria, Cairo and Giza.

**Aphytis maculicornis (Masi): (previously recorded by Priesner & Hosny, 1940).**

Hosts: *Abgrallaspis cyanophylli* (Signoret) on *Psidium guajava*; *Lepidosaphes ulmi* (Linnaeus) on *Vitis vinifera*; *Diaspis echinocacti* (Bouché) on *Opuntia* sp.; *Parlatoria oleae* on *Olea* sp.

Distribution: Beni-Suef, Cairo, El-Arish and Giza.

**Aphytis mytilaspidis (Le Baron): (previously recorded by Priesner & Hosny, 1940).**

Hosts: *Abgrallaspis cyanophylli* on *Mangifera indica*; *Aspidiotus hederae* on *Jasminum grandiflorum*; *Aonidiella aurantii* on *Citrus* sp.; *Chionaspis stanotophri* on *Cupressus* sp.; *Diaspis echinocacti* on *Cactus* sp.; *Hemiberlesia lataniae* (Signoret) on *Mangifera indica*; *Lepidosaphes beckii* (Newman) on *Mangifera indica*; *L. ulmi* (Linnaeus) on *Ficus carica*; *Mycetaspis personata* (Comstock) on *Phoenix dactylifera* L.

Distribution: Behira, Beni-Suef, Cairo, Giza and Sharqiya.

**Aphytis phoenicis De Bach & Rosen*.**

Host: *Parlatoria blanchardii* (Targioni-Tozzetti) on *Phoenix dactylifera* L.

Distribution: El-Arish.

**Aphytis sp.*.**

Hosts: *Chrysomphalus dictyospermi* (Morgan) on *Ficus nitida*; *Insulaspis pallidula* (Green) on *Mangifera indica*; *Leucaspis riccae* Targioni-Tozzetti on *Olea* sp.

Distribution: Cairo, Fayoum, Giza and Sharqiya.

**Coccophagoides sp.*.**

Host: *Parlatoria oleae* on *Olea* sp.

Distribution: Northern Coast.

***Encarsia aurantii (Howard)*.***

Host: *Parlatoria oleae* on *Olea* sp.
Distribution: Northern Coast.

***Encarsia citrina (Craw): (previously recorded by Priesner & Hosny, 1940).***

Hosts: *Abgrallaspis cyanophylli* on *Mangifera indica*; *Aonidiella aurantii* on *Citrus* sp.; *Aspidiotus hederae* on *Nerium* sp.; *Chrysomphalus dictyospermi* on *Ficus nitida*; *C. ficus* on *Phoenix dactylifera* L.; *Insulaspis gloveri* (Packard) on *Citrus* sp.; *Lepidosaphes beckii* on *Mangifera indica*; *Lindingaspis floridana* on *Ficus nitida*; *Parlatoria ziziphi* on *Citrus* sp.
Distribution: Behira, Cairo, El-Arish, Giza and Qalyubiya.

***Encarsia lounsburyi (Berlese & Paoli): (previously recorded by Priesner & Hosny, 1940).***

Hosts: *Abgrallaspis cyanophylli* on *Psidium guajava*; *Aonidiella aurantii* on *Citrus* sp.; *Aspidiotus hederae* on *Nerium* sp.; *Chionaspis stanotophri* on *Cupressus* sp.; *Chrysomphalus ficus* on *Phoenix dactylifera*; *Diaspis echinocacti* on *Opuntia* sp.; *Hemiberlesia lataniae* on *Nerium* sp.; *Insulaspis pallidula* on *Mangifera indica.*
Distribution: Assiut, El-Minya, Beni-Suef and Giza.

***Marietta leopardina Motschulsky*.***

Hosts: *Aonidiella aurantii* on *Citrus* sp.; *Chrysomphalus dictyospermi* on *F. nitida*; *Parlatoria oleae* on *Olea* sp.; *P. ziziphi* on *Citrus* sp.
Distribution: Beni-Suef, Cairo, El-Arish, Fayoum, Northern Coast, Qalyubiya and South Sinai.

***Marietta sp.*.***

Host: *Chrysomphalus dictyospermi* on *Ficus nitida.*
Distribution: Cairo.

## Encyrtidae

### ***Habrolepis aspidioti* Compere & Annecke*.**

Hosts: *Chrysomphalus dictyospermi* on *Ficus nitida*; *Hemiberlesia lataniae* on *Mangifera indica*; *Parlatoria ziziphi* on *Citrus* sp.

Distribution: Giza, Minyufiya, Northern Coast, Qalyubiya, Sohag and South Sinai.

### ***Habrolepis* sp.***

Host: *Chrysomphalus dictyospermi* on *F. nitida*

Distribution: Qalyubiya.

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ABD-RABOU, S.; HANAFI, A.; HUSSEIN, N.
*Plant Protection Research Institute, Agricultural Research Center, Dokki-Giza, Egypt*

# NOTES ON THE PARASITOIDS OF THE SOFT BROWN SCALE, *COCCUS HESPERIDUM* (HEMIPTERA: COCCIDAE) IN EGYPT.

## ABSTRACT

NOTES ON THE PARASITOIDS OF THE SOFT BROWN SCALE, *COCCUS HESPERIDUM*
(HEMIPTERA: COCCIDAE) IN EGYPT.

Thirteen species of hymenopterous parasitoid were found in association with *Coccus hesperidum* at three locations in Egypt: 4 species of Aphelinidae (of which three were recorded for the first time); seven species of Encyrtidae (of which three were recorded for the first time), the first record of a species of Mymaridae, plus a species of Pteromalidae. The relative abundance of these parasitoids is discussed.

Key words: survey, rearing methods, percentage parasitism, *Coccophagus*, *Marietta*, *Diversinervis*, *Metaphycus*, *Microterys*, *Parachthrodryinus*, *Prochilonerus*, *Alaptus*, *Scutellista.*

## INTRODUCTION

The soft brown scale, *Coccus hesperidum* L. (Hemiptera: Coccidae) is one of the most cosmopolitan and polyphagous coccid species (Gill *et al.*, 1977). It has been recorded off about 236 host plants in 93 plant families, distributed among 112 countries (Ben-Dov, 1993). In Egypt, it is considered to be a serious pest, attacking 18 plant species belonging to 15 families, including citrus, guava and some ornamental plants (Mohammad & Nada, 1991). Both in Egypt and elsewhere, there have been numerous studies on the role of parasitoids in the control of the soft brown scale. In Egypt, Priesner & Hosny (1940) recorded 5 aphelinid species and an encyrtid associated with *C. hesperidum.* In California, Bartlett (1978) emphasised the important role of *Metaphycus luteolus* Timberlake in the control of this species, while, in Israel, Rosen (1967) recorded 15 species of parasitoid belonging to the Aphelinidae, Encyrtidae, Euphilidae and Pteromalidae.

The parasitoid species discussed below were those collected in Egypt in association with *C. hesperidum.*

## MATERIALS AND METHODS

A survey of the species and abundance of the parasitoids associated with *C. hesperidum* in Egypt, was carried out between June 1996 and June 1997 on

*Ficus nitida*, *Psidium guajava* and *Nerium* sp. in three localities, namely El-Arish, Gharbiya and Giza. The eggs, larvae and non-ovipositing stages of *C. hesperidum* were sampled monthly on the leaves of each host (30 infested leaves per sample). These were transferred to the laboratory in well-ventilated boxes and then all first-instar larvae and ovipositing adults were removed, as well as all other insects. The total number of each of the remaining *C. hesperidum* stages was recorded per leaf. Each leaf was stored in a well-ventilated glass tube and monitored daily for the emergence of parasitoids. In the calculations of percentage parasitism, it was assumed that only one parasitoid emerged from each scale individual. All emerging parasitoids were either card or slide mounted (depending on family) and identified to species.

## RESULTS AND DISCUSSION

Thirteen species of hymenopterous parasitoid and hyperparasitoid were collected from samples of *C. hesperidum* on *F. nitida*, *P. guajava* and *Nerium* sp. in Giza, Gharbiya and El-Arish locations. These are listed in alphabetical order below:

### Aphelinidae

*Coccophagus bivittatus* Compere: here recorded from Egypt for the first time parasitising *C. hesperidum* but restricted to Giza, where the percentage parasitism on *F. nitida* was 0.7%, with a peak of 4% in Feb. 1997. *C. bivittatus* has also been recorded as a parasitoid of *C. hesperidum* from South Africa (Compere, 1931a), Argentina (De Santis, 1948), Italy (Zinna, 1961), India (Sankaran, 1955) and Israel (Rosen, 1967).

*Coccophagus ishii* Compere: here recorded from Egypt for the first time parasitising *C. hesperidum* but restricted to El-Arish, where the percentage parasitism on *Nerium* sp. was 0.4%, with a max. of 2% in June 1996. *C. ishii* has been recorded from Japan as a parasitoid of various soft scale species, especially of the genus *Pulvinaria* (Compere, 1931a; Ishihara, 1977).

*Coccophagus scutellaris* (Dalman): first recorded in Egypt in Alexandria by Priesner & Hosny (1940) parasitising *C. hesperidum* and *Pulvinaria floccifera* (Westwood) on citrus and *Ficus* respectively; in this study, only found at Gharbiya, where the percentage parasitism on *P. guajava* was 1.1%, with a peak of 7% in Nov. 1996. *C. scutellaris* is a well-known, cosmopolitan parasitoid of various soft scale species (Rosen, 1967). Nikol'skaya (1952) recorded it associated with *Saissetia oleae* (Olivier) and *Ceroplastes floridensis* (Comstock).

*Marietta picta* (André): here recorded for the first time as a hyperparasitoid from *C. hesperidum* in Egypt but only recorded from El-Arish, where the percentage parasitism on *Nerium* sp. was 2.5%, with a peak of 8% in Feb. 1997. *M. picta* is a well-known and widely distributed species in the Palaearctic region and has also been recorded from Canada, India and Mexico (Hayat, 1986).

### Encyrtidae

*Diversinervus elegans* Silvestri: first recorded in Egypt by Priesner & Hosny (1940) parasitising *S. oleae*, *P. floccifera* and *C. hesperidum*; in the present study only recorded from Giza and Gharbiya. Percentage parasitism in Giza on *F. nitida* was 5.3% and in Gharbiya on *P. guajava* 10.9%, with a max. in Giza of 15% in Oct. 1996 and in Gharbiya of 23% in June 1996. First recorded from Eritrea (Silvestri, 1915) but now also known from Australia (Compere, 1931b; Wilson, 1960) and Southern Africa (Annecke, 1964). It has been found to be a common parasitoid of *S. oleae* on olives but rare in *Saissetia coffeae* (Walker) (Rosen *et al.*, 1971).

*Metaphycus flavus* (Howard): first recorded from Delta and Upper Egypt by Priesner & Hosny (1940) parasitising *C. hesperidum* on citrus, *P. floccifera* on *P. guajava* and *S. oleae* on *Cycas revoluta*; in the present study, only recorded from Giza and Gharbiya. Percentage parasitism in Giza on *F. nitida* was 1.4% and in Gharbiya on *P. guajava* was 3.9%, with a maximum parasitism of 12% in Giza in June and 7% at Gharbiya in July.

*Metaphycus helvolus* (Compere): recorded here for the first time in Egypt parasitising *C. hesperidum*, but only recorded from El-Arish and Gharbiya. Percentage parasitism in Gharbiya on *P. guajava* 0.9% and in El-Arish on *Nerium* sp. 4.0%, with a max. parasitism of 4% in Gharbiya during March, 1997 and of 14% in El-Arish in June, 1997. *M. helvolus* was originally described from South Africa (Compere, 1926), where it is an abundant primary parasitoid of various soft scales, including *Saissetia* sp., *Marsipococcus proteae* (Brain) and *C. hesperidum* (Annecke, 1964).

*Microterys flavus* (Howard): here recorded from Egypt for the first time parasitising *C. hesperidum*, but only recorded from Giza and Gharbiya. Percentage parasitism in Giza on *F. nitida* 11.2%, with a max. of 24%. *M. flavus* is a widely distributed parasitoid of various soft scale insects and has been recorded from North America, North and South Africa, the Far East, Australia, New Zealand, Europe and around the Mediterranean Basin (Thompson, 1954; Annecke, 1964; Rosen, 1967; Saakyan-Baranova, 1968).

*Microterys* sp.: here recorded from Egypt for the first time parasitising *C. hesperidum*, but only found at El-Arish, where the percentage parasitism was 1.9% on *Nerium* sp., with a peak of 6% in June, 1996.

*Parechthrodryinus coccidiphagus* (Mercet): first recorded from Lower and Upper Egypt by Priesner & Hosny (1940) parasitising *C. hesperidum* on citrus and *Parasaissetia nigra* (Nietner) on *Ficus carica* respectively; in the present study, only found at Gharbiya, where the percentage parasitism was 0.2% on *P. guajava*, with a peak of 1% in July 1996.

*Prochilonerus aegyptiacus* (Mercet): first recorded in Egypt by Priesner & Hosny (1940) parasitising various coccid species on *Zilla* sp.; in the present study, only recorded from El-Arish, where the percentage parasitism was 2% on *Nerium* sp., with a peak of 1% in June and Aug., 1996.

**Mymaridae**

*Alaptus pallidicornis* Forester: here recorded from Egypt for the first time parasitising *C. hesperidum*, but only from El-Arish, where percentage parasitism was 1% on *Nerium* sp., with a peak of 5% in June, 1996.

**Pteromalidae**

*Scutellista caerulea* (Fonscolombe): first recorded from Lower and Upper Egypt by Priesner & Hosny (1940) from a range of soft scale species: namely *Ceroplastes africanus* Green on *Acacia nilotica*, *Albizzia lebbek*, *F. carica* and *Tamarix* sp.; *Ceroplastes rusci* (L.) on *F. carica*; *P. nigra* on *Ficus sycomorus*; *S. oleae* on Compositae, and *S. coffeae* on olive. In the present study it was only found at Giza and Gharbiya. Percentage parasitism in the present study was 5.5% in Giza on *F. nitida* and 6.1% in Gharbiya on *P. guajava*, with peaks in Sept. 1996 of 13% in Giza and 25% in Gharbiya. This species is a cosmopolitan egg predator and a facultative ectoparasitoid of various soft scale insects, probably of African or Far Eastern origin (Smith &

Compere, 1928; Rubtsov, 1954). Bodenheimer (1951) listed it as an important natural enemy of several soft scale insects, while Rosen (1967) found it to be often the dominant parasitoid of *C. floridensis* and abundant in *S. oleae* but rare in *C. rusci* on citrus.

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ABOU-ELKHAIR, S.
*Plant Protection Institute, Agricultural Research Station, Elsabaheia, Baccos, Alexandria, Egypt.*

# SCALE INSECTS (HEMIPTERA: COCCOIDEA) AND THEIR PARASITOIDS ON ORNAMENTAL PLANTS IN ALEXANDRIA, EGYPT.

## ABSTRACT

SCALE INSECTS (HEMIPTERA: COCCOIDEA) AND THEIR PARASITOIDS ON ORNAMENTAL PLANTS IN ALEXANDRIA, EGYPT.

This paper discusses the scale insects (Coccoidea) and their parasitoids on ornamental plants in the Alexandria district of Egypt, between 1995 and 1998. Thirty-nine coccoid species belonging to eight families were noted: Asterolecaniidae, Coccidae, Diaspididae, Eriococcidae, Margarodidae, Ortheziidae, Phoenicococcidae and Pseudococcidae. Twelve genera of Hymenoptera belonging to five families were recorded as parasitoids: Aphelinidae (*Aphytis*, *Coccophagus* and *Encarsia*); Encyrtidae (*Anagyrus*, *Arrhenophagus*, *Gyranusoidea*, *Habrolepis*, *Metaphycus* and *Rhopus*); Eulophidae (*Aprostocetus*); Pteromalidae (*Scutellista*) and Signiphoridae (*Signiphora*). Four endoparasitoids were recorded from Egypt for the first time: *Arrhenophagus* sp. and *Gyranusoidea litura* Prinsloo (Encyrtidae), *Aprostocetus* sp. (Eulophidae) and *Signiphora fax* Girault (Signiphoridae).

Key words: urban environment, biological control, host plants.

## INTRODUCTION

Ornamental herbaceous plants and trees are an important part of urban environments. Unfortunately, they are attacked by several species of scale insect which are important and destructive pests (Hammad & Moussa, 1973; Moursi *et al.*, 1991; Abou-Elkhair & Karam, 1994). The present survey of ornamental plants in the Alexandria area was conducted between 1995 and 1998 and included the scale insects parasitoids which might provide some biological control of these pests (Priesner & Hosny, 1940; Temerak, 1981; Hamed & Hassanein, 1991; Karam & Abou-Elkhair, 1996).

## MATERIALS AND METHODS

Samples of 10-20 leaves or 10cm lengths of twig and/or roots were collected every 2-3 months from plants heavily infested with scale insects from (i) the International Garden, Elsabaheia Research Station, Faculty of Agriculture, (ii) some private gardens at Mina Tourist Village (Northern Coast) and (iii) trees and shrubs along the streets and roads in Alexandria City. The scale insects were prepared for microscopical studies using McKenzie's method (1956) and were identified using the keys of McKenzie (1956, 1967) and Hamon & Williams (1984).

In the laboratory, the plant samples were divided so that each consisted of a single scale insect species on a specific host plant. Each sample was then placed in a dark jar with a clear emergence tube to which any emerging parasitoids would fly. For the following two weeks, all emerging hymenopterous parasitoids were removed and placed in lactic acid for 24h, rinsed in distilled water and then mounted on a labelled glass slide in Hoyer's solution. These were kept in an oven at 35-40°C for a week after which they were identified by using the keys of Compere (1955), Quednau (1964), Prinsloo & Annecke (1979), Prinsloo (1980, 1983) and Viggiani (1987).

## RESULTS

| **Coccoidea** | **Host plants** | **Parasitoids** |
|---|---|---|
| **Asterolecaniidae** | | |
| *Russellaspis pustulans* (Cockerell) | *Acacia* sp., *Bauhinia* sp. (Leguminosae); *Nerium oleander* (Apocynaceae) | |
| **Coccidae** | | |
| *Ceroplastes floridensis* Comstock | *Ficus benghalensis*, *F. nitida* (Moraceae); *N. oleander* | |
| *C. rusci* (L.) | *Ficus* spp.; *Murraya koenigii* (Rutaceae) | |
| *Chloropulvinaria psidii* (Maskell) | *Aralia longifolia* (Araliaceae); *Solanum pseudocapsicum* [illegible] | |
| *Coccus hesperidum* L. | [illegible] *pulchrum*, *Schefflera actinophylla* (Araliaceae); *Ficus* spp. | *Coccophagus* sp. (Aphelinidae) |
| *C. longulus* (Douglas) | *Murraya koenigii*; *Ficus* spp.; *Hibiscus rosa-sinensis* (Malvaceae) | *Metaphycus flavus* Howard (Encyrtidae) |
| *Kilifia acuminata* (Signoret) | *Murraya koenigii* | |
| *Pulvinaria chrysanthemi* Hall | *Chrysanthemum morifolium* (Compositae) | |
| *Saissetia oleae* (Olivier) | *Nerium oleander*, *Hibiscus* spp. | *Scutellista cyanea* Motschulsky (Pteromalidae) |
| **Diaspididae** | | |
| *Abgrallaspis cyanophylli* (Signoret)* | *Acacia saligna* (Leguminosae) | *Aphytis maculicornis* (Masi) |
| *Aonidiella aurantii* (Maskell) | *Ficus benghalensis*; *Hedera helix* (Araliaceae); *Jasminum* sp. (Oleaceae); *Rosa* sp. (Rosaceae) | *Aphytis melinus* DeBach (Aphelinidae) |
| *A. citrina* (Coquillett)* | *Ficus* spp. | |
| *A. orientalis* (Newstead) | *Ficus* spp. | |
| *Aspidiotus nerii* Bouché | *Nerium oleander*, *Ficus benghalensis* | *Aphytis* [illegible] DeBach; *Encarsia lounsburyi* (Berlese & Paoli) (Aphelinidae) |
| *Carulaspis minima* (Targioni Tozzetti) | *Cupressus sempervirens*, *Thuja orientalis* (Pinaceae) | *Aphytis mytilaspidis* (Le Baron); *Encarsia citrina* (Craw) |
| *Chrysomphalus aonidum* (L.) | *Ficus nitida*; *Jasminum* sp.; *Nerium oleander* | |

| | | |
|---|---|---|
| *Diaspidiotus* [illegible] ([illegible])* | *Populus* [illegible] (Salicaceae) | |
| *Diaspis echinocacti* (Bouché)* | *Cactus* sp. (Cactaceae) | *Aphytis maculicornis* (Masi) *Aphytis diaspidis* (Howard); *A. flavus* Compere, *A. fisheri* DeBach, *A. mytilaspidis*, *Signiphora fax* Girault* (Signiphoridae), *Habrolepis rouxi* Compere (Encyrtidae) |
| *Hemiberlesia lataniae* (Signoret) | *Acacia nilotica*, *Mangifera indica*; *Melia azedarach* (Meliaceae); *Ficus nitida*. | |
| *H. rapax* (Comstock) | *Ficus* spp.; *Nerium oleander* | |
| *Lineaspis striata* (Newstead) | *Cupressus sempervirens*, *Thuja orientalis* | *Encarsia citrina* |
| *Mycetaspis personata* (Comstock) | *Ficus nitida*, *Jasminum* sp. | |
| *Oceanaspidiotus spinosus* (Comstock)* | *Ficus* spp.; *Nerium oleander* | |
| *Odonaspis ruthae* Kotinsky | *Cynodon dactylon* (Gramineae) | |
| *Pinnaspis aspidistrae* (Signoret) | *Aspidistra* spp. (Liliaceae) | *Aphytis diaspidis*, *A. flavus*, *Arrhenophagus* sp.*† (Encyrtidae); *Encarsia citrina* |
| *P. strachani* (Cooley)* | [illegible] spp. ([illegible]) | *Aphytis* sp. |
| *Pseudaulacaspis pentagona* (Targioni Tozzetti) | *Myoporum pictum* (Myoporaceae), *Pelargonium* spp. (Geraniaceae) | *Aphytis* sp.; *Encarsia fasciata* (Malenotti) |
| Eriococcidae<br>*Eriococcus araucariae* (Maskell) | *Araucaria* sp. (Araucariaceae) | |
| Margarodidae<br>*Icerya aegyptiaca* (Douglas) | *Ficus bengalensis*; *Myoporum pictum* | |
| *I. purchasi* Maskell | *Ficus* spp. | |
| *I. seychellarum* (Westwood) | *Ficus* spp.; *Latania* [illegible] (Palmaceae) | |
| Ortheziidae<br>*Orthezia insignis* Douglas | *Coleus* sp. (Labiatae); *Lantana camara* (Verbenaceae) | |
| Phoenicococcidae<br>*Phoenicococcus marlatti* Cockerell | *Phoenix dactylifera*, *Washingtonia filifera* (Palmaceae) | |
| Pseudococcidae<br>*Antonina graminis* (Maskell) | *Cynodon dactylon* | *Anagyrus* [illegible] Noyes; *Anagyrus* sp. nr. [illegible] Noyes & Hayat (Encyrtidae) |
| *Brevennia rehi* (Lindinger) | *Cynodon dactylon* | [illegible] (Girault) (Encyrtidae) |
| *Ferrisia virgata* (Cockerell) | [illegible] sp. (Amaranthaceae) | |
| *Maconellicoccus hirsutus* (Green) | *Hibiscus* spp., *Cupressus sempervirens* | *Anagyrus kamali* Moursi, *A. aegyptiacus* Moursi, *Aprostocetus* sp.* (Eulophidae); *Signiphora* sp. (Signiphoridae) |
| *Planococcus citri* (Risso) | *Myoporum pictum*, *Nerium oleander*, *Pelargonium* spp. | |
| *Pseudococcus longispinus* (Targioni Tozzetti) | *Nerium oleander* | [illegible]* (Encyrtidae) |

where * = first record for Egypt; and † = endoparasite in male *Pinnaspis aspidistrae.*

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FRANCO, J.C.[1]; MAROTTA, S.[2]

*[1]Secção de Protecção Integrada, Dep. Protecção das Plantas e de Fitoecologia, Instituto Superior de Agronomia, 1399 Lisboa Codex, Portugal*

*[2]Dip. Biologia, Difesa e Biotecnologie Agro-Forestali, Università della Basilicata, Via Nazario Sauro 85, 85100 Potenza, Italia*

# A SURVEY OF MEALYBUGS (HEMIPTERA: COCCOIDEA: PSEUDOCOCCIDAE) IN CITRUS GROVES IN CONTINENTAL PORTUGAL.

## ABSTRACT

A survey of mealybugs (Hemiptera: Coccoidea: Pseudococcidae) in citrus groves in Continental Portugal.

A survey of mealybugs living in citrus groves was carried out in order to elucidate the identity and relative importance of the species associated with this crop in Continental Portugal. Samples were collected in 76 citrus groves from the districts of Beja, Coimbra, Évora, Faro, Lisboa, Porto, Santarém, Setúbal and Viseu. The presence of mealybugs was detected in 93% of the citrus groves studied. Four species were identified, i.e. *Planococcus citri* (Risso), *Pseudococcus calceolariae* (Maskell), *P. viburni* (Signoret) and *P. longispinus* (Targioni Tozzetti). *P. citri* and *P. calceolariae* were the most frequent species, present in 66% and 63% of the citrus groves, respectively. *P. viburni* and *P. longispinus* were identified in 29% and 14% of the sites, respectively. Apparently, *P. calceolariae* has the widest geographical distribution on citrus in Portugal. The co-existence of at least two species in the same citrus grove was found in 59% of the cases. *P. citri* and *P. calceolariae* were found associated in 37% of the citrus groves; *P. viburni* was always found associated with at least one of the three other species.

Key words: Universal Transverse Mercator, *Citrus sinensis*, *C. limon*, *C. reticulata.*

## INTRODUCTION

Sixty-one species of mealybugs belonging to 19 genera are listed on *Citrus* spp. in Ben-Dov's (1994) Systematic Catalogue, but only a few are actually considered major pests. *Planococcus citri* (Risso) is probably the most important and cosmopolitan species.

However, pest status may change with pest management systems. Mealybug outbreaks were recently reported from Southern Africa (Hatting & Tate, 1997), where they had been considered relatively minor pests on citrus prior to 1990. Therefore, minor mealybug pests could be considered potential major pests. Furthermore, when more than one species is present, damage may occur as the result of the activity of the phloem-feeding guild of mealybugs, independent of the pest status of individual species.

Prior to the end of 1980 s, *P. citri* and *Pseudococcus longispinus* (Targioni Tozzetti) were the only mealybugs known from citrus in Portugal. Preliminary studies conducted in Algarve suggested the existence of other species of Pseudococcidae (Carvalho, 1988) and these were subsequently identified as *Pseudococcus calceolariae* (Maskell) and *P. viburni* (Signoret) (= *P. affinis* Maskell) (Franco & Carvalho, 1990).

In order to know whether other mealybugs were associated with citrus and to elucidate their relative importance, a survey was conducted in nine regions of Continental Portugal and the results of this study are presented here and discussed.

## MATERIALS AND METHODS

Samples were collected in 76 citrus groves from the districts of Beja, Coimbra, Évora, Faro, Lisboa, Porto, Santarém, Setúbal and Viseu. Each citrus grove was labelled according to the Universal Transverse Mercator (UTM) system of co-ordinates (Rasmont & Andre, 1989). A total of 41 10km$^2$ UTM squares were sampled.

Most of the samples were collected in sweet orange (*Citrus sinensis* (L.) Osbeck) groves, but other citrus species were also considered in a few regions. For instance, in Mafra (Lisbon district), all the samples were collected from lemon (*C. limon* Burmann), the only citrus species growing in the region, while in Ribatejo-Oeste Region, where the citrus groves are traditional mixed citrus groves of *C. sinensis*, *C. limon* and *C. reticulata* Blanco, collections were made on all three species.

Samples were mainly collected between 1991 and 1994 from July to September, i.e. the period when mealybug populations are usually at their greatest. Each sample was obtained by observing mainly fruits on trees which had been randomly selected. When the mealybug population was low, particular attention was paid to the space between the sepals and the fruit, where the probability of detecting mealybugs is greatest (e.g., Meyerdirk *et al.*, 1981).

Each grove was studied for 30 to 60 minutes, depending on the size of the grove and the frequency and abundance of the mealybugs.

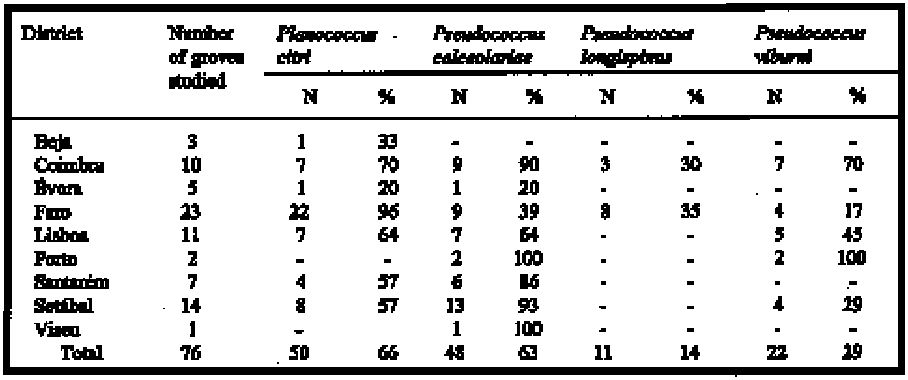
When available, at least five adult females of each species were collected in each grove. In some groves, only immature stages were found. These specimens were identified using the keys in Panis (1969).

## RESULTS AND DISCUSSION

Mealybugs occurred in 93% of the investigated citrus groves, including some commercial groves intensively sprayed with insecticides. Mealybugs were not detected in two citrus groves in the district of Beja, nor in three groves in the district of Évora.

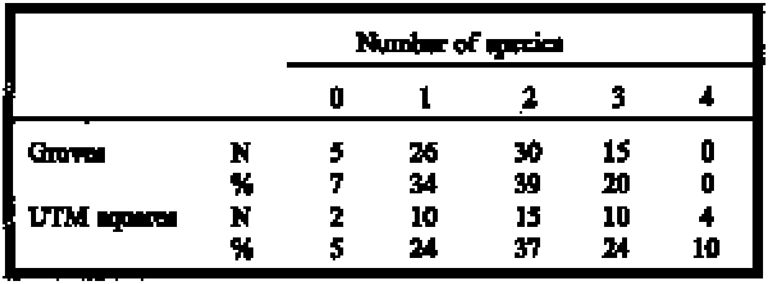
Four mealybug species were identified from the 500 specimens collected (*P. citri*, *P. calceolariae*, *P. longispinus* and *P. viburni)*, including 407 adult females and 93 young stages. *P. citri* was the most frequent species, present in 66% of the groves (Table 1). It was followed by *P. calceolariae*, *P. viburni* and *P. longispinus*, present in 63%, 29% and 14% of the groves respectively. However, the relative frequency of the four species was variable from region to region. For example, *P. citri* was collected in 96% of groves in the province of

Table 1. Number of citrus groves by district where the presence of mealybugs was detected. Where - = species not found.



| District | Number of groves studied | *Planococcus citri* | | *Pseudococcus calceolariae* | | *Pseudococcus longispinus* | | *Pseudococcus viburni* | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | % | N | % | N | % | N | % |
| Beja | 3 | 1 | 33 | - | - | - | - | - | - |
| Coimbra | 10 | 7 | 70 | 9 | 90 | 3 | 30 | 7 | 70 |
| Évora | 5 | 1 | 20 | 1 | 20 | - | - | - | - |
| Faro | 23 | 22 | 96 | 9 | 39 | 8 | 35 | 4 | 17 |
| Lisboa | 11 | 7 | 64 | 7 | 64 | - | - | 5 | 45 |
| Porto | 2 | - | - | 2 | 100 | - | - | 2 | 100 |
| Santarém | 7 | 4 | 57 | 6 | 86 | - | - | - | - |
| Setúbal | 14 | 8 | 57 | 13 | 93 | - | - | 4 | 29 |
| Viseu | 1 | - | | 1 | 100 | - | - | - | - |
| Total | 76 | 50 | 66 | 48 | 63 | 11 | 14 | 22 | 29 |

Table 2. Frequency distribution of the number of citrus groves and UTM squares as a function of the number of mealybug species identified.



| | | Number of species | | | | |
|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 |
| Groves | N | 5 | 26 | 30 | 15 | 0 |
| | % | 7 | 34 | 39 | 20 | 0 |
| UTM squares | N | 2 | 10 | 15 | 10 | 4 |
| | % | 5 | 24 | 37 | 24 | 10 |

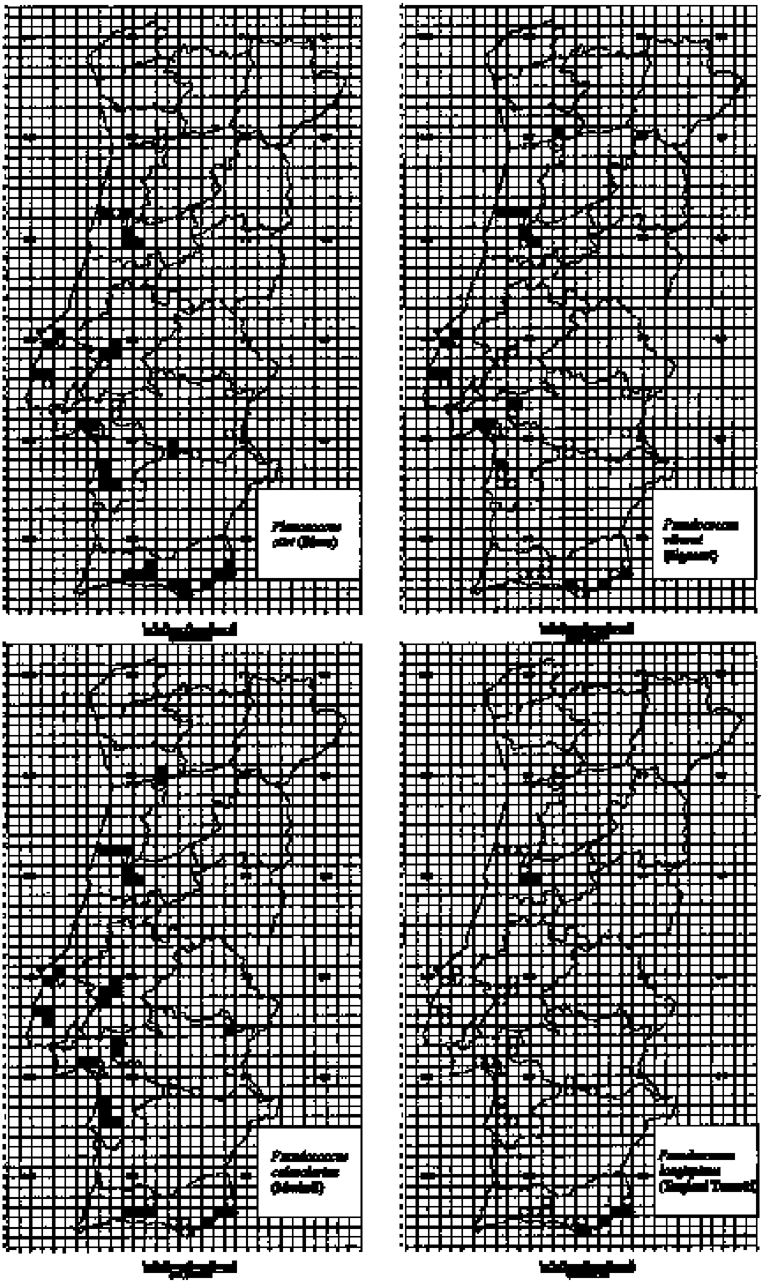


Fig. 1. Geographical distribution of the four mealybug species identified from citrus groves in Continental Portugal. The sampled UTM squares (10km x 10km) are shown as circles, black when a species was present and white when absent.

Algarve (district of Faro), against less than 40% for the other three mealybug species in the same area. *P. calceolariae* was the most frequent species in the districts of Setúbal, Santarém and Coimbra, where it was present in between 86% and 93% of the groves. *P. longispinus* was collected in only two of the nine districts studied, namely Coimbra and Faro. For *P. viburni*, it seems that there is a frequency gradient, increasing from south to north, i.e. Faro (17%), Setúbal (29%), Lisboa (45%), Coimbra (70%) and Porto (100%).

Based on the UTM system (Fig. 1), the most frequent species was *P. calceolariae*, present in 78% of the UTM squares studied. It was followed by *P. citri* (76%), *P. viburni* (41%) and *P. longispinus* (15%). Thus, although *P. citri* was the most common species in the citrus groves studied, *P. calceolariae* had a wider geographical distribution in citrus in Continental Portugal.

The results also showed that it was common to find two or more mealybug species co-existing in the same grove or in different groves in the same geographic region. In fact, this co-existence was detected in 59% of citrus groves and 71% of UTM squares (Table 2). *P. citri* and *P. calceolariae* were found alone in only 17% and 16% of the groves respectively, and co-existing in 37%. *P. viburni* was always associated with at least one of the other three mealybug species, while *P. longispinus* was alone in one citrus grove only.

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JANSEN, M.G.M.

*Section Entomology, Plant Protection Service, Geertjesweg 15, P.O. Box 9102, 6700 HC Wageningen, The Netherlands*

# AN ANNOTATED LIST OF THE SCALE INSECTS (HEMIPTERA: COCCOIDEA) OF THE NETHERLANDS.

## ABSTRACT

AN ANNOTATED LIST OF THE SCALE INSECTS (HEMIPTERA: COCCOIDEA) OF THE NETHERLANDS.

Sixty-six species of scale insects (Hemiptera: Coccoidea) have been recorded in The Netherlands up to August 1998. The species belong to 9 families, the most numerous of which are the Coccidae (19 species), the Pseudococcidae (15 species) and the Diaspididae (15 species). Nine species are recorded here for the first time: *Matsucoccus matsumurae* (Kuwana), *Parthenolecanium rufulum* (Cockerell), *Phyllostroma myrtilli* (Kaltenbach), *Physokermes hemicryphus* (Dalman), *Quadraspidiotus marani* Zahradnik, *Quadraspidiotus perniciosus* (Comstock), *Steingelia gorodetskia* Nassonov, *Trionymus aberrans* Goux and *Trionymus tomlini* Green. *Carulaspis visci* (Schrank) must be removed from the list.

Key words: Ortheziidae, Margarodidae, Eriococcidae, Cryptococcidae, Kermesidae, Asterolecaniidae, Dutch climate, ecology, zoogeography, introduced species, quarantine interceptions.

## INTRODUCTION

In the past, three checklists of Dutch scale insects have been published (De Graaf *et al*., 1862; van der Goot, 1912; Reyne, 1957). The last list was published over forty years ago and so there has been a growing need for more up-to-date information. Reyne (1957) listed 57 species, partly unidentified, from the open of The Netherlands. Since then, several new species have been recorded (Reyne, 1958, 1963, 1965; van Rossem *et al*., 1979; Jansen, 1996a, 1996b).

Information on scale insects can also be found in the Dutch Plant Protection Service Annual Reports. These are not an obvious source of data and have only a small distribution, and so are almost unknown. The purpose of this publication is to compile an up-to-date checklist of the Coccoidea known to occur in The Netherlands from all literature sources and from the collection material available, so that this information can be used for a project devoted to the composition of the Dutch fauna.

## MATERIAL AND METHODS

The faunal list is based on published data and collection material and is partly the result of recent field work. The collections of the Dutch Plant Protection Service at Wageningen, the Institute of Systematics and Population Biology (Zoologisch Museum), Amsterdam and at the National History Museum, Naturalis, Leiden, were consulted. Collection material of the Dutch Plant Protection Service is partly the result of finds by quarantine inspectors and private owners and contains predominantly microscopic slides.

The collection of the Zoologisch Museum at Amsterdam is based on the Reyne-collection which contains both microscopic slides and material preserved on alcohol. Reyne collected scales in the period 1940-1965. Van der Goot and Hille Ris Lambers, who were working on aphids, also collected many scales during their field trips. Unfortunately the collection of Van der Goot, who was working in the beginning of this century (until 1912), could not be traced and is probably lost. The specimens collected by Hille Ris Lambers are part of the Reyne collection. In the period 1912-1940, nobody paid special attention to scale insects and only a small part of the material collected prior to 1940 seems to have been preserved.

Regular collecting trips have been made by the author in the last few years to different parts of The Netherlands to rediscover specimens of species recorded previously and to look for new species in interesting habitats. The insects collected by the author in recent years are deposited as microscopic slides or dry material in the Dutch Plant Protection Service. Unless otherwise stated, all slides of species new to the Dutch fauna are deposited in the collection of the Dutch Plant Protection Service, Wageningen. Part of this collection is still unidentified, never published or only recorded in one of the annual reports of the Service.

## RESULTS

The total number of species recorded in the open is 66, including nine species which are new to the Dutch fauna: *Matsucoccus matsumurae* (Kuwana), *Parthenolecanium rufulum* (Cockerell), *Phyllostroma myrtilli* (Kaltenbach), *Physokermes hemicryphus* (Dalman), *Quadraspidiotus marani* Zahradnik, *Quadraspidiotus perniciosus* (Comstock), *Steingelia gorodetskia* Nassonov, *Trionymus aberrans* Goux and *Trionymus tomlini* Green. The 66 species belong to 9 families; of these, the most speciose families are the Coccidae (19 species), the Pseudococcidae (15 species) and the Diaspididae (15 species). *Carulaspis visci* is removed from the Reyne list because it is here considered to be a misidentification of *C. juniperi*.

**Species list**.

Abbreviations: I - introduced and established species; G - greenhouse species; N - new to the fauna; Po - occasional pest species; Pc - common pest species; R - rare species, found in only 1-3 sites; S - Status unknown (collection material not located); PPS - Plant Protection Service.

## *ORTHEZIIDAE*

*Newsteadia floccosa* (De Geer)

R *Orthezia urticae* (Linnaeus)

R *Ortheziola vejdovskyi* Sulc

## *MARGARODIDAE*

N *Matsucoccus matsumurae* (Kuwana) - Zeist, *Pinus sylvestris*, on trunk: 7♀♀, 27.III.1969, H. Burger; 6♀♀, 22.IV.1969, D. Doom; 2♀♀, 29.IV.1969, H. Burger; 6♀♀, 7.V.1969, D. Doom; 12♀♀, -.VI.1969, D. Doom; 4♀♀, 28.VIII.1969, H. Burger; 2♀♀, 5.IX1969, D. Doom.

R,S *Porphyrophora polonica* (Linnaeus)

N *Steingelia gorodetskia* Nassonov - 5♀♀, Leersum, Leersummerveld, *Carex* x *elythroides*, on the roots, 6.VI.1997, M. Jansen; 1♀, 1♂, Roozendaal, Bedriegertjes, *Betula pendula*, under bark, 23.IV.1997, M. Jansen.

## *PSEUDOCOCCIDAE*

R *Atrococcus paludinus* (Green)

*Chnaurococcus subterraneus* (Newstead)

*Euripersia tomlini* (Newstead)

R *Heterococcus nudus* (Green)

G,Po *Phenacoccus aceris* (Signoret)

*Phenacoccus hordei* (Lindeman)

R *Phenacoccus sphagni* (Green)

*Rhizoecus albidus* Goux - 3♀♀, Rhenen, *Ballota nigra*, roots, 2.X.1982, E. Hille Ris Lambers.

R *Rhodania occulta* Schmutterer

*Spinococcus calluneti* (Lindinger)

N *Trionymus aberrans* Goux - 1♀, Scheveningen, dunes, *Ammophila arenaria*, 3.VII.1995, F. Kozár, coll. Plant Protection Institute, Budapest.

*Trionymus newsteadi* (Green)

| | |
|---|---|
| | *Trionymus perrisii* (Signoret) |
| | *Trionymus radicum* (Newstead) R |
| N | *Trionymus tomlini* Green - 3 nymphs, Veenendaal, Blauwe Hel: *Holcus lanatus*, 24.VII.1997, M. Jansen; 1♀, 2 nymphs, *Holcus lanatus*, 23.VIII.1997, M. Jansen; 3♀♀, *Phalaris arundinacea*, between leaves, 14.VII.1997, M. Jansen. |

## *ERIOCOCCIDAE*

| | |
|---|---|
| R,S | *Acanthococcus aceris* Signoret |
| | *Acanthococcus devoniensis* (Green) |
| R | *Acanthococcus greeni* (Newstead) |
| R | *Anophococcus inermis* (Green) |
| Po | *Gossyparia spuria* (Modeer) |
| R | *Rhizococcus insignis* (Newstead) |

## *CRYPTOCOCCIDAE*

| | |
|---|---|
| Po | *Cryptococcus fagisuga* Lindinger |
| Po | *Pseudochermes fraxini* (Kaltenbach) |

## *KERMESIDAE*

| | |
|---|---|
| | *Kermes quercus* (Linnaeus) |
| R,S | *Kermes roboris* (Fourcroy) |

## *COCCIDAE*

| | |
|---|---|
| | *Eriopeltis festucae* (Fonscolombe) |
| | *Eriopeltis lichtensteini* Signoret |
| | *Eulecanium ciliatum* (Douglas) |
| | *Eulecanium tiliae* (Linnaeus) |
| R | *Lecanopsis formicarum* Newstead |
| R | *Lichtensia viburni* Signoret |
| R | *Luzulaspis* sp. |
| | *Palaeolecanium bituberculatum* (Targioni Tozzetti) |
| Pc,G | *Parthenolecanium corni* (Bouché) |
| | *Parthenolecanium fletcheri* (Cockerell) |
| | *Parthenolecanium pomeranicum* (Kawecki) |

*Parthenolecanium rufulum* (Cockerell) - Recorded in the Annual Report of the Dutch Plant Protection Service (Jansen, 1995b). Imported from Hungary in great numbers on *Quercus* sp., Opheusden, 7.XII.1994, J. Heesters; 1♀, Kaatsheuvel, next to Efteling, *Quercus* sp., 19.III.1998, J. Heesters.
N *Phyllostroma myrtilli* (Kaltenbach) - 1♀, Leersum, Leersummerveld, *Vaccinium myrtillus*, 6.VI.1997, M. Jansen.
N *Physokermes hemicryphus* (Dalman) - 2♀♀, Lottum, *Picea abies*, 9.XI.1965, PPS; 16♀♀, Lottum, *Picea abies*, 5.V.1966 (coll. Zoologisch Museum, Amsterdam and coll. PPS, Wageningen), PPS; 10♀♀, Tegelen, *Picea abies*, 4.V.1966 (coll. Zoologisch Museum, Amsterdam and coll. PPS, Wageningen), PPS; 3♀♀, Venlo, *Picea abies*, 10.V.1967, PPS.
R *Physokermes piceae* (Schrank)
G,I,Pc *Pulvinaria floccifera* (Westwood)
I,Pc *Pulvinaria hydrangeae* (Steinweden)
I,Po *Pulvinaria regalis* Canard
G,Pc *Pulvinaria vitis* (Linnaeus)

## ***ASTEROLECANIIDAE***

Po *Asterodiaspis variolosa* (Ratzeburg)

## ***DIASPIDIDAE***

*Aulacaspis rosae* (Bouché)
Pc *Carulaspis juniperi* (Bouché)
*Chionaspis salicis* (Linnaeus)
*Diaspidiotus bavaricus* (Lindinger)
Po *Epidiaspis leperii* (Signoret)
Pc *Lepidosaphes ulmi* (Linnaeus)
*Leucaspis pini* (Hartig)
*Nuculaspis abietis* (Schrank)
I,R *Pseudaulacaspis pentagona* (Targioni Tozzetti)
*Quadraspidiotus gigas* (Thiem & Gerneck)
N *Quadraspidiotus marani* Zahradnik - Recorded in an Annual Report, Dutch Plant Protection Service (Anonymous, 1955). 1♀, Wageningen, *Pyrus communis*, 31.I.1955, PPS; 2♀♀, Wageningen, *Pyrus communis*, 14.IX1954, H. Burger; 8♀♀, Beesel, *Malus* sp., 19.II.1960, PPS; 2♀♀, Rijckholt, *Pyrus* sp., 25.II.1954, H. Verest, PPS; 4♀♀, Blerick, unknown plant, 24.II.1960, PPS.

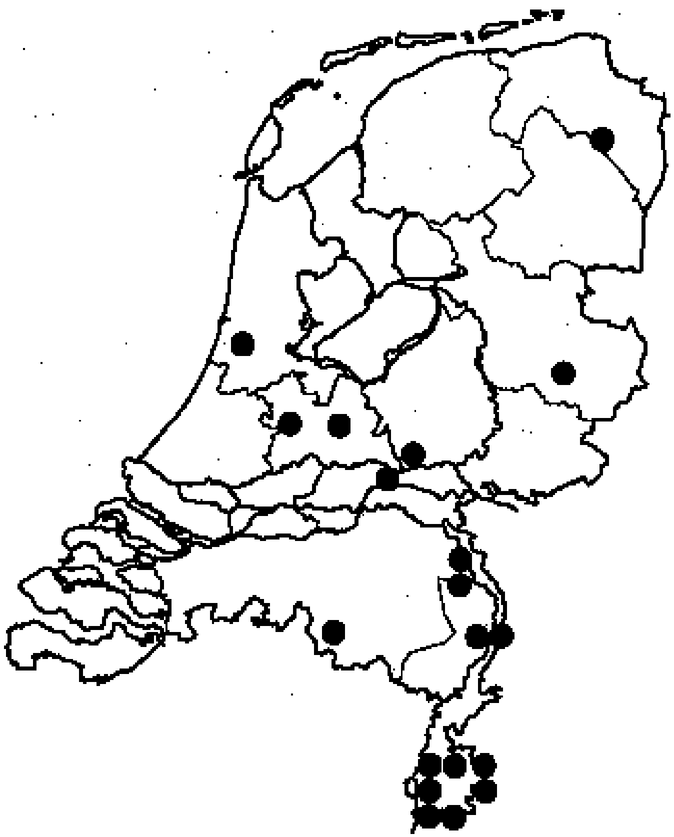

Fig. 1. Distribution map of *Quadraspidiotus perniciosus* (Comstock) in The Netherlands in the period 1950-1998.

Pc *Quadraspidiotus ostreaeformis* (Curtis)

N *Quadraspidiotus perniciosus* (Comstock) - Fig. 1. Although regularly imported into The Netherlands for more than 50 years and found in many locations, the records listed below, which do not appear to be a direct result of import, have never been published. In 1950, an eradication programme was started and a year later, at Maasbree, an experimental field was designated on an isolated site to gain insight in its host plant range, its noxiousness and its vitality in the Dutch climate. Records: 1 slide, Wageningen, unknown plant, Jan 1950, identification Reyne, PPS; 1 slide, Eijsden, *Malus* sp, 10.IX.1951, P. Vlaming; 1 slide, Rijssen, unknown plant, 18.VII.1951, H. van Vugt; 1 slide, Zeist, *Pyrus* sp., 27.IV.1951, H. van Vugt; 1 slide, Haarlem, unknown plant, 4.VIII.1952, J. Scheele; 1 slide, Eijsden, *Malus* sp., 5.VI.1953, P. Vlaming; 1 slide, Eijsden, *Malus* sp., 19.VI.1951, L. van Cruchten; 1 slide, Heijen, *Pyrus* sp., 6.IX.1952, P. Vlaming; 1 slide, Rimburg, unknown plant, 22.VI.1951, P. Vlaming; 1 slide, Eijsden, *Malus* sp., 15.X.1953, H. Verest; 1 slide, Kamerik, *Pyrus* sp., 19.V.1951, L. Eigeman; 1 slide, Beek, unknown plant, 9.V.1951, L. van Caldenborgh; 1 slide, Gronsveld, *Malus* sp., 4.XII.1953, H. Verest; 5 slides, Eijsden, *Malus* sp., 17.X.1952, P. Vlaming; 3 slides, Eijsden, *Malus* sp., 24.V.1952, P. Vlaming; 1 slide, Heerlen, *Pyrus* sp., 19.IV.1951, P. Vlaming; 1 slide, Rijckholt, *Malus* sp., 23.III.1954, H. Verest; 1 slide, Sint Geertruid, *Malus* sp., 12.XI.1953, H. Verest; 1 slide, Geleen, *Pyrus* sp., 4.IV.1951, B.Wehman; 1 slide, Amby, *Malus* sp., 12.IV.1954, H. Verest; 1 slide, Reusel, *Malus* sp., 8.III.1951, J. Snellen; 1 slide, Wageningen, unknown plant, 24.I.1951, G.H. Jansen; 2 slides, Moerslag, *Malus* sp., 18.XI.1952, J. Vreeburg; 2 slides, Valkenburg, unknown plant, 19.VI.1953, P. Vlaming; 3 slides, Epen, *Malus* sp., 2.VI.1953, P. Vlaming; 1 slide, Terwinselen, *Pyrus* sp., 29.VII.1954, H. Verest; 1 slide, Veendam, *Pyrus* sp., 22.VII.1953, Jansen; 2 slides, Blerick, unknown plant, 24.II.1960, PPS; 1 slide, Hoensbroek, unknown plant, 17.VIII.1954, H. Verest; 1 slide, Rimburg, unknown plant, 16.VI.1953, P. Vlaming; 1 slide, Blerick, unknown plant, 22.X.1959, PPS; 1 slide, Rijckholt, *Malus* sp., 7.V.1953, P. Vlaming; 1 slide, Amby, *Malus* sp., 8.IV.1954, H. Verest; 1 slide, Beneden-Leeuwen, unknown plant, 7.V.1954, J. Bremmer; 1 slide, Rimburg, unknown plant, 2.III.1953, P. Vlaming; 1 slide, Mesch, *Malus* sp., 22.V.1953, P. Vlaming; 1 slide, Blerick, unknown plant, 23.III.1960, PPS; old females and nymphs, Maasbree, experimental field, *Prunus* sp., 7.I.1994, M. Jansen & J. Schamp.

Pc *Quadraspidiotus pyri* (Lichtenstein)
*Quadraspidiotus zonatus* (Frauenfeld)

## DISCUSSION

Bearing in mind the number of species of Coccoidea recorded from the United Kingdom and from Germany, the fauna of The Netherlands is likely to be much richer than suggested by the above records and could probably be doubled. This checklist is therefore to be considered as a starting point for further investigation.

The scale insect fauna known from the open in The Netherlands has only been studied superficially in the past. During the period 1950-1955, the Dutch Plant Protection Service gave much attention to the scales living on trees and shrubs with the aim of detecting the newly introduced *Quadraspidiotus perniciosus.* As a result, *Quadraspidiotus marani* and *Epidiaspis leperii* (Signoret) were found but only during that period. However, there have been no further surveys since 1955.

The Dutch climate is oceanic and characterized by much wind in the coastal zones, relatively warm winters, generally a lack of summer warmth and substantial rainfall in all seasons. The geomorphological structure can be briefly characterized as flat landscape, interrupted in places by relicts from the ice ages, with few hills and an absence of mountains and valleys. In addition, the Dutch landscape has been greatly influenced by man, and most heaths, fens and bogs are now cultivated. Nor do the few south-facing xerotherm slopes, which are mostly woodland, contribute to a high number of thermophilous species. In this respect, the most interesting habitats are the sand-dunes alongside the coast, and the hills with calcareous grasslands in the most southern part of the country. *Atrococcus paludinus* (Green) and *Trionymus tomlini* were found in 1997 in a semi-natural marsh, in which the use of materials such as fertilizers was forbidden.

Some Dutch species which seem to be typical for the temperate zones are *Chnaurococcus subterraneus* (Newstead), *Rhodania occulta* Schmutterer, *Eriopeltis lichtensteini* Signoret and *Eulecanium ciliatum* (Douglas). Another characteristic element of the Dutch scale insect fauna is *Phenacoccus sphagni* (Green), recently found in a new location, which is only otherwise known from the United Kingdom. *Epidiaspis leperii* (Signoret), *Phyllostroma myrtilli* (Kaltenbach) and *Acanthococcus aceris* Signoret can be considered as Central-European elements. However, the scanty ecological data concerning the occurrence of many other interesting species in The Netherlands, which are known from only a few locations, make a detailed zoogeographical analysis impossible.

Regular trade and transport of vegetative material has brought about the introduction of such exotic species as *Pseudaulacaspis pentagona* (Targioni Tozzetti) and *Quadraspidiotus perniciosus.* Although the latter has been regularly imported into The Netherlands for more than 50 years and has been recorded from many locations, no records of this species in The Netherlands have ever been published. In 1950, an eradication programme was started and a year later, at Maasbree, an experimental field was designated on an isolated site to gain insight into its host plant range, its noxiousness and its vitality in the Dutch climate. The distribution of these records is shown in Fig. 1.

In addition, *Pulvinaria regalis* Canard and *Pulvinaria hydrangeae* (Steinweden) were probably introduced into other European countries where they spread rapidly and, together with the related *Pulvinaria floccifera*, they are now amongst the most common species in The Netherlands and have become established in towns and villages throughout the country and are locally common in some nature reserves (Jansen, 1996a).

The number of introduced species found during quarantine interceptions and in greenhouses is 162 (Jansen, 1995a), and thus only a very few of these species have become acclimatized and established. For instance, *Chaetococcus phragmitis* (Marchal) has been regularly introduced in large numbers from several Central European countries on *Phragmites australis* for many decades but no specimens have been found on its host to-date. In addition, Hofker *et al* (1991) presented evidence that it was unlikely that *Phenacoccus avenae* Borchsenius, which is regularly intercepted at quarantine on bulbs and corms of various Liliaceae, Iridaceae and Amaryllidaceae, could survive a Dutch winter. Another species, *Coccus hesperidum* Linnaeus, a common greenhouse species which was found on *Hedera helix* in a garden in Wageningen, did not survive either.

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NUCIFORA, S.[1]; WATSON, G.W.[2]
[1] *Istituto di Entomologia agraria, Università degli Studi di Catania, Via Valdisavoia 5, 95123 Catania, Italy*
[2] *CABI BIOSCIENCE, c/o Entomology Department, The Natural History Museum, Cromwell Road, London, SW7 5BD, UK*

# ARMOURED SCALE INSECTS (HEMIPTERA: COCCOIDEA: DIASPIDIDAE) NEW TO SICILY: RECORDS AND OBSERVATIONS.

## ABSTRACT

Armoured scale insects (Hemiptera: Coccoidea: Diaspididae) new to Sicily: records and observations.

The central location of Sicily in the Mediterranean basin makes studies of its fauna particularly interesting. Recent collections from the scrub vegetation on the South-East coast of Sicily and the slopes of Mount Etna have produced four new records of Diaspididae for Sicily: *Aonidia ?mediterranea* (Lindinger)*, Ferreroaspis hungarica* (Vinis), *Mercetaspis isis* (Hall) and *Chionaspis etrusca* Leonardi. The presence of the first three species suggests old faunistic links with other regions, mainly eastern Mediterranean. Our findings are presented here in the hope of stimulating more such research.

Key words: *Callitris*, *Cupressus*, *Juniperus*, *Thuja*, *Tamarix*, *Acer*, *Cerasus*, *Carulaspis silvestrii*, *C. minima*, *C. juniperi*, ecology, host reaction.

## INTRODUCTION

Armoured scales were collected from natural vegetation on the south-eastern coast of Sicily and the eastern slopes of Mount Etna.

## MATERIALS AND METHODS

Adult female scales were prepared for slide-mounting using the method given by Williams & Watson (1998) and were mounted in either Faures medium or Canada balsam. These were identified using Balachowsky (1951, 1954), Vinis (1981) and Danzig (1993), and by reference to museum specimens.

## RESULTS

***Aonidia ?mediterranea*** (Lindinger): previous records have been from Armenia, Azerbaijan, Greece, Spain, Algeria and Italy (Sardinia) on members of the Cupressaceae belonging to the genera *Callitris, Cupressus, Juniperus* and *Thuja*. The species is here recorded from Malta (on *Cu. sempervirens*, Malta Mosta, 13.III.1994, coll. D. Mifsud) and, tentatively, from Sicily for the first time.

The scale cover or test of adult female *A. ?mediterranea* collected from Sicily is very similar to those described by Balachowsky (1951) and Koronéos (1934). Balachowsky (1951) described the exuviae as pale yellow ('jaune paille'); Koronéos (1934) described them as bright orange. Our specimens have the first-stage exuviae yellowish and the second-stage exuviae bright orange; initially, the first-instar exuviae is covered with a thin, white waxy covering which is often lost later, so that the scale darkens with age.

The shape and number of the pygidial lobes in our material resemble those described by Balachowsky (1951) and Koronéos (1934); the third lobe mentioned by Lindinger (1912) is absent, but Balachowsky (1951) stated that 'chez quelques rares individus un léger tubercule à la place de L3 qui fait toujours défaut'; and Koronéos (1934): 'Malgré le désaccord sur les appendices du pygidium j'aime à croire qu'il s'agit de l'espèce décrite par Lindinger (I) N° 584 et qu'il a eu lieu erreur dans la description qu'il a donnée'.

The Sicilian specimens of *A. ?mediterranea* posses an unusually short, wide pygidium with two macroducts between each median and second lobe, whereas Balachowsky's (1951) description and illustration show only one duct in this position. The material consists of very few specimens and so it is difficult to be sure whether these differences are due to environmentally induced variation or whether the specimens represent an undescribed species.

In Sicily, *A. ?mediterranea* was collected from the district of Ragusa, near Donnalucata, on *Juniperus oxycedrus* ssp. *macrocarpa*, 7.X.1997, coll. S. Nucifora. The host-plants were growing in a coastal nature reserve known as 'macchia foresta del fiume Irminio' (forest scrub of the Irminio river), a sand dune habitat which is rare in Sicily. The vegetation consists of *J. oxycedrus* and other species of Mediterranean scrub plants. *Juniperus phoenicea* is the only other member of the Cupressaceae present in this habitat but *A. ?mediterranea* has not been found on it. Female scales were found on the needles (leaves) of *J. oxycedrus* ssp. *macrocarpa*, mainly on the lower surface; examination of the bark and fruit failed to locate any scales, and no males were recorded. *A. ?mediterranea* is rare in Sicily; only a few plants were infested, mostly on small shoots springing directly from the trunk, where they were sheltered from direct sunlight and from the wind blowing from the sea.

*Carulaspis silvestrii* Lupo and *Ca. minima* (Targioni Tozzetti) were frequently found with *A. ?mediterranea. A. ?mediterranea* and *Ca. silvestrii* were rare but *Ca. minima* is very abundant on *J. oxycedrus*, particularly on the fruit. *A. ?mediterranea* was not found on *J. hemisphaerica, J. phoenicea,* *Cupressus* sp. or *Thuja* sp. near Donnalucata or in other localities, although *Ca. minima* has been found frequently on these hosts. *Carulaspis juniperi* (Bouché) also occurs in Sicily, but only on *J. hemisphaerica* at or above 1300m a.s.l. on Mount Etna and never in association with *A. ?mediterranea.*

***Chionaspis etrusca*** Leonardi: recorded previously from Algeria, Morocco, Tunisia, Italy, Sardinia, Israel, Republic of Georgia, India and Pakistan on *Tamarix* spp. In Sicily, it was collected from the district of Ragusa, 4km from Donnalucata, on the bank of the Irminio river, on *Tamarix* sp., 7.X.1997, coll. S. Nucifora. *C. etrusca* was particularly abundant on the rare *Tamarix gallica* growing along the bank of the Irminio river, near its mouth; it also occurred in small numbers on *Tamarix africana*, a commoner species with lusher vegetation that favoured sites between the sand dunes which provided shelter from the wind. This scale was also collected on *Tamarix* sp. from district of Messina, near Milazzo, 18.X.1998, coll. S. Nucifora; and from the district of Catania, Torre Archirafi beach, 2.II.1999 and 19.II.1999, coll. S. Nucifora.

*Chionaspis etrusca* showed a preference for branches 4-6 cm in diameter. Both sexes occurred at these locations at quite high densities on the bark (about 500 specimens on 30cm of a twig 4cm in diameter), but tended to be in single sex aggregations within the colony.

The scale cover of adult female *C. etrusca* is white and elongate, broader distally, with yellowish or pale brown exuviae at the narrow end. The characters of the slide-mounted adult female match those shown in Balachowsky's (1954) illustration. The scale cover of the male is similar to that of the female but smaller, white and non-carinate, with pale yellow terminal exuviae.

***Mercetaspis isis*** (Hall): recorded previously from Turkmenistan, Tadjikistan, Israel, Egypt, Iraq, Iran and Pakistan on *Tamarix* sp. It was collected in Sicily from the district of Ragusa, Donnalucata coast, on the bark of the trunk, twigs and branches of *Tamarix* sp., 16.I.1997, coll. S. Nucifora. A heavy infestation was found on a single, very old, isolated, roadside tree, with a trunk circumference of about 160cm and a height of more than 4m. *Tamarix* sp. occur on various other parts of the Sicilian coast but so far no other infestations of *M. isis* has been found.

In life, the scale cover of female *M. isis* is mussel-shaped and off-white, with yellow exuviae located at the narrow end. The insects consistently possessed massive median lobes, which were frequently retracted into the pygidium. Such massive development of the median lobes is unusual in the genus *Mercetaspis.*

***Ferreroaspis hungarica*** (Vinis): recorded previously from Turkmenistan, Tadjikistan and Hungary on *Acer campestris, A. pubescens* and *Cerasus* sp. In Sicily, it was collected from the district of Catania, near Milo, 550m a.s.l., on twigs and small branches of *Acer obtusatum*, 3.I.1997, coll. S. Nucifora. It occurred on maple *(A. obtusatum)* on the east slope of Mount Etna, near the towns of S. Alfio and Zafferana, between 550 and 850m. a.s.l. A small wood of *A. obtusatum* and *Ostrya carpinifolia* near Milo was infested. The scale also occured on maples growing as isolated plants or in occasional small groups on uncultivated marginal land in the area. Maples are less common on the western slopes of Mount Etna, but this area has not yet been examined for the presence of *F. hungarica.*

*Ferreroaspis hungarica* is difficult to find because of its cryptic colour and small size. The female scale is mussel-shaped and brown in life. The first-stage exuviae is glassy and transparent; the second-stage exuviae is brown, glossy, elongated and broadest at the posterior end. Frequently the first exuviae is lost, making the scale more difficult to detect. The insects occur on twigs, generally at levels between 0.1 and 5 individuals per 30cm of young twig. Males have not been observed in Sicily, but were recorded by Vinis (1981) and Kosztarab & Kozár (1988).

A reaction by the plant was observed at some feeding sites of *F. hungarica.* Sometimes a dark, amorphous mass was present at the point of stylet insertion. This mass was easily dislodged because contact with the twig occurred at only one point; no imprint was left when it was removed. The mass was compact, not compressible but easily crushed; inside was a dark, amorphous material. It seems likely that this material consists of solidified plant exudate (rather than a proliferation of cells), and was probably an accumulation of sugars where sap seepage had dried. Normally an individual of *F. hungarica* was on top of each mass, but sometimes it was partially included within it.

## DISCUSSION

*A. ?mediterranea, F. hungarica* and *M. isis* are here recorded from the Central Mediterranean region for the first time. All have previously known distributions mainly towards or beyond the eastern end of the Mediterranean sea, suggesting a past faunal link between these regions. *Ch. etrusca* is a new record for Sicily, but is well established in the Mediterranean region; it is not clear whether its origin lies further east, or whether the eastern records reflect introductions from the Mediterranean.

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ÜLGENTÜRK, S.; TOROS, S.
*University of Ankara, Faculty of Agriculture, Department of Plant Protection, Diskapi, 06110, Ankara, Turkey*

# FAUNISTIC STUDIES ON THE COCCIDAE ON ORNAMENTAL PLANTS IN ANKARA, TURKEY.

## ABSTRACT

Faunistic studies on the Coccidae on ornamental plants in Ankara, Turkey.

The coccid species present in parks, gardens and greenhouses in Ankara, Turkey, and their host plants were studied in 1992, '94, '95 and '96. Thirteen species of Coccidae were detected on ornamental plants: two species of *Eulecanium*, four species of *Parthenolecanium* and one species each from the genera *Coccus*, *Filippia*, *Palaeolecanium*, *Physokermes*, *Pulvinaria*, *Saissetia* and *Sphaerolecanium.* The most common species was *Parthenolecanium corni*, found on 36% of the infested ornamental plants. *Physokermes picea* was found on four species of *Picea*, of which it infested 16.3% of the plants surveyed. *Filippia follicularis* was detected on 2% of *Fraxinus* spp. while *Physokermes piceae*, *Filippia follicularis*, *Parthenolecanium persicae* and *P. pomeranicum* were recovered on 16, 2, 1 and 1% of the infested plants respectively.

Key words: Coccoidea, Coccidae, urban, ornamental plantings, hosts, geographic distribution.

## INTRODUCTION

Soft scale insects (Hemiptera: Coccoidea: Coccidae) are the third most abundant family in the Coccoidea in terms of species, and many attack agricultural, ornamental and greenhouse plantings throughout the world. The economic importance of the group is perhaps considerably underestimated because isolated infestations on ornamental plants are usually overlooked and the death of a plant is often attributed to some other cause. In addition to the loss of plant sap caused by feeding, these scales eliminate a large amount of honeydew which serves as a medium for the growth of sooty mould fungi. These fungi not only inhibit photosynthesis but, due to their dirty or sooty appearance, cause the ornamental plants to lose their aesthetic value (Williams & Kosztarab, 1972; Hamon & Williams, 1984).

In Turkey, the most comprehensive study of Coccidae so far undertaken was by Bodenheimer (1953). More recent collections are those of: Çanakçioglu (1977), who collected 40 species of Coccoidea from forest trees and shrubs, 10 of them Coccidae; Öncüer (1977), who found seven species when studying the coccids on fruit trees in Izmir province (Aegean Region); Selmi (1978), who found 15 species of Coccoidea causing damage to conifers in Marmara Region, four of which were coccids; Özkazanç & Yücel (1984), who identified 11 coccoid species on trees in gardens, parks and plantations in Central Anatolia, four of them Coccidae, and lastly Yasar (1990), who reported 8 species of Coccidae on ornamental plants in Izmir province.

In Turkey, there is a trend to plant more ornamental plants, especially in large cities such as Ankara, where more than 100,000 ornamental trees have been planted in the last few years. There have been few studies on the effect of coccids on ornamental plantings and therefore this study was undertaken.

## MATERIALS AND METHODS

Coccids were sampled from a range of parks, gardens and greenhouses in Ankara between 1992 and 1996. Samples were collected from 1-2 year old branches from all infested plants once a week between 1st April to the 15th June and twice a month between 15th June and 30th October from the four sides of each plant. Specimens were slide mounted using the method of Kosztarab & Kozár (1988) and some of the dry and mounted material has been deposited at the Department of Plant Protection, Ankara University, Turkey. The percentage infestation was calculated as a proportion of the total number of infested plants.

## RESULTS AND DISCUSSION

A total of 8 genera and 13 species belonging to the family Coccidae were found. The most common species was *Parthenolecanium corni* (Bouché), which was collected on 36% of the infested ornamental plants, while the percentage of plants infested with *Eulecanium tiliae* (L.), *Coccus hesperidum* L. and *Eulecanium ciliatum* (Douglas) was 14%, 12% and 10% respectively. *Physokermes picea* (Schrank) was found on 16.3% of *Picea* spp. *Filippia follicularis* (Targ.) was detected on 2% of *Fraxinus* spp., while *Parthenolecanium pomeranicum* (Kawecki) and *P. persicae* (Fabricius) were each collected only once. *F. follicularis* and *P. pomeranicum* were new records for the fauna of Ankara and Central Anatolia. However, several species which had been recorded in this region by earlier authors (Bodenheimer, 1953; Çobanoglu, 1993) were not found in this survey, namely: *Eulecanium transvittatum* (Green) and *Parthenolecanium tamaricis* (Bodenheimer) but these species probably have a narrow host range on indigenous hosts.

About a third of the species found are considered pests of fruit crops and are targeted in pest control programs in Turkey, e.g., *C. hesperidum*, *E.*

*ciliatum*, *P. corni*, *Palaeolecanium bituberculatum* (Signoret) and *Sphaerolecanium prunastri* (Fonscolombe).

LIST OF SOFT SCALE SPECIES, WITH HOST PLANTS

***Coccus hesperidum*** Linnaeus: only found on house plants; only ♀ found. Hosts: *Acer pseudoplatanus*, *Aloe* sp., *Citrus* sp., *Dianthus barbaratus*, *Dieffenbachia* sp., *Euphorbia pulcherima*, *Ficus benjamina*, *Hedera helix*, *Howardia* sp., *Nerium oleander*, *Pilea cadieri*, *Rosa* sp., *Saintpaulia* sp. and *Schefflera arbicola* hybr. (Dates: II, III, IV, V, VI, VII, IX: 1992, '94 -'96).

***Eulecanium ciliatum*** (Douglas): common in parks and gardens in Ankara; a harmful species on some species of Aceraceae and Rosaceae, on which dense populations can cause the branch tips to dry up and even the death of the whole plant. Previously only known from Ankara; both ♂ and ♀ found. Hosts: *Acer campestre*, *A. pseudoplatanus*, *A. pseudoplatanus* var. *atropurpurea*, *Crataegus* sp., *C. monogyna*, *C. oxyacantha rosea*, *Cydonia vulgaris*, *Prunus domestica*, *P. spinosa*, *P. persica*, *Ribes aureum* and *Rosa plena* (Dates: IV, V: 1994, '96).

***Eulecanium tiliae*** (Linnaeus): previous records: Central Anatolia, Mediterranean, Marmara and Black Sea regions; both ♂ & ♀ found. Hosts: *Acer platanoides, A. pseudoplatanus*, *Aesculus hippocastaneum*, *Betula* sp., *Cercis siliquastrum*, *Cornus alba* var. *gibirica*, *Crataegus cruscalia*, *C. oxyacantha*, *C. monogyna*, *Cydonia vulgaris, Malus communis*, *Platanus orientalis*, *Populus* sp., *P. nigra*, *Prunus amygdalus*, *Rosa* sp., *Tilia* sp. and *Ulmus campestre* (Dates: IV, V: 1992, 1994-'96).

***Filippia follicularis*** (Targioni Tozzetti): has particularly large populations on *Fraxinus* spp. in Ankara. Previous records: Mediterranean, Aegean and Marmara regions. Both ♂ & ♀ found. Hosts: *Fraxinus* sp., *F. americana* and *F. excelsa* (Dates: IV, V: 1992, '95).

***Palaeolecanium bituberculatum*** (Signoret): here only collected on Rosaceae. Previous records: Central, South-East and East Anatolia regions. Both ♂ and ♀ found. Hosts: *Malus* sp., *Malus floribunda*, *Crataegus cruscalia*, *C. monogyna*, *C. oxyacantha* and *Crataegus* sp. (Dates: IV, V, VI, VIII, IX: 1992, '94, '95).

***Parthenolecanium corni*** (Bouché): commonest species in Ankara; both ♂ and ♀ encountered in all samples. Previous records: all regions. Hosts: *Acer negundo*, *A. platanoides*, *Aesculus hippocastaneum*, *A. lutea*, *Ailanthus altissima*, *Betula verrucosa*, *Cercis siliquastrum*, *Colutea arborescens*, *Cornus alba* var. *gibirica*, *Corylus maxima* var. *atropurpurea*, *Crataegus oxyacantha rosea*, *Fraxinus* sp., *F. americana*, *F. excelsa*, *Ginkgo biloba*, *Gleditsia* *triacanthos*, *Hibiscus syriacus*, *Juglans regia*, *Koelreuteria paniculata*, *Laburnum vulgare*, *Liriodendron tulipifera*, *Lonicera tartarica*, *Ligustrum* sp., *Malus* sp., *Morus alba*, *M. nigra pendula*, *Philadelphus coronarius*, *Prunus armeniaca*, *P. domestica*, *P. cerasifera* var. *pissardii nigra*, *P. serrulata* var. *shidare sakkura*, *Pyracantha coccinea*, *Quercus* sp., *Ribes* sp., *Robinia pseudoacacia*, *Sambucus nigra*, *Sophora japonica*, *Tamarix tetrandra*, *Tilia cordata*, *Ulmus campestris* and *Viburnum lantana* (Dates: IV, V, VII: 1992, ‘94 -’96).

***Parthenolecanium persicae*** (Fabricius): previous records: Black Sea and Aegean regions. Host: *Cercis siliquastrum* (Date: III: 1992).

***Parthenolecanium pomeranicum*** (Kawecki): previous records: Marmara region. Host: *Taxus baccata* (Date: IV: 1994).

***Parthenolecanium rufulum*** (Cockerell): previous records: Central Anatolia, Black Sea and Marmara regions. Hosts: *Quercus robur*, *Quercus* sp. (Dates: IV, V: 1992, ‘94 -’96).

***Physokermes piceae*** (Schrank): common and harmful on *Picea* spp. in parks and gardens in Ankara; both ♂ and ♀ were found. Previous records from Turkey: Central Anatolia and Marmara regions. Hosts: *Abies pinsopa*, *Picea excelsa*, *P. pungens*, *P. pungens* var. *glauca*, *P. excelsa* var. *maxwelli* and *P. orientalis* (Dates: VI, V, VI: 1992, ‘94 -’96).

***Pulvinaria vitis*** (Linnaeus): previous records: Aegean, Central, West Anatolia, Marmara and Mediterranean regions. Hosts: *Acer* sp., *Betula* sp., *Crataegus* sp., *Populus alba*, *P. nigra*, *Populus* sp., *Pyrus communis* (Dates: III, V, VI, VII: 1992, ‘94 -’96).

***Saissetia coffeae*** (Walker): only collected from house plants; only ♀ noted; previous records: Central Anatolia, Aegean and Marmara regions. Hosts: *Hippeastrum* sp., *Nephrolepis exaltata* and *Sedum* sp. (Dates: II, III, IX: 1995, ‘96).

***Sphaerolecanium prunastri*** (Fonscolombe): a very common and harmful species on stone fruits; both ♂ and ♀ found. Previous records: Central, South-East and West Anatolia, and the Marmara regions. Hosts: *Prunus armeniaca*, *P. cerasifera*, *P. cerasifera* var. *Pissardii Nigra*, *P. domestica, P. serrulata* var. *shidare sakkura*, *Prunus* sp. (Dates: IV, V, VI: 1992, ‘94, ‘95).

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ÜLGENTÜRK, S.; TOROS, S.
*University of Ankara, Faculty of Agriculture, Department of Plant Protection, Diskapi, 06110, Ankara, Turkey*

# NATURAL ENEMIES OF THE OAK SCALE INSECT, *EULECANIUM CILIATUM* (DOUGLAS) (HEMIPTERA: COCCIDAE) IN TURKEY.

## ABSTRACT

NATURAL ENEMIES OF THE OAK SCALE INSECT, *EULECANIUM CILIATUM* (DOUGLAS) (HEMIPTERA: COCCIDAE) IN TURKEY.

*Eulecanium ciliatum* Douglas is an important pest of ornamental plants in the Palaearctic region and has a wide range of natural enemies. In Ankara, Turkey, eight hymenopterous parasitoids and one hyperparasitoid species have been bred from this scale, and nine predators were collected in association with it, seven Coleoptera and two Hemiptera.

Key words: urban, ornamental plantings, parasitoid hosts, predator hosts, Aphelinidae, Encyrtidae, Eulophidae, Pteromalidae, Anthribidae, Coccinellidae, Cybocephalidae, Miridae.

## INTRODUCTION

*Eulecanium ciliatum* (Douglas) is a harmful soft scale, common on ornamental and forest plants in the Palaearctic Region. It has one generation a year and overwinters as 2nd-instar nymphs (Kosztarab & Kozár, 1988). Previous records of parasitoids in this species are the encyrtids *Blastothrix britannica* Girault, *B. sericea* (Dalman), *Cheiloneurus formosus* (Boheman) and *Microterys tricolocornis* (De Stefani), while the beetle *Anthribus nebulosus* Förster has been recorded as a predator (Schmutterer, 1952; Sugonyaev, 1976; Trjapitzin, 1973; Kosztarab & Kozár, 1988).

This paper discusses the natural enemies of *E. ciliatum* in the parks of Ankara, Turkey, where it is a common pest of amenity trees.

## MATERIALS AND METHODS

This survey was carried out on park and ornamental trees in Ankara between 1994 and 1996. Ten centimetre lengths of 1-2 year old branches of each infested host-plant of *E. ciliatum* were collected once a week between 1st April and 15th June and twice a month between 15th June and 30th November from four sides of each plant; the parasitoids were then bred out in the laboratory. The predators were collected by shaking the infested branches over a muslin tray.

## RESULTS AND DISCUSSION

The results of this survey are given in Table 1. Eight parasitoid and 1 hyperparasitoid species were collected from *E. ciliatum*, belonging to 4 families of Hymenoptera. The most common parasitoid in Ankara was *Encyrtus infidus* (Rossi), which made up 66% of all parasitoids collected. The remaining species were as follows: *Pachyneuron muscarum* (L.) (9%); *Metaphycus dispar* Mercet (5%); *M. bellae* Triapitzin (4%); *Aprostocetus trjapitzini* (Kostjukov); *Coccophagus aterrimus* Vikberg, *Encyrtus* sp. nr. *albitarsus* (Zetterstedt), *Microterys hortulans* Erdös and *Psyllaephagus procerus* (Mercet) with 3%, and *Eunotus areolatus* (Tatzeburg) with 1%.

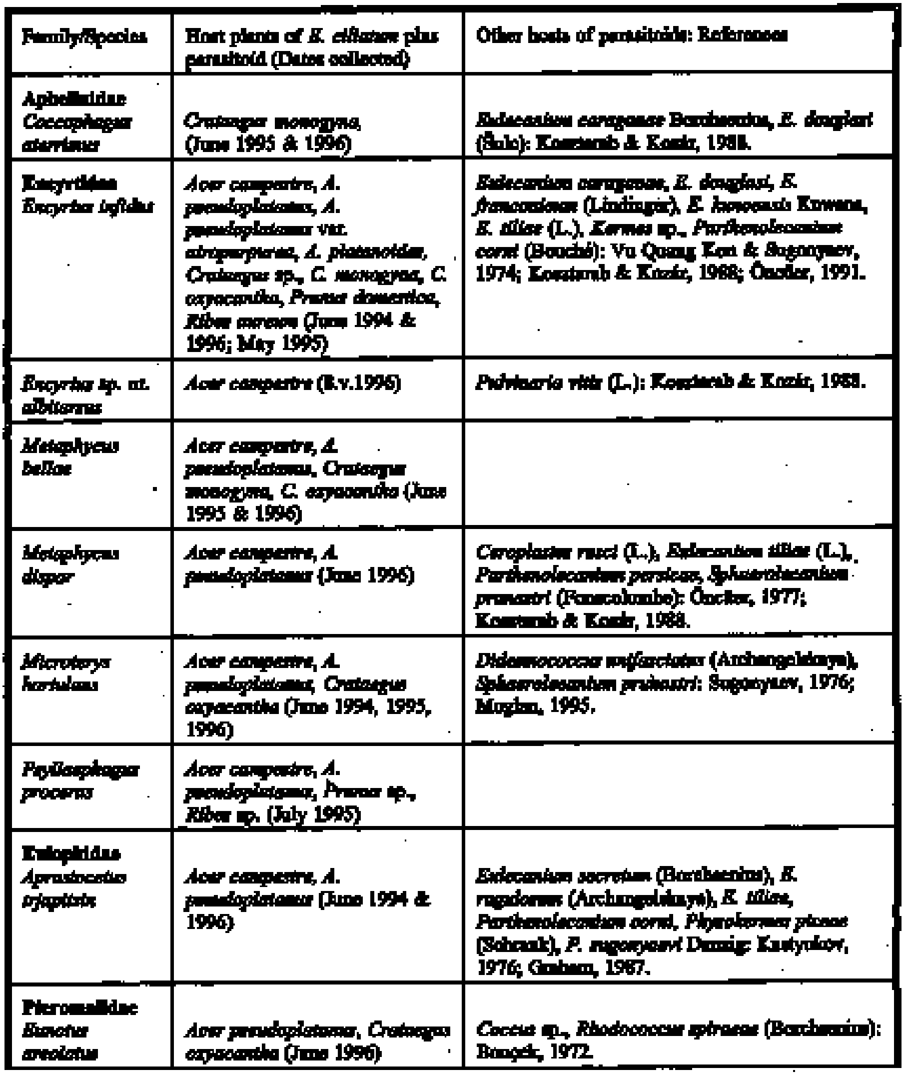
The predators (Table 2) belonged to three families of Coleoptera and one hemipteran. The anthribid *Anthribus fasciatus* (Förster) was by far the most common coleopteran, comprising 73% of all predators. In addition, there were *Exochomus quadripustulatus* L. (17%); *Atractotomus mali* (Meyer-Dür) (3%); *Deraeocoris ruber* (L.) and *Adalia fasciatopunctata revelieri* (Mulsant) (2%), and *Synharmonia conglabata* (L.), *Chilocorus bipustulatus* (L.) and *Adalia bipunctata* (L.) (1%). *C. bipustulatus* has also been commonly observed in Izmir, Turkey (Öncüer, 1977).

*Anthribus fasciatus* is reported to have one generation a year in Turkey (Öncüer, 1991), overwintering as an adult. It is an effective predator of *E. tiliae* (Ülgentürk & Toros, 1996).

In addition to the above parasitoids, the encyrtid *Homalotylus flaminius* Dalman was collected from samples of *E. ciliatum* on *Acer campestre* in June, 1996, on the campus of the University of Ankara. This is a known parasite of predators, such as *C. bipustulatus,* in Turkey (Öncüer, 1977) and it has been suggested (Nikolskaya, 1952) that it is also an important parasitoid of *Exochomus quadripustulatus* and *Hyperaspis guttalata* Fairm.

This study has shown that there are a number of common and effective parasitoids of *E. ciliatum* which might be used in the control of this coccid. However, more detailed studies on the rearing and release of these beneficial insects are required.

Table 1. Hymenopterous parasitoids and host plants of *Eulecanium ciliatum* (Douglas) in Turkey.



| Family/Species | Host plants of *E. ciliatum* plus parasitoid (Dates collected) | Other hosts of parasitoids: References |
|---|---|---|
| **Aphelinidae**<br>*Coccophagus aterrimus* | *Crataegus monogyna*, (June 1995 & 1996) | *Eulecanium caraganae* Borchsenius, *E. douglasi* (Šulc): Kosztarab & Kozár, 1988. |
| **Encyrtidae**<br>*Encyrtus infidus* | *Acer campestre*, *A. pseudoplatanus*, *A. pseudoplatanus* var. *atropurpureum*, *A. platanoides*, *Crataegus* sp., *C. monogyna*, *C. oxyacantha*, *Prunus domestica*, *Ribes aureum* (June 1994 & 1996; May 1995) | *Eulecanium caraganae*, *E. douglasi*, *E. franconicum* (Lindinger), *E. kunoensis* Kuwana, *E. tiliae* (L.), *Kermes* sp., *Parthenolecanium corni* (Bouché): Vu Quang Con & Sugonyaev, 1974; Kosztarab & Kozár, 1988; Öncüer, 1991. |
| *Encyrtus* sp. nr. *albitarsus* | *Acer campestre* (8.v.1996) | *Pulvinaria vitis* (L.): Kosztarab & Kozár, 1988. |
| *Metaphycus bellus* | *Acer campestre*, *A. pseudoplatanus*, *Crataegus monogyna*, *C. oxyacantha* (June 1995 & 1996) | |
| *Metaphycus dispar* | *Acer campestre*, *A. pseudoplatanus* (June 1996) | *Ceroplastes rusci* (L.), *Eulecanium tiliae* (L.), *Parthenolecanium persicae*, *Sphaerolecanium prunastri* (Fonscolombe): Öncüer, 1977; Kosztarab & Kozár, 1988. |
| *Microterys hortulanus* | *Acer campestre*, *A. pseudoplatanus*, *Crataegus oxyacantha* (June 1994, 1995, 1996) | *Didesmococcus unifasciatus* (Archangelskaya), *Sphaerolecanium prunastri*: Sugonyaev, 1976; Mugian, 1995. |
| *Psyllaephagus procerus* | *Acer campestre*, *A. pseudoplatanus*, *Prunus* sp., *Ribes* sp. (July 1995) | |
| **Eulophidae**<br>*Aprostocetus trjapitzini* | *Acer campestre*, *A. pseudoplatanus* (June 1994 & 1996) | *Eulecanium secretum* (Borchsenius), *E. rugulosum* (Archangelskaya), *E. tiliae*, *Parthenolecanium corni*, *Physokermes piceae* (Schrank), *P. sugonjaevi* Danzig: Kostyukov, 1976; Graham, 1987. |
| **Pteromalidae**<br>*Eunotus areolatus* | *Acer pseudoplatanus*, *Crataegus oxyacantha* (June 1996) | *Coccus* sp., *Rhodococcus spiraeae* (Borchsenius): Bouček, 1972. |

Table 2. Predators and plants of *Eulecanium ciliatum* (Douglas) in Turkey.

| Order/Family/Species | Host plant of *E. ciliatum* plus predator (dates collected) | Other hosts of predators: references |
|---|---|---|
| COLEOPTERA<br>Anthribidae<br>*Anthribus fasciatus* | *Acer campestre*, *A. pseudoplatanus*, *A. pseudoplatanus* var. *purpurea*, *Crataegus* sp., *C. monogyna*, *C. oxyacantha*, *Prunus amygdalis*, *P. domestica*, *P. persicae* var. *rosa plena*, *P. spinosa*, *Ribes aureum* (May 1994 & 1995; June 1994, 1995 & 1996) | *Eulecanium tiliae* (L.), *Parthenolecanium corni* (Bouché), *Pulvinaria vitis* (L.), *Rhodococcus perornatus* (Cockerell & Parrott): Canard, 1980; Kosztarab & Kozár, 1988; Öncüer, 1991; Ülgentürk & Toros, 1996) |
| Coccinellidae<br>*Adalia bipunctata* | *A. pseudoplatanus* (May 1995) | *Parthenolecanium corni*, *Saissetia oleae* (Olivier), *Sphaerolecanium prunastri* (Fonscolombe): Güdan, 1974; Soydanbay, 1976; Kosztarab & Kozár, 1988. |
| *Adalia fasciatopunctata revelierei* | *Crataegus oxyacantha* (June 1995; July 1996) | *Lepidosaphes ulmi* (L.), *Palaeolecanium bituberculatum* (Signoret): Erol & Yaşar, 1996. |
| *Chilocorus bipustulatus* | *A. pseudoplatanus* (June 1996) | *Ceroplastes rusci* (L.); *Coccus hesperidum* (L.), *C. pseudomagnoliarum* (Kuwana), *Filippia follicularis* (Targioni Tozzetti), *Saissetia oleae*: Öncüer, 1977. |
| *Exochomus quadripustulatus* | *Acer pseudoplatanus*, *Crataegus monogyna*, *C. oxyacantha*, *Prunus domestica* (April 1995; June 1995 & 1996; July 1996) | *Chloropulvinaria floccifera* (Westwood), *Coccus hesperidum*, *C. pseudomagnoliarum*, *Palaeolecanium bituberculatum*, *Physokermes piceae* (Schrank), *Saissetia oleae*, *Sphaerolecanium prunastri*: Öncüer, 1977; Selmi, 1978; Erol & Yaşar, 1996. |
| *Synharmonia conglobata* | *Acer pseudoplatanus* (June 95) | *Coccus pseudomagnoliarum*, *Ceroplastes rusci*, *Filippia follicularis*, *Palaeolecanium bituberculatum*, *Saissetia oleae*, *Sphaerolecanium prunastri*: Soydanbay, 1976; Öncüer, 1977; Erol & Yaşar, 1996. |
| Cybocephalidae<br>*Cybocephalus fodori minor* | *Crataegus oxyacantha* (June 1996) | *Planococcus citri* (Risso), *Sphaerolecanium prunastri*: Kansu & Uygun, 1980. |
| HETEROPTERA<br>Miridae<br>*Atractotomus mali* | *Crataegus monogyna*, *C. oxyacantha* (May 1995 & 1996) | *Hyalopterus pruni* (Geoffroy): Remaudière & Leclant, 1971. |
| *Deraeocoris ruber* | *Crataegus monogyna*, *C. oxyacantha* (May 1995 & 1996) | *Aphis* sp., *Pulvinaria vitis*: Düzgüneş et al., 1982; Malumphy, 1991. |

| | | |
|---|---|---|
| *Pachyneuron muscarum* (hyperparasitoid) | *Acer campestre*, *A. pseudoplatanus*, *Crataegus monogyna*, *C. oxyacantha* (April 1992; June 1994 & 1996; May 1996) | *Acanthococcus aceris* Signoret, *Aphis fabae* Scop., *Ceroplastes floridensis* Comstock, *C. rusci*, *Coccus hesperidum* L., *C. pseudomagnoliarum* (Kuwana), *Didesmococcus* sp., *Eriopeltis festucae* (Fonscolombe), *Filippia follicularis* (Targioni Tozzetti), *Parthenolecanium corni*, *Planococcus citri* (Risso), *Pulvinaria vitis*, *Saissetia oleae* (Olivier), *Sphaerolecanium prunastri*: Nikolskaya, 1952; Peck *et al.*, 1964; Rosen, 1967; Gürkan, 1974; Önder, 1977; Moglan, 1995 |

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WILLIAMS, M.L.
*Department of Entomology, 301 Funchess Hall, Auburn University,*
*Alabama, 36849-5413*

# SCALE INSECT DIVERSITY IN CENTRAL AMERICA, WITH EMPHASIS ON THE SOFT SCALES (HEMIPTERA: COCCIDAE).

## ABSTRACT

SCALE INSECT DIVERSITY IN CENTRAL AMERICA, WITH EMPHASIS ON THE SOFT SCALES (HEMIPTERA: COCCIDAE).

Central America, which includes Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama, has provided a continuous land bridge for the mixing of the floras and faunas of North and South America for millions of years. Due to their complex geological and climatic histories, these countries have experienced repeated invasions and establishment of flora and fauna from both North and South America and have served as centres of speciation and biotic diversification. Today, this area boasts one of the highest diversities of insect species and yet little is known about the scale insects of this region. This paper represents a summary of the current understanding of soft scale insect diversity and distribution for these seven countries of Central America, from which only 20 genera and 56 species of Coccidae are recorded.

Key words: biodiversity, Neotropical region.

The soft scale insect family Coccidae contains 1088 species in 144 genera (Ben-Dov, 1993), making it the third largest family of the Coccoidea in terms of species. Kozár and Ben-Dov (1997) list 51 genera and 298 species of Coccidae from the Neotropical Region and state that the scale insect fauna of the Neotropics tends to be specialized and rich, with 20 endemic genera and 247 endemic species. They also indicate a pressing need for further collecting throughout the entire Neotropical Region, as almost all records are restricted to a relatively small area of Brazil.

In terms of land area, Central America, which includes Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama, makes up only a small part of the Neotropical Region, being only about the size of the state of Texas in the USA. However, for millions of years Central America has served as a continuous land bridge for the interchange of flora and fauna between North and South America, and today boasts one of the highest diversities of insect species in the world (Quintero & Aiello, 1992). In spite of this region being a center for speciation and biotic diversification, little is known about the scale insects of any of the countries which make up the Central American region of the Neotropics.

Information on the soft scale insects of Central America is scattered throughout the literature and generally includes information and/or descriptions of only a few species. Harold Morrison's paper on "Some Neotropical Scale Insects Associated With Ants" (Morrison, 1929) provided coverage of 7 genera and 17 species (including 1 new genus and 8 new species), primarily from Panama. A number of records were also presented in "A Systematic Catalogue of the Soft Scale Insects of the World" by Ben-Dov (1992), but there has not been a comprehensive study of the scale insect fauna for any country within Central America.

Table 1. Coccidae of Central America

*Akermes sp. near punctata* (Cockerell)
*Akermes cordiae* Morrison

*Ceroplastes ceriferus* (Fabricius)
*Ceroplastes cirripediformis* Comstock
*Ceroplastes cistudiformis* Cockerell
*Ceroplastes dugesii* Lichtenstein
*Ceroplastes floridensis* Comstock
*Ceroplastes giganteus* Dozier

*Coccus acutissimus* (Green)
*Coccus capparidis* (Green)
*Coccus hesperidum* Linnaeus
*Coccus longulus* (Douglas)
*Coccus moestus* De Lotto
*Coccus pseudohesperidum* (Cockerell)
*Coccus viridis* (Green)

*Cryptostigma biorbiculatus* Morrison
*Cryptostigma inquilina* (Newstead)
*Criptostigma reticulolaminae* Morrison
*Criptostigma* sp.

*Cyclolecanium hyperbaterum* Morrison

*Eucalymnatus delicatus* Hempel
*Eucalymnatus hempeli* Costa Lima
*Eucalymnatus tessellatus* Signoret
*Eucalymnatus* sp.

*Inglisia vitrea* Cockerell
*Inglisia* sp.

*Kiliffia acuminata* (Signoret)

*Mesolecanium inquelinum* Morrison
*Mesolecanium perditulum* Cockerell & Robbins
*Mesolecanium* sp.

*Milviscutulus mangiferae* (Green)

*Neolecanium craspeditae* Morrison
*Neolecanium derameliae* Morrison
*Neolecanium sallei* (Signoret)
*Neolecanium* sp.

*Parasaissetia nigra* (Nietner)

*Philephedra broadwayi* (Cockerell)
*Philephedra lutea* (Cockerell)
*Philephedra tuberculosa* Nakahara & Gill

*Protopulvinaria longivalvata* Green
*Protopulvinaria pyriformis* Cockerell

*Pulvinaria elongata* Newstead
*Pulvinaria floccifera* (Westwood)
*Pulvinaria peninsularis* Ferris
*Pulvinaria psidii* Maskell
*Pulvinaria urbicola* Cockerell

*Saissetia auriculata* Morrison
*Saissetia coffeae* (Walker)
*Saissetia miranda* (Cockerell & Parrott)
*Saissetia neglecta* De Lotto
*Saissetia oleae* (Olivier)

*Schizochlamidia* sp.

*Tillancoccus mexicana* Ben-Dov
*Tillancoccus tillandsiae* Ben-Dov

*Toumeyella* sp.

*Vinsonia stellifera* (Westwood)

The listing of the soft scale insects of Central America presented in Table 1 has been compiled from searches of the literature; from slide mounted specimens and records in the US National Museum of Natural History, Beltsville, Maryland; from specimens collected by the author in Costa Rica, Guatemala, and Honduras; and from the collections of Michael Kosztarab from Costa Rica. This list represents our current knowledge of the biodiversity of the soft scale insects of Central America, with the exception of two undescribed genera and approximately five undescribed species known to the author.

The family Coccidae is represented in Central America by 20 genera and 56 species, discounting the undescribed taxa mentioned above. Taxonomic diversity by country is as follows (genera/species): Belize - 5/7; Costa Rica - 15/21; El Salvador - 12/15; Guatemala - 18/27; Honduras - 13/24; Nicaragua - 13/18, and Panama - 18/36. Central America's much larger neighbour to the north, Mexico, is represented by 24 genera and 62 species of soft scales (Miller, 1996). It can be concluded that one only has to compare the above diversity of soft scales known from Central America and Mexico to appreciate the importance of studying this area before habitat destruction eliminates much of the scale insect biodiversity before we can collect, study, identify and catalogue them.

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## ZOOGEOGRAPHY AND FAUNISTICS Posters and Abstracts:

# DENDROPHILOUS COCCOIDS (HEMIPTERA: COCCOIDEA) OF THE WALNUT-FRUIT FOREST AREA OF KYRGYZSTAN.

ABDRASHITOVA, N.
*Forest Institute, apt. 54, 82 Turesbekov st, Bishkek 720001, Kyrgyzstan.*
*Email: lemzina@imfiko.bishkek.su*

A study of dendrophilous coccoid fauna of the walnut-fruit forest area of southern Kyrgyzstan (the Fergana and Chatkal mountain ranges) was undertaken. Forty-five coccoid species were discovered belonging to 27 genera and 6 families: Diaspididae (9 genera, 18 species), Coccidae (9 genera, 15 species), Pseudococcidae (6 genera, 9 species) and Margarodidae, Eriococcidae and Ortheziidae (1 species each). The scale insect fauna contains 9 species which are basically from Central Asia (20%) and 14 species which are subendemic to the Iranian and Turanian regions (31%). The rest of the species are Mediterranean (7 spp., 16%), European (2 spp., 5%), Palaearctic (4 spp., 9%) and Holarctic (3 spp., 7%). The complex of accidental species includes 6 species (13.5%). These scale species could be referred to three groups: polyphagous - 24 species (53.3%), oligophagous - 18 species (40%) and monophagous - 3 species (6.7%). In addition, on the basis of their frequency and damage, 10 species were categorised as numerous, 21 species as moderately numerous and 14 species as rare or infrequent.

The most numerous and economically important species was *Sphaerolecanium prunastri* (Fonsc.), which caused extensive damage to the local alycha species (*Prunus sogdiana* Vass.). In these areas of Kyrgyzstan, biological control of the scale insect fauna is considered the most appropriate and promising method and such encyrtid parasitoids as *Discodes coccophagus* Ratz. and *Microterys hortulanus* Erd. play an important role in the control of *S. prunastri.*

# A ZOOGEOGRAPHICAL ANALYSIS OF THE ITALIAN SCALE INSECT FAUNA.

LONGO, S.[1]; MAROTTA, S.[2]; PELLIZZARI, G.[3]; RUSSO, A.[1]; TRANFAGLIA, A.[2]
*[1]Istituto di Entomologia Agraria, Università di Catania, via Valdisavoia 5, 93123 Catania, Italy;*
*[2]Dipartimento di Biologia, Difesa e Biotecnologie Agro-forestali, Università della Basilicata, via N. Sauro 85, 85100 Potenza, Italy; 3Istituto di Entomologia Agraria, Università di Padova, Agripolis, via Romea 16, 35020 Legnaro (PD), Italy.*
*Email: longosan@mbox.unict.it*

The results of a zoogeographical analysis of the Italian scale insect fauna, which currently includes 365 species were presented. Eleven species were excluded in the analysis, either because they were poorly described and were therefore of doubtful identity or because they had not been recorded since their original description. This analysis divided the Italian scale insect fauna into three major groups according to the distributional patterns currently used in faunistic studies in the Western Palaearctic

Region: A) Species primarily of the Western-Palaearctic Region (226 species). This group included the following sub-groups: i) species widely distributed in the Holarctic region (115 spp.); ii) species widely distributed in Europe (52 spp.); iii) species widely distributed in the Mediterranean Basin (57 spp.), and iv) Afrotropical or Oriental species also present in the Mediterranean area (2 spp.). B) Cosmopolitan species or cultural immigrants (111 spp.). C) Endemic species (17 spp). Each major group or sub-group included several species which had a more restricted distribution pattern. The analysis revealed that the Italian scale insect fauna (with the exclusion of the cosmopolitan species, which are of little zoogeographical interest), was represented mainly by widely distributed species in the Holarctic region (31.5% of total scale fauna); those which were widely distributed in the Mediterranean Basin (15.6%) and those widely distributed in Europe (14.25%). The Afrotropical or Oriental species represented only 0.5% of the total. A brief comment on each group was given.

## SCALE INSECTS (HEMIPTERA: COCCOIDEA) INTERCEPTED ON IMPORTED PLANT MATERIAL AND RECENT INTRODUCTIONS IN ENGLAND AND WALES.

MALUMPHY, C.
*Central Science Laboratory, Sand Hutton, York YO41 1LY, UK*
*Email: c.malumphy@csl.gov.uk*

There have been almost 300 species of Coccoidea intercepted on imported plants and plant produce in England and Wales since 1968, which is more species of Coccoidea intercepted than any other superfamily of invertebrates. For example, in 1995, a third of all species intercepted on imported plant material were Coccoidea. This makes scale insects the most significant superfamily of invertebrates being dispersed in the international plant trade, in terms of numbers of species. The most frequently intercepted species are listed and the reasons why they are so commonly transported briefly discussed. Despite the large number of exotic scale insects entering Britain very few have become established and even fewer have become widespread. New introductions of exotic species reported in non-commercial premises in Britain since 1968 are also listed. Finally, recent outbreaks of exotic pest species at commercial nurseries are given, all of which have been successfully eradicated.

## AN ANNOTATED LIST OF SCALE INSECTS (HEMIPTERA: COCCOIDEA) FROM TURKEY.

ÖNCUER, C.[1]; UYGUN, N.[2]; ERKILIC, L.B.[3]; KARSAVURAN, Y.[4]
*[1]Department of Plant Protection, University of Adnan Menderes, Aydin, Turkey; [2]Department of Plant Protection, University of Cukurova, 01330 Adana, Turkey; [3]Plant Protection Research Institute, PK 21, 01321 Adana, Turkey; [4]Department of Plant Protection, University of Ege, Izmir, Turkey. Email: citrusp@pamuk.cu.edu.tr*

A list of the 171 species of Coccoidea from Turkey, belonging to 10 families, is presented. This list is based on the authors' collection data and on bibliographical sources. The most numerous families are Diaspididae (92 species), Coccidae (31 species) and Pseudococcidae (18 species). The remaining families have between 1 and 7 species each. Among this 171 species are 15 species which are considered to be endemic and their distribution was discussed. In our orchard ecosystems, 11 species are of sufficient importance to require control measures, while in our citrus pest management program, 4 species have pest status. In addition to the cultivated plants, non-cultivated plants have many scale insect species because of the zoogeographical situation of Turkey, lying as it does between the Mediterranean, the Irano-Turanian and Euro-Siberian subregions of Palaearctic. This list is unlikely to be complete and further studies are needed.

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## AN ANNOTATED LIST OF THE NATURAL ENEMIES OF THE SCALE INSECTS (HEMIPTERA: COCCOIDEA) OF TURKEY.

UYGUN, N.[1]; ÖNCUER, C.[2]; KARACA, I.[1]; YOLDAS, Z.[3]; SENGONCA, C.[4]
*[1]Department of Plant Protection, University of Cukurova, 01330 Adana, Turkey; [2]Department of Plant Protection, University of Adnan Menderes, Aydin, Turkey; [3]Department of Plant Protection, University of Ege, Izmir, Turkey; [4]Institut für Pflanzenkrankheiten der Universitat Bonn, D-53115 Bonn, Germany Email: karaca@pamuk.cc.cu.edu.tr*

A list of the known natural enemies collected from the Coccoidea of Turkey was presented, based on the authors' collection data and from bibliographical sources. This includes 70 species belonging to 7 orders and 17 families. The most numerous family of predators is the Coccinellidae (Coleoptera) with 30 species, while the most numerous hymenopteran parasitoid families are the Aphelinidae with 21 species and the Encyrtidae with 12 species. The remaining orders include the Acarina, Thysanoptera, Heteroptera, Neuroptera, Diptera and Lepidoptera, which have between 1 to 5 species each. Some of these natural enemies are considered to be effective in decreasing the scale populations. For instance, in our citrus ecosystem, 18 species of natural enemies are known for *Aonidiella aurantii* (Maskell). Other Diaspididae, from a variety of ecosystems, are particularly parasitised by several *Aphytis* spp. Twenty-five species of native natural enemies give good control of *Planococcus citri* Risso, while *Rodolia cardinalis* (Mulsant) completely controls *lcerya purchasi* Maskell. Seven new records of biocontrol agents in Turkey were discussed.

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BLUMBERG, D.; BEN-DOV, Y.; MENDEL, Z.
*Department of Entomology, Agricultural Research Organization,*
*The Volcani Center, Bet Dagan 50250, Israel.*

# THE CITRICULUS MEALYBUG, *PSEUDOCOCCUS CRYPTUS* HEMPEL, AND ITS NATURAL ENEMIES IN ISRAEL: HISTORY AND PRESENT SITUATION.

## ABSTRACT

The citriculus mealybug, *Pseudococcus cryptus* Hempel, and its natural enemies in Israel: history and present situation.

The citriculus mealybug, *Pseudococcus cryptus* Hempel, was first discovered in Israel in 1937 and very rapidly became a key pest of citrus. However, since the early 1940s, the mealybug population has sharply decreased. This occurred in parallel with the establishment of the introduced parasitoid *Clausenia purpurea* Ishii, which was then believed to be the main cause of the biological control of the mealybug. Since the late 1980s, outbreaks of *P. cryptus* have been recorded mainly in new citrus varieties, such as red grapefruits, pomelo, "sweety" and several peeling varieties. The current outbreaks are probably related to the susceptibility of these mentioned varieties to *P. cryptus*, and to the adverse effects of Insect Growth Regulators to coccinellid predators, especially *Scymnus* spp. The introduced *C. purpurea* and two other local encyrtid parasitoids, *Leptomastix* near *algirica* and *Anagyrus diversicornis* Mercet, rarely emerged from samples of *P. cryptus* collected during 1996-1998. Four further parasitoid species were introduced into Israel during 1996-1997 against *P. cryptus*: from central Asia, the platygasterids *Allotropa burrelli* Muesebeck and *A. convexifrons* Muesebeck and the encyrtid, *Pseudaphycus malinus* Gahan; and from Japan, *Anagyrus sawadai* Ishii. *A. convexifrons* and *A. sawadai* successfully parasitized *P. cryptus* and, therefore, were released in the field but only *A. sawadai* has so far been recovered. A considerable reduction in population densities of the pest has been recorded since May, 1998, in the major release site of the latter species.

Key words: distribution, host plants, *Pseudococcus comstocki*, *P. citriculus*, *P. viburni*, IGR, Coccinellidae, *Planococcus citri*, *P. ficus*, *Aonidiella aurantii*, *Ceroplastes floridensis*, *Anagyrus pseudococci*, *Leptomastidia abnormis*, *Leptomastix flavus*, *Cryptolaemus montrouzieri*, Cecidomyiidae, Sympherobiidae, Chrysopidae.

## THE MEALYBUG

The citriculus mealybug *Pseudococcus cryptus* Hempel (Hemiptera: Pseudococcidae) is widespread in the tropical and subtropical regions of Africa, Central and South America, East Asia, China and Japan. It is a severe pest of citrus in Japan and Israel and has been also recorded from many host plants, including the roots of coffee trees in South America, mango, avocado, banana, guava, palm trees, oleander and persimmon (Ben-Dov, 1994). Based on the distribution of its principal parasitoids, the presumed origin of *P. cryptus* is south-east Asia.

Upon its discovery in Israel, *P. cryptus* was identified as the Comstock mealybug, *Pseudococcus comstocki* (Kuwana) (Klein & Perzelan, 1940). Later studies indicated that this was a misidentification and the species was named in Israel as *Pseudococcus* aff. *citriculus* (Bodenheimer, 1951; Rivnay, 1968). Subsequently, Borchsenius (1956) identified material taken from citrus in Israel as *P. citriculus* Green. In 1992, Williams and Granara de Willink synonymized *P. citriculus* with *P. cryptus* Hempel. The mealybug material collected by us on citrus in Israel since the 1960s to the present, was studied and found to agree well with the modern redescription of *P. cryptus* by Williams & Granara de Willink (1992).

In Israeli citrus groves, *P. cryptus* usually occurs together with the citrus mealybug, *Planococcus citri* (Risso). However, *P. citri* occurs and develops on the fruits but *P. cryptus*, while it can infest all parts of the tree, is found mainly on the leaves and twigs. Damage to citrus has been associated with fruit and flower drop, wilting and general debilitation of the plant and also, importantly, with the unsightly appearance of the fruit due to the large quantities of honeydew on which sooty mould develops. When the infestation levels of *P. cryptus* are high, it tends to aggregate in dense colonies covering the leaves, twigs and trunk. In the Coastal Plain of Israel, the mealybug is able to produce 6 generations annually (Gruenberg, 1956), which allows rapid population build up.

## NATURAL ENEMIES OF *P. CRYPTUS*.

Fifteen species of predators, mainly coccinellids, and 12 species of hymenopterous parasitoids, mainly encyrtids, have been recorded from *P. cryptus* (Table 1). Among the recorded parasitoids, the principal ones are probably those from the Far East. Although *P. cryptus* serves as a food for many coccinellids in different regions, for most or all of them the mealybug is an accidental suitable prey.

## OUTBREAKS OF *P. CRYPTUS* IN ISRAEL:

### *Late 1930s.*

*Pseudococcus cryptus* was first recorded in Israel in 1937, in a citrus grove on the Coastal Plain, where it rapidly dispersed to most of the citrus plantations in the south (Avidov & Harpaz, 1969), becoming a devastating citrus pest. A major control project was, therefore, initiated (Bodenheimer, 1951; Rivnay, 1968). However, within 3-4 years, the populations of the mealybug in citrus groves dropped to very low levels and no further economic damage was recorded (Bodenheimer, 1951; Rivnay, 1968). This remarkable change in the pest status of *P. cryptus* in Israel was considered a case history of classical biological control, attributed to the encyrtid parasitoid *Clausenia purpurea* Ishii (Hymenoptera: Encyrtidae), which was introduced into Israel in 1940 (DeBach, 1974; Rosen, 1967).

Table 1. Natural enemies of *Pseudococcus cryptus*[1]

| Order & Family | Species | Distribution | Reference |
|---|---|---|---|
| **Diptera** | | | |
| Cecidomyiidae | *Diplosis* sp. | Far East | Bodenheimer, 1951 |
| **Neuroptera** | | | |
| Sympherobiidae | *Sympherobius sanctus* (Tjeder) | Mediterranean | Rivnay, 1968 |
| Chrysopidae | *Chrysoperla carnea* (Stephens) | Cosmopolitan | Present study (1996-1998) |
| **Coleoptera** | | | |
| Coccinellidae | *Hyperaspis quinquenotata* Mulsant | South America | de Moraes (pers. comm) |
| | *H. pumila* Mulsant | Mediterranean | Rivnay, 1968 |
| | *Oxynychus marmottani* Salm | Mediterranean | Bodenheimer, 1951 |
| | *Pentilia* sp. | South America | de Moraes (pers. comm.) |
| | *Scymnus bipunctata* Kugelan | Far East | Bodenheimer, 1951 |
| | *S. fenestratus* Sahlberg | Mediterranean | Rivnay, 1968 |
| | *S. suturalis* Thunberg | Mediterranean | Rivnay, 1968 |
| | *S. quadrimaculatus* Hbst. | Mediterranean | Rivnay, 1968 |
| | *S. apetzi* Mulsant | Mediterranean | Bodenheimer, 1951 |
| | *S. pallidivestis* Mulsant | Mediterranean | Kehat & Greenberg, 1975 |
| | *S. includens* Kirsch | Mediterranean | Rivnay, 1968 |
| | *Cryptolaemus montrouzieri* Mulsant | Australia | Mendel *et al.* 1992 |
| **Hymenoptera** | | | |
| Encyrtidae | *Anagyrus diversicornis* Mercet | Cosmopolitan | Noyes & Hayat, 1988 |
| | *A. pseudococci* (Girault) | Mediterranean | Rivnay, 1968 |
| | *A. sawadai* Ishii | Far East | Noyes & Hayat, 1988 |
| | *Clausenia purpurea* Ishii | Far East | Rivnay, 1968 |
| | *Cryptanusia albiclava* Girault | South-east Asia | Noyes & Hayat, 1988 |
| | *Leptomastidea abnormis* (Girault) | Mediterranean | Bodenheimer, 1951 |
| | *Leptomastix* nr *algirica* Trjapitzin | Mediterranean | Present study |
| | *L. citri* Ishii | Far East | Bodenheimer, 1951 |
| | *L. epona* (Walker) | ? | Noyes (pers. comm) |
| | *L. flava* Mercet | West Palaearctic | Bodenheimer, 1951 |
| | *Chrysoplatycerus flavicollis* (De Santis) | ? | Hall, 1974 |
| Platygasteridae | *Allotropa convexifrons* Muesebeck | Turkmenistan | Present study |

[1] indicates association between the listed natural enemy and *P. cryptus*

*The 1990s.*

Since the early 1990s, severe outbreaks of *P. cryptus* have been recorded in the Coastal Plain, in Western Galilee and in the Yizre'el Valley, where damage has been mainly caused to red grapefruits, pomelo, "sweety" and several peeling varieties. Such outbreaks occurred also in citrus groves maintained strictly under biological control management and, therefore, the tendency was not to relate the outbreaks to the disruption of biological balance. Currently, chemical control of *P. cryptus* in Israel is achieved by applications of the organophosphate insecticide chlorpyriphos.

There are two possible reasons for the present outbreaks of *P. cryptus* in Israeli citrus plantations: the first is the increasing and intensive use of Insect Growth Regulators (IGRs) for the control of armoured and soft scale insects in citrus, as well as whiteflies and lepidopteran pests in adjacent cotton fields. The adverse effects of IGRs on natural enemies of scale insects, mainly predators, were demonstrated in several studies conducted in recent years (Mendel *et al.*, 1994; Peleg, 1983). IGRs differ in their toxicity to natural enemies of different groups and species; coccinellids are apparently more sensitive to these chemicals than hymenopteran parasitoids (Mendel *et al.* 1994; Peleg & Gothilf, 1980). IGRs affect coccinellids throughout their life cycle, some are highly residual and, therefore, their adverse effects on lady beetles may last for longer than that of the conventional organophosphate or carbamates used in Israel. Coccinellids are highly susceptible to pyriproxifen (Mendel *et al.* 1994), an IGR chemical which is commonly used in Israel for the control of the California red scale, *Aonidiella aurantii* (Maskell) and the Florida wax scale, *Ceroplastes floridensis* Comstock (Peleg & Bar-Zacay, 1995). The second reason for outbreaks is the susceptibility of the new citrus varieties to mealybugs. Since the 1970s, new citrus varieties, such as red grapefruit, "sweety", pomelo and peeling varieties, have been planted in Israel. Outbreaks are far more frequent in orchards planted with the new varieties than in those planted with the traditional ones, such as Shamouti, Valencia or Navel oranges (Table 2).

## BIOLOGICAL CONTROL OF *P. CRYPTUS* IN ISRAEL

*Local natural enemies.*

Soon after the first outbreak of *P. cryptus* in 1937, a survey of natural enemies of the pest was initiated (Rivnay, 1968). The predator fauna included four lady beetles of the genus *Scymnus*, namely *S. fenestratus* Sahlb., *S. suturalis* Thumb., *S. includens* Kirsch and *S. quadrimaculatus* Hbst., which were abundant in the spring and early summer and which, in these seasons, succeeded in keeping the population of the mealybug at a low level (Rivnay, 1968). These coccinellids are also common predators of *P. citri* in Israel.

Three encyrtid parasitoids were recorded from *P. cryptus* in the early 1940s: *Anagyrus pseudococci* (Girault), *Leptomastidea abnormis* (Girault) and *Leptomastix flavus* Mercet. The first two species are common parasitoids of *P. citri* in the Mediterranean, whereas the latter species was collected from the Mediterranean vine mealybug, *Planococcus ficus* (Signoret) in the Negev, Southern Israel (Berlinger, 1977).

Table 2. Infestation level (Number of infested plots) of *P. cryptus* on various citrus varieties in 1996-1997

| **Citrus variety** | **No. of plots examined** | **Infestation level** | | |
|---|---|---|---|---|
| | | **None** | **Low** | **High** |
| **Red Grapefruit** | **5** | **0** | **3** | **2** |
| **"Sweety"** | **7** | **0** | **2** | **5** |
| **Pomelo** | **7** | **0** | **1** | **6** |
| **Peeling Varieties** | **21** | **0** | **2** | **19** |
| **Shamouti Orange** | **13** | **10** | **2** | **1** |
| **Valencia Orange** | **5** | **0** | **0** | **0** |

Table 3. Parasitoids introduced into Israel in 1996-1997 for the control of *P. cryptus*.

| **Natural enemy** | **Area of collection - year of introduction (Host mealybug)** | **Successfully reared on *P. cryptus*** | **Successfully established in citrus groves in Israel** |
|---|---|---|---|
| **Platygasteridae** | | | |
| ***Allotropa burrelli* Mues.** | **Republic of Georgia - 1996 (*P. comstocki*)** | **No** | **No** |
| ***Allotropa convexifrons* Mues.** | **Turkmenistan - 1997 (*P. comstocki*)** | **Yes** | **No** |
| **Encyrtidae** | | | |
| ***Pseudaphycus malinus* Gahan** | **Republic of Georgia - 1996 (*P. cryptus*)** | **No** | **No** |
| ***Anagyrus sawadai* Ishii** | **Japan - 1997 (*P. cryptus*)** | **Yes** | **Yes** |

In the present study (1996-1998), only *A. pseudococci* and *L. flavus* were collected in mid-summer and always in very small numbers. In 1997, two additional encyrtid parasitoids were recorded for the first time in Israel from samples of *P. cryptus*, namely *Anagyrus diversicornis* Mercet and *Leptomastix* near *algirica* Trjapitzin. *Anagyrus diversicornis* is distributed in Europe and

Asia, where it parasitizes many mealybug species of various genera (Noyes & Hayat, 1988). John Noyes (pers. comm.) indicated that *L.* near *algirica* is very close to *Leptomastix epona* (Walker). The latter is used in augmentative releases against *Pseudococcus viburni* (Signoret) in tomato greenhouses in western Europe, and was successfully reared on *P. cryptus* in our laboratory.

*Introduction and release of exotic parasitoids*:

The search for exotic parasitoids in the 1940s was based on the misidentification in Israel of the mealybug discovered in 1937. Therefore, the emphasis was on parasitoids of *P. comstocki* rather than of *P. cryptus*. Three parasitoid species were imported from Japan in 1940, namely *Clausenia purpurea* Ishii (Encyrtidae), *Leptomastix* sp. (Encyrtidae) and *Allotropa burelli* Muesebeck (Platygasteridae), but only *C. purpurea* was mass-reared in Israel (Bodenheimer, 1951; Rivnay, 1968). *Clausenia purpurea* was released in large numbers and rapidly became established in many of the infested sites. High parasitization rates were reported within less than two years (Rivnay, 1968). Based on the rapid establishment of *C. purpurea*, Gruenberg (1956) regarded *C. purpurea* one of the major factors that contributed to the complete control of this pest in many parts of the Coastal Plain during the 1940s.

In the course of this study (1996-1998), *C. purpurea* emerged from samples of *P. cryptus*, collected from most of the infested citrus plantations surveyed. However, although *C. purpurea* was more common than other parasitoids, only small numbers were recorded during the second half of the summer and parasitism by this parasitoid was always below 0.5%.

Six attempts at establishing *Cryptolaemus montrouzieri* Mulsant in Israel to improve the control of mealybugs in citrus groves, have been conducted during the last 70 years, including an introduction from eastern Australia, its native area. Successful establishment has been achieved with material collected in Spain in the late 1987 (Manes Wysoki, pers. comm.) but the beetle is not an important biocontrol agent of mealybugs (Mendel *et al.*, 1992) and has rarely been observed in populations of *P. cryptus*.

Four parasitoid species were introduced into Israel during 1996-1997 for the control of *P. cryptus* (Table 3). These were: *Allotropa burrelli* Mues. and *Pseudaphycus malinus* Gahan from the Republic of Georgia, *Allotropa convexifrons* Mues. from Turkmenistan and *Anagyrus sawadai* Ishii from Japan. The first two parasitoids were collected from colonies of *P. comstocki*, while the last two species were reared from *P. cryptus*. Only *A. convexifrons* and *A. sawadai* have successfully parasitised *P. cryptus* in Israel. They were, therefore, reared in our laboratory and released in the infested orchards. For rearing purposes, small lemon twigs attached to the fruit and heavily infested with *P. cryptus* were used. However, due to difficulties in their mass-rearing, we were able to release only small numbers of each of these two parasitoids. Releases of about 1,500 *A. sawadai* were made during April-May, 1997, and of about 200 individuals of *A. convexifrons* during April-September, 1997.

So far, only *A. sawadai* has become established in a release site in the Yizre'el Valley. The first recovery was recorded by the end of July, 1997, less than four months after the first release in late March. Since then, large numbers of *A. sawadai* have emerged in all samples of the mealybug collected at the major release site. The recovery of this new parasitoid in January and in February, 1998, and especially the large numbers of adults that emerged during June, 1998, undoubtedly indicates that they survived the cold season and so were not adversely affected by the low winter temperatures. In June, 1998, the parasitoid also emerged in large numbers in several infested plots adjacent to the release site and were the dominant parasitoid in all samples of *P. cryptus* taken from the release site. In July, 1998, *A. sawadai* was recorded in a sample of the mealybug collected in the southern Coastal Plain, following a single release of 300 individuals in March, 1998.

## DISCUSSION

When introduced into Israel in 1937, *P. cryptus* was not accompanied by any of its principal natural enemies. Chemical control was not effective and, therefore, efforts were made toward biological control of the mealybug. Biological control studies included a survey of local natural enemies and the importation of exotic parasitoids (Bodenheimer, 1951; Rivnay, 1968). The parasitoid, *C. purpurea* was imported into Israel in 1940 and was released in several infested groves. However, before major releases were conducted, a reduction in the pest population levels was recorded in many of the infested plots (Gruenberg, 1956). We assume, therefore, that the reduction in the pest population could not be related to the effect of the parasitoid, although Gruenberg (1956) considered that *C. purpurea* was an efficient parasitoid, very well adapted to *P. cryptus*, and believed that it ad been the major factor responsible for the control of the mealybug in many areas in the Coastal Plain in Israel. This conclusion was subsequently accepted as a case history of classical biological control of an exotic pest (Harpaz & Rosen, 1971; DeBach, 1974). On the other hand, Bodenheimer (1951) suggested that the role of *Scymnus* spp. was extremely valuable in the biological control of *P. cryptus*, and he had expressed doubts as to the crucial role of *C. purpurea* in its successful control. He stated that "if *Clausenia* had not been introduced, the final result would have been rather similar. Perhaps the regression of the mealybug would not have been as quick as it actually was". Moreover, Bodenheimer (1951) also reported that the introduction of the mealybug into Cyprus without the introduction of *C. purpurea* was not accompanied by any major outbreak. Rivnay (1968) pointed out that there was competition for *P. cryptus* between the various natural enemies; in one grove, *Anagyrus pseudococci* was dominant while *L. flavus* was more prevalent in another. In another grove, *Scymnus* spp. were dominant and the pest was overcome before *C. purpurea* could become established.

Although we can not exclude the contribution of *C. purpurea* to the successful control of *P. cryptus* in the 1940s, its very low abundance in our present study (1996-1998) in most of the infested groves, and the fact that it was not able to prevent the present and continuous (1990-1998) outbreak, also support the opinion that its role in the 1940s was minor.

The role of *A. pseudococci* and *L. flavus* in the 1940s is also questionable. Rivnay (1968) suggested that these parasitoids, together with the activity of *Scymnus* spp., played an important role in the control of *P. cryptus*. *Anagyrus pseudococci* is mainly a parasitoid of *Planococcus* spp. and, in the present study, rarely emerged from large samples of *P. cryptus*. *Leptomastix flavus* is extremely rare in local groves and does not play any role in the reduction of the population level of *P. cryptus*.

Unlike the citrus mealybug, *P. cryptus* develops in clumps, forming large aggregates on leaves, branches and stems. Thus, these colonies are easy targets for coccinellid predators. The adverse effects of IGRs on these predators may well explain the recent outbreaks of *P. cryptus*. IGRs do not seem to have any critical effects on the parasitoid fauna in the groves (Mendel *et al.* 1994). Although their effects on *C. purpurea* were not investigated, we assume that, like other parasitoids, it is less susceptible to IGRs than coccinellids. Therefore, the consistent low prevalence of *C. purpurea* in most of the citrus groves is here considered not to be due to the negative effects of IGRs.

The successful establishment of *A. sawadai* in 1997-1998 may have contributed to the improvement of the biological control of *P. cryptus*. However, it is difficult to forecast whether a reduction in the use of IGRs in the citrus grove will enable *A. sawadai* to efficiently control the mealybug on susceptible varieties. It is also too early to evaluate the role of this parasitoid in the control of *P. cryptus* in Israel.

Several species of *Scymnus* were very abundant in the *A. sawadai*-release sites, and probably contributed to the reduction in the population densities of the pest recorded since May, 1998, in these sites. *Scymnus* spp. are at low densities during the winter and spring (Bodenheimer 1951) and they are unable to multiply fast enough to limit the rapid build-up of *P. cryptus* populations on susceptible citrus varieties until the second half of the summer. Hence, effective biological control of the mealybug on susceptible varieties may be achieved if the interference of IGRs in the ecosystem is markedly reduced.

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KOZÁR, F.[1]; MILLER, D.R.[2]

[1]*Plant Protection Institute, Hungarian Academy of Sciences, H-1525, Budapest Pf. 102, Hungary.*
[2]*U. S. Department of Agriculture, Agricultural Research Service, Systematic Entomology Service, Beltsville, Maryland 20705 U.S.A.,*

# OBSERVATIONS ON COLLECTING SCALE INSECTS (HEMIPTERA: COCCOIDEA).

## ABSTRACT

OBSERVATIONS ON COLLECTING SCALE INSECTS (HEMIPTERA: COCCOIDEA).

Scale insects have been primarily collected visually. Because scales are usually firmly attached to the host substrate, most mass-collecting techniques are ineffective. This paper provides information on the use of Berlese funnels, DVAC suction, pit-fall traps, sweeping, beating and screening for collecting scale insects and provides observations on how these methods compare with visual collecting methods.

Key words: collecting methods, visual methods, pheromone traps, suction traps, lights, vicarious collecting, herbaria specimens, Margarodidae, Ortheziidae, Pseudococcidae, Eriococcidae, Hungary, Africa.

## INTRODUCTION

Mass-collecting techniques for sampling insects have been developed and refined so that many museums currently are unable to process the large number of specimens that are collected using these methods. Pit-fall traps, Malaise traps, canopy fogging, Berlese funnels and other such collecting methods have been important tools for sampling and understanding the extent of some components of insect biodiversity. Unfortunately, most mass-sampling techniques are unsuitable for scale-insect studies because generally scales are sessile, are firmly attached to their host and therefore remain on the host rather than being taken in the sampling device.

The purpose of this paper is to summarize information on scale-insect collecting methods and to provide new observations on the subject.

## MATERIALS AND METHODS

A sampling survey was made in the Sashegy Nature Reserve and in the Körös-Maros National Park in Hungary, comparing a hand-held DVAC suction system (Samu & Sárospataki 1995), visual observations and pitfall traps. We are reporting on the results for the scale collections only, although many different kinds of organisms were sampled in the survey. For pitfall traps, 25 traps were placed in each collecting site; the traps were 70mm in diam., were filled with ethylene glycol, and were changed every three weeks from April through October in 1995, 1996 and 1997. Visual surveys were made by two individuals five times each year and at least 6 hours were spent looking for scales on each sampling excursion. The diameter of the DVAC was 0.01 square meters and collections were carried out once each month. In each location, 5 different habitats were sampled by running a transect in each habitat. Each transect was comprised of 15 samples.

## RESULTS AND DISCUSSION

### Review of collecting methods

Scale-insect collecting strategies have been discussed in a general way by several authors including: McKenzie (1967), Kosztarab & Kozár (1988), Kozár (1990), Wilkey (1990), Kosztarab (1996) and others, but no definitive work has been written which compares the effectiveness of current available methods.

**Berlese funnels:** are effective for collecting species of soil inhabiting mealybugs, such as *Rhizoecus* (McKenzie, 1967) and *Eumyrmococcus* (Williams, 1998). Morrison (1952) indicated that Berlese funnels had been used to collect species of ortheziids infesting moss or soil litter. Ramona Beshear (retired from the University of Georgia) used this technology to collect additional specimens once she had visually located specimens in the field (personal communication). This method was particularly important for collecting eriococcids in the south-eastern U.S. and is mentioned in Miller *et al.* (1992) as a collecting strategy for locating specimens of *Eriococcus droserae* Miller, Liu & Howell. The first author has recently discovered a “treasure trove” of scale-insect material in Berlese samples that were initially collected by acarologists. Mahunka (Budapest, Hungary) and his colleagues ran Berlese samples in nearly all areas of the world and, after removing the mites of interest, kept the samples for future use by colleagues studying other groups (for more information see Mahunka & Mahunka-Papp, 1992). From Africa alone, 856 samples were examined and ortheziids and mealybugs were the predominant scale insects. Eighty-six samples contained ortheziids, including 225 adult females and 276 immatures. The number of adult female specimens in each genus were as follows: 129 *Ortheziola,* 64 *Newsteadia*, 31 *Nipponorthezia* and 1 *Orthezia*. A series of papers are planned that will describe this adult female ortheziid material, of which the first paper is complete (Kozár & Miller, 2000).

The **beating sheet** is an under-utilized collecting method that can be quite effective for collecting mealybugs (McKenzie, 1967), ortheziids, margarodids and eriococcids. The second author has used this method for collecting such mealybugs as *Spilococcus larreae* Ferris and *Pseudococcus beardsleyi* Miller & McKenzie, and eriococcids such as *Eriococcus macrobactrus* (Miller & Miller) and *Eriococcus quercus* (Comstock) when the mealybugs or eriococcids were scattered on abundant host-plant material.

The use of **sifting screens** is another method that has been used in a limited way for collecting scale insects. McKenzie (1967) discussed the use of a series of screens with differing sizes of wire mesh for locating mealybugs in soil samples, and this strategy also is effective for sifting through soil litter and moss. When the first author was searching for ortheziids in South Africa, he had the opportunity to examine 601 samples that were collected by Endrödy-Younga (Transvaal Museum, Pretoria, South Africa). Ortheziids were present in about 5% (31) of these samples, with 60 specimens of *Ortheziola* in 14 samples, 61 specimens of *Newsteadia* in 16 samples and 1 specimen of *Orthezia* in one sample.

**Visual collecting** is a particularly useful and common collecting strategy, but it is worth mentioning some techniques that sometimes will make this method more effective. All parts of the plant should be examined whenever possible. Undersides of leaves, particularly in concealed areas near the veins, are good settling sites for scales. Young branches and stems also are favoured by many coccoids. Perhaps the most under-collected areas of the host are the upper canopy and the root system of trees. For small plants, the subterranean area can be examined using a shovel, but coccidologists should take advantage of situations where areas of land are being cleared and examine the recently upended trees, both on the roots and in the upper parts of the trees. For large trees, it is often productive to pull off pieces of the loose bark where scales like to settle. Also cracks in the bark and scar areas are preferred settling sites of many scales. After studying the root system of a plant, it can be productive to pull the crown area apart, since often scales are found at the bases of branches or in open cavities in the centre of the crown. Ants frequently give a clue that some sap-feeding insect is present, so plant material with ants on it should be carefully examined. Many coccidologists locate large samples of field collected host material that is likely to contain scale insects and transport it back to the laboratory where it is examined with a dissecting microscope. This is a very effective way of collecting species that can only be found when examining the host carefully at high magnification.

Some miscellaneous collecting methods include collecting with a **sweep**

**net** which was used in sampling for an eriococcid, armoured scale and mealybug by Denno (1977). The sample sizes of *Eriococcus dennoi* (Miller & Miller) were large enough to give a general idea of its life history. Raupp and Denno (1979) also used a **DVAC** to sample other "homopterans" and scales in their studies in the salt marshes of New Jersey, but indicated that it was not very efficient. **Canopy fogging** has been done extensively in recent years, but the only life-history stages that appear in samples with any degree of frequency are adult males (T. Erwin, Department of Entomology, National Museum of Natural History, Washington, DC, personal communication), and they are difficult or impossible to determine without associated females. **Pheromone traps** have been used to attract males of a particular species of scale insect, but this method is currently unsuitable for collecting a diversity of scale-insect species. A **suction trap** was developed to collect males and parasitoids of the San José scale by Kozár (1976) and coloured sticky boards were used to collect males of various scales and parasitoids (Kozár, 1973; Sheble & Kozár, 1995). In some instances **lights** are attractive to scale insects. A recent example is when adult males, adult females and immatures of a rare margarodid (*Palaeococcus fuscipennis* Burmeister) were attracted in large numbers to a black light placed in the field by a lepidopterist (Kozár *et al.*, 1994).

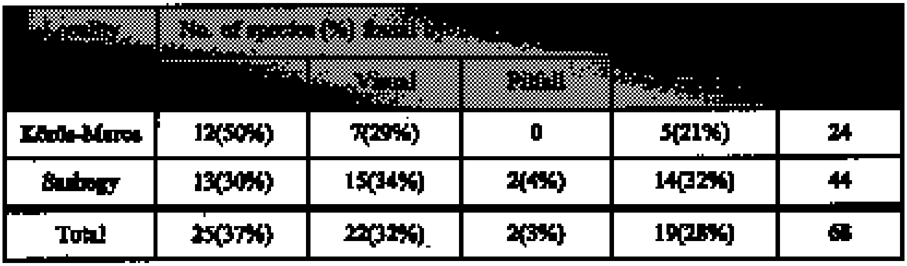
It also is worth mentioning "vicarious collecting," i.e., when scientists collect specimens of interest to them and at the same time inadvertently collect and preserve scale insects. An interesting example is that of Russell (1943, 1945) when she was searching for whiteflies on *Coccoloba* in the Caribbean. Rather than going to the Caribbean for time-consuming field work, she went to the herbarium of the Smithsonian's Botany Department and was rewarded with hundreds of specimens of whiteflies and armoured scales that had inadvertently been collected and pressed by field botanists. In fact, this material served as the basis for not only the papers by Russell, but also a revision of the armoured scale genus *Crenulaspidiotus* by Miller & Davidson (1981). Additional examples include studies by Hoy (1962) and Miller & González (1975) who vicariously collected Chilean eriococcids in herbaria.

## A Collecting Experiment in Hungary

Although the experiment comparing three collecting methods was designed to examine other groups of insects, the first author was able to compare the scale-insect catches with visual examinations at the two locations where the traps were placed. Results are summarized in the following tables.

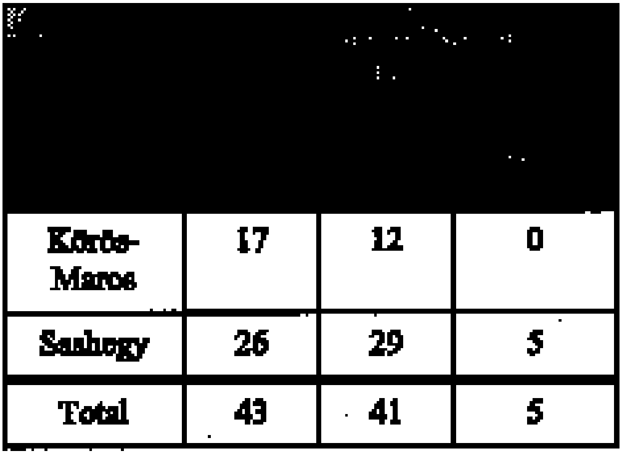
These results were unexpected and demonstrate that the specialized DVAC

Table 1. Number and percentage of species collected by three collection techniques at two localities in Hungary (i) using one method only and (ii) by more than one method.



| Locality | No. of species (%) found by | | | | |
|---|---|---|---|---|---|
| | [illegible] | Visual | Pitfall | [illegible] | [illegible] |
| Kőrös-Maros | 12(50%) | 7(29%) | 0 | 5(21%) | 24 |
| Sashegy | 13(30%) | 15(34%) | 2(4%) | 14(32%) | 44 |
| Total | 25(37%) | 22(32%) | 2(3%) | 19(28%) | 68 |

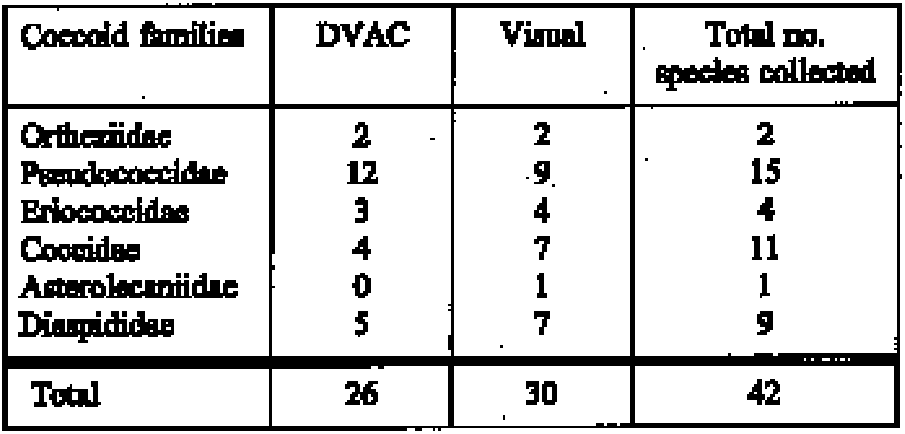
Table 2. Total number of species collected at each of two sites in Hungary, regardless of the collection method.



| | | | |
|---|---|---|---|
| Kőrös-Maros | 17 | 12 | 0 |
| Sashegy | 26 | 29 | 5 |
| Total | 43 | 41 | 5 |

suction machine used in this study was just as effective at collecting scale insects as by visual inspection, which had been considered would be the most productive method. Thus, of the Pseudococcidae collected at Sashegy, 12 species were collected by DVAC but only nine visually (Table 3). The first author was surprised, even frustrated, by the number of species that were collected with the DVAC that he could not locate visually at exactly the same sampling site. However, it should be remembered that members of all families could probably be found as dead insects on the soil surface.

Table 3. Number of species in six coccoid families collected at Sashegy by either DVAC or by visual collection.



| Coccoid families | DVAC | Visual | Total no. species collected |
|---|---|---|---|
| Ortheziidae | 2 | 2 | 2 |
| Pseudococcidae | 12 | 9 | 15 |
| Eriococcidae | 3 | 4 | 4 |
| Coccidae | 4 | 7 | 11 |
| Asterolecaniidae | 0 | 1 | 1 |
| Diaspididae | 5 | 7 | 9 |
| Total | 26 | 30 | 42 |

Note: the total number of species collected at Sashegy was actually 44 - 2 additional species were collected by pitfall traps. Also note that no two species of Coccidae collected by these two methods were the same.

Another interesting result was that about 70% of the species were collected by one method only and that only slightly less than half of the species were collected visually. This suggests that collectors of scale insects should spend more time and effort using such methods as Berlese funnels and DVAC if they wish to find a high percentage of the world species of scale insects.

## CONCLUSIONS

Many strategies for collecting scale insects have not been tested extensively. There is a tendency within the coccidology community to use the “tried and tested” methods of visual collection and not to experiment with methods that might prove more effective. For some scale insects that are permanently attached to their host, such as armoured scales, methods other than visual inspection are not effective. However, although most species adhere tightly to their host, most can retract their stylets and move from their settling site if given enough time. The use of fogging technologies kills the scales before they can move, but the slow heat of a Berlese funnel allows the scales time to move into the collection container. Methods such as beating sheets and sweeping have rarely been tried for scale collecting, but they may have much more potential than previously realized.

Finally, there may be many scale insects available in collections in places where we never considered looking previously. Our current knowledge of the genus *Crenulaspidiotus* received major enhancement because of the herbarium collecting done by Louise Russell. The new knowledge that is being accumulated about ortheziids in moss and soil litter habitats around the world is due to the first author's examination of Berlese and wire mesh screening samples that were already present in museums. Clearly there are many more herbaria specimens and alcohol samples with valuable scale-insect specimens just waiting for extraction.

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MENDEL, Z.[1]; GROSS, S.[2]; STEINBERG, S.[3]; COHEN, M.[3]; BLUMBERG, D.[1]
[1]*Dept. of Entomology, Agricultural Research Organization, The Volcani Center, Bet Dagan 50250, Israel* [2]*Dept. of Plant Protection, Agricultural Extension Service, Ministry of Agriculture, Tel Aviv 61070, Israel* [3]*Biological Control Industries, Sedé Eliyyahu 10810, Israel.*

# TRIALS FOR THE CONTROL OF THE CITRUS MEALYBUG IN CITRUS ORCHARDS BY AUGMENTATIVE RELEASE OF TWO ENCYRTID PARASITOIDS.

## ABSTRACT

TRIALS FOR THE CONTROL OF THE CITRUS MEALYBUG IN CITRUS ORCHARDS BY AUGMENTATIVE RELEASE OF TWO ENCYRTID PARASITOIDS.

Since the 1980s, the citrus mealybug *Planococcus citri* (Risso) has become a key pest in Israel, owing to intensive planting of highly susceptible varieties, the introduction of Insect Growth Regulators (which adversely affect coccinellids) and the development of resistance to chlorpyrifos. Management of the mealybug populations in citrus orchards by augmentative releases of parasitoids was investigated between 1993 and 1996 in a series of tests involving the release of 5,000-10,000 *Leptomastix dactylopii* (Howard) (Encyrtidae) per hectare. Results showed no significant effect on the density of the mealybug on the fruits. In general, the establishment of *L. dactylopii* was poor and population levels were inferior to those of the naturally occurring *Anagyrus pseudococci* (Girault) (Encyrtidae). In 1996-1997, augmentative early-spring releases of *A. pseudococci* at the rates of 10,000-50,000 individuals per hectare markedly increased the population density of *A. pseudococci* during April and June but had no significant effect on either the mealybug infestation or on fruit damage caused by the pest and its fruit moth associates.

Key words: grapefruit, persimmon, custard apple, coffee, cacao, *Citrus*, *Diospyros*, *Annona*, life cycle, damage, *Coccidoxenoides peregrinus*, *Cryptolaemus montrouzieri*, *Sympherobius sanctus*, mass rearing, cork ring, potato sprout, potato trap, low temperatures, fruit moths.

## INTRODUCTION

The citrus mealybug, *Planococcus citri* (Risso) (Homoptera: Pseudococcidae) is a highly polyphagous pest. In open areas, it is mainly a serious pest of citrus but can also attack persimmon (*Diospyros kaki*) and custard apple (*Annona* spp.), coffee and cacao. The exact area of origin of the citrus mealybug, believed to be from the tropics, is uncertain.

In the Mediterranean, the mealybug is multivoltine and occurs on all parts of the citrus tree. It overwinters in crevices next to callus of old wounds on the stem and main branches. In the spring, the females migrate to the canopy and settle on young fruits or young flush. In all citrus varieties, they first occupy cryptic sites on the fruits or contact points between fruits. They can also be found under the sepals on navel orange, where they settle in the fruit navel and on the terminal twig segments next to the fruit (Bodenheimer, 1951). It can also be found on the roots of young trees (Bodenheimer, 1951).

In Israel, the citrus mealybug damages the fruit during the warm season. The course of injury is as follows: (i) between early May and early June, the mealybug causes flower and early fruit drop; (ii) from mid-May to late June, they damage the young fruits by feeding; (iii) from late June to mid-August, they feed on the immature fruit, producing much honeydew on which sooty mould fungi develop, causing premature fruit drop, and (iv) from late July to late September, the honeydew attracts the fruit boring moths *Ectomyelois ceratoniae* (Zeller) and *Cryptoblabes gnidiella* Miller, whose larvae damage the fruit (Bodenheimer, 1951; Gookes & Porath, 1974; Avidov & Harpaz, 1969).

In Israel, the citrus mealybug has for decades been considered a moderate pest of Marsh grapefruit (*Citrus paradisi*) but it has progressively become a major pest since the 1980s, due to the planting of susceptible varieties and to major changes in the chemical pest management in citrus groves and their surroundings. From the mid-1970s, highly susceptible varieties, mainly red grapefruit (Star Ruby) and Sweetie (*Citrus paradisi* X *C. grandis*) have been planted. Even at moderate densities, the mealybug could cause notable damage on these varieties. During the 1960s and the 1970s, the mealybug remained at low levels in Israeli citrus orchards, mainly due to the widespread application of organophosphate - carbamate “spray cocktails” against Florida wax scale (*Ceroplastes floridensis* Comstock) and California red scale (*Aonidiella aurantii* Maskell). Since the late 1980s, Insect Growth Regulators (IGRs) have been intensively used in Israeli agriculture (Peleg & Bar-Zakay, 1995). These chemicals are directed mainly against whiteflies and lepidopteran pests in cotton and tomatoes, and against armoured and soft scales in citrus and pome fruits. While mealybugs are not susceptible to IGRs, these insecticides have a destructive effect upon coccinellids (Mendel *et al.*, 1994), the major biocontrol agents of mealybugs in citrus in Israel. In South Africa (Hattingh & Tate, 1995) and Israel (Mendel, unpublished data), application of IGRs (mainly of pyriproxyfen) has resulted in frequent outbreaks of the citrus mealybug during the last decade. Consequently, treatments with the organophosphate chlorpyrifos have become routine in local groves against the citrus mealybug since the late 1980s. In spite of the fact that the mealybug has become highly resistant to chlorpyrifos in many orchards, the chemical is currently the sole tool for managing the mealybug on fruit-bearing trees.

In the Mediterranean, several local species of predators and parasitoids are associated with the citrus mealybug. However, their role as biocontrol agents in lowering the population to an economically acceptable level has never been thoroughly assessed. The major introduced natural enemies are not well adapted to the Mediterranean climate. In Israel, for example, the encyrtids *Leptomastix dactylopii* (Howard) and *Anagyrus pseudococci* are both susceptible to low temperatures; the former has failed to become established due to the low winter temperatures, while the latter manages to survive the winter although in reduced numbers. The activity of another encyrtid, *Coccidoxenoides peregrinus* (Timberlake), is low due to the high summer temperatures, whereas the coccinellid *Cryptolaemus montrouzieri* Mulsant occurs in very low densities and is unable to respond in time to the population changes of this mealybug. Since the origin of the citrus mealybug is not clear, there is little chance of improving its control by acclimatization of additional specific enemies.

Since classical biological control has failed to solve the problem of the citrus mealybug in many citrus-growing countries, augmentative releases have been suggested and practised. Augmentative releases against insect pests have been successfully practised in controlled environments (Van Lenteren & Woets, 1988). Effective augmentative biological control of the mealybugs has been achieved in interior landscapes and greenhouses (Hennekam *et al.*, 1987; Tingle, 1985; Carvalho, 1994). The inferiority of inundative releases in open areas as compared with greenhouses is evident and augmentation of natural enemies is often too expensive to compete with synthetic insecticides. However, there are some reports of successful use of *L. dactylopii* and/or *C. montrouzieri* in Queensland (Smith *et al.*, 1988), Spain (Llorens, 1994), Italy (Spicciarelli *et al.*, 1994), India (Krishnamoorthy & Singh, 1987; Krishnamoorthy, 1990) and Turkey (I. Karaca, pers. comm.).

This paper reports the results of a five-year project on the control of the citrus mealybug by augmentative releases of parasitoids. Two hymenopterous species were selected for this project. *Leptomastix dactylopii*, which displays a high specificity to *Planococcus* spp., was the first obvious choice. The parasitoid has been frequently used in greenhouses against the pest in Europe (Copland *et al.*, 1985). Although our findings indicate that *L. dactylopii* cannot survive the winter in Israel (e.g., Klein, 1994), this was not thought to be a significant obstacle in augmentative biological control, since it was expected to act during the warm season (e.g., Tingle & Copland, 1988). *Anagyrus pseudococci* (Girault) is another promising candidate, although it had been considered less specific than the former (Bodenheimer, 1951) and a significant portion of its progeny is lost due to egg encapsulation (Blumberg *et al.*, 1995). It is the dominant parasitoid of *P. citri* in the relatively warmer parts of the Mediterranean region and so is probably more suited to the climate of the Near East than *L. dactylopii.* However, when the project was initiated, *A. pseudococci* was not commercially available and, hence, this species has only been used in the last two years of the project. Augmentative releases of two predator species, *C. montrouzieri* and the sympherobiid *Sympherobius sanctus* Tjider, were also considered during the planning of this project but preliminary results showed that their establishment was very poor and the recovery of *S. sanctus* was practically nil (Gross, Steinberg & Mendel, unpublished data).

## MATERIALS AND METHODS

The experiments were carried out between 1993 and 1997. All treatments were conducted in commercial groves of *P. citri*-susceptible varieties, i.e. "Sweetie", red grapefruit, Marsh grapefruit or pomelo. Each experiment consisted of plots where the parasitoids were released (treated) as well as control (untreated) plots. Each plot was at least 2 hectares. The details for each experiment are given in Tables 1-4. In general, samples consisted of 20 fruits/tree in spring (until early June) and of 10 fruits/tree in summer, taken from 10 randomly selected trees, as suggested by Klein (1994). In 1994, we established 4 groups of 6 neighbouring trees in each plot (treated or control); we also eliminated the released parasitoids from two of the groups by caging them with 50 mesh nets. Fruit samples in 1994 consisted of 15 fruits per tree (24 trees per plot). The following parameters were recorded for each sample: number of (a) heavily infested fruits, (b) live mature larvae and live females of *P. citri* per fruit, (c) parasitized mealybugs per fruit, (d) fruits injured by fruit moths and (e) development of cork ring (a scar or necrotic ring that develops as a result of a wound periderm induced by feeding by the mealybug).

Mass rearing of the natural enemies was conducted by the Biological Control Industries, Sedé Eliyyahu, Israel, on citrus mealybug infesting potato sprouts. Releases were made mainly in the morning and, in most cases, a single introduction of the natural enemies was made but in a few cases, sequential releases over a period of 10 days were conducted. The initial number of released parasitoids, 5,000 per hectare, was established according to a compromise between our estimated optimal density (e.g., Smith *et al.*, 1988) and cost. The price of 5,000 individuals (more than 50% females) per hectare is equivalent to a single application of chlorpyrifos.

The relative density of natural enemies was determined in 1993-1995 by counting all emerging parasitoids from *P. citri* removed from the sampled fruits. In 1996-1997, use was made of small cages baited with a potato sprout infested with several hundred adult females of *P. citri*. These "potato-traps" were suspended inside the crowns of five trees per plot selected at random in treated and control plots for two weeks. The immature larvae of predators were removed and each potato sprout was placed in a rearing box from which the emerging parasitoids were collected daily and counted.

The mean number of emerging parasitoids per 'potato-trap' per plot was calculated. We combined the means obtained with either species or species combination (in 1996) and release rates (in 1997) into a single mean, and compared the results to those of the control plots. Differences in rates of fruit infestation and mealybug density per fruit between regions, groups of adjacent plots and between treated and non-treated plots were examined by two-way ANOVA (Sokal & Rohlf, 1981).

## RESULTS

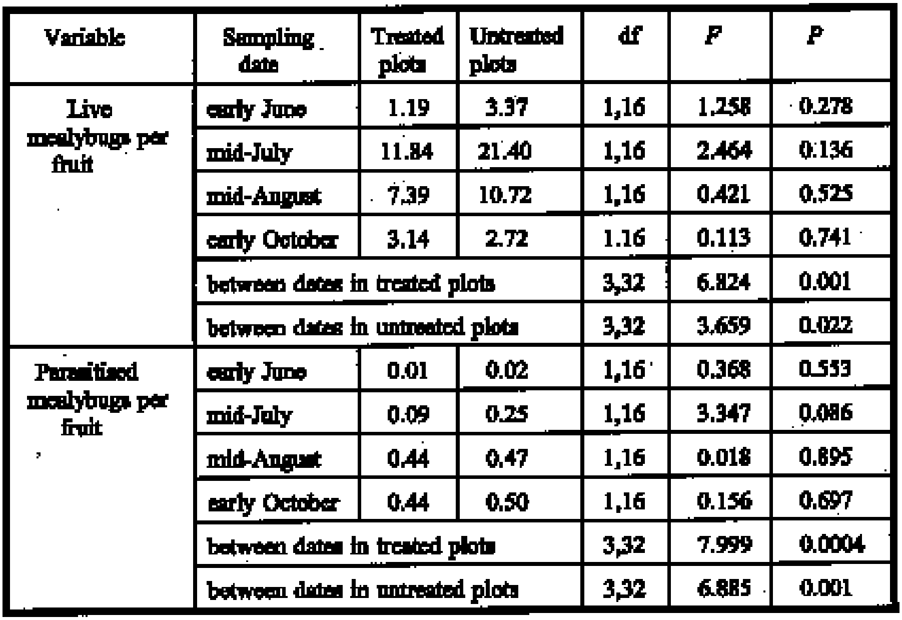
Except for a single occurrence of each of *L. abnormis* and *C. peregrinus,* only *L. dactylopii* and *A. pseudococci* emerged in significant numbers from the mealybug infested fruits or 'potato-traps'.

In 1993, *L. dactylopii* was present in all release plots as well as in most adjacent control plots situated a distance of 200-500m from the treated plots. In early July, *L. dactylopii* was the major parasitoid emerging from mealybugs removed from fruits taken from treated (79.3 ± 21.8%) and control (74.4 ± 29.5%) plots. The level of fruit infestation varied a great deal among plots ($P<0.0001$). Significant differences in live and parasitized mealybugs per fruit were found between sampling dates for treated and untreated plots. However, differences in the number of live and parasitized mealybugs between treated and control plots were not significant at any sampling date (Table 1).

In contrast to the results of 1993, recovery of *L. dactylopii* in 1994 was only from the treated plots and consisted of 4.7 ± 2.7% of the total parasitoids emerging from the infested fruits. All other recovered parasitoids were *A. pseudococci*. Differences in the number of live and parasitized mealybugs per fruit and the damage by fruit moths were not significant between treated and untreated plots, nor between netted and non-netted trees for the three sampling dates (Table 2).

Recovery of *L. dactylopii* in early July 1995 from mealybug-infested fruits was as low as 2.0 ± 2.3%; all other parasitoids were *A. pseudococci.* In 1996, the recovery of *L. dactylopii* and *A. pseudococci* from 'potato traps' varied with time, with practically nil parasitoids being recovered from traps in the control plots exposed during the first two weeks after the release, whereas, in the treated plots, the mean number of *L. dactylopii* and *A. pseudococci* per trap was 13.0 and 22.0 respectively (Fig. 1). On May 16, the number of *A. pseudococci* had increased to 40.0 per trap, while that of *L. dactylopii* had decreased to the same level as that of *A. pseudococci* in the non-treated plots, i.e. about 8.0 individuals per trap. Two months later, the number of *A. pseudococci* per 'potato-trap' was the same in the treated and control plots, and a further decrease was recorded in number of *L. dactylopii.* By mid-August, the number of *A. pseudococci* per trap had dropped to 2.0 per trap in both treated and untreated plots, whereas *L. dactylopii* failed to recover. The number of live and parasitized mealybugs per fruit, the rate of fruit heavily infested by the scale and the percentage fruits damaged by fruit moths did not differ significantly between treated and non-treated plots in either early August 1995 or in late July 1996 (see Table 3).

Table 1. Mean number of live and parasitised citrus mealybugs in 1993 (means from 4 locations (Bet She'an Valley, Sharon, western Galilee, Yezrae'el Valley); total number of plots for each treatment = 11). Inundative releases of 5000 *Leptomastix dactylopii* per hectare between the end of May and early July.



| Variable | Sampling date | Treated plots | Untreated plots | df | F | P |
|---|---|---|---|---|---|---|
| Live mealybugs per fruit | early June | 1.19 | 3.37 | 1,16 | 1.258 | 0.278 |
| | mid-July | 11.84 | 21.40 | 1,16 | 2.464 | 0.136 |
| | mid-August | 7.39 | 10.72 | 1,16 | 0.421 | 0.525 |
| | early October | 3.14 | 2.72 | 1.16 | 0.113 | 0.741 |
| | between dates in treated plots | | | 3,32 | 6.824 | 0.001 |
| | between dates in untreated plots | | | 3,32 | 3.659 | 0.022 |
| Parasitised mealybugs per fruit | early June | 0.01 | 0.02 | 1,16 | 0.368 | 0.533 |
| | mid-July | 0.09 | 0.25 | 1,16 | 3.347 | 0.086 |
| | mid-August | 0.44 | 0.47 | 1,16 | 0.018 | 0.895 |
| | early October | 0.44 | 0.50 | 1,16 | 0.156 | 0.697 |
| | between dates in treated plots | | | 3,32 | 7.999 | 0.0004 |
| | between dates in untreated plots | | | 3,32 | 6.885 | 0.001 |

Table 2. Mean number of live and parasitised citrus mealybugs in 1994 (means from 2 locations: eastern Galilee, Yezrae'el Valley); total number of plots for each treatment = 3). Inundative releases of 5000 *Leptomastix dactylopii* per hectare over a period of 10 days in mid-June. Additional netted trees served as a control in both the treated and untreated plots

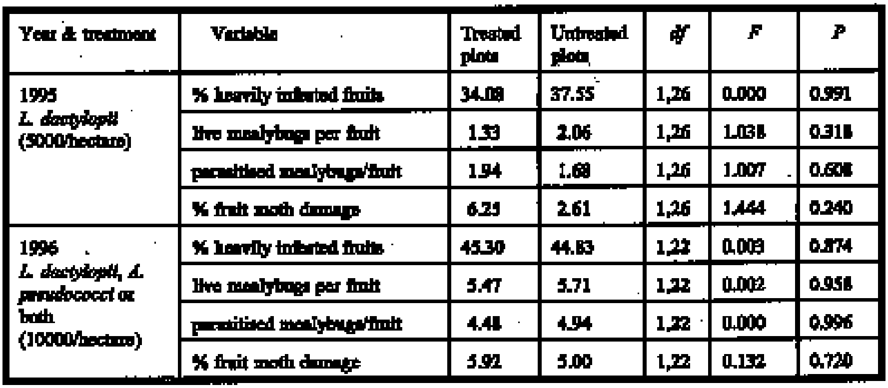
| **Variable** | **sampling date** | **Treated plots** | | **Untreated plots** | | ***F* (3,20)** | ***P*** |
|---|---|---|---|---|---|---|---|
| | | **netted trees** | **un-netted trees** | **netted trees** | **un-netted trees** | | |
| **Live mealybugs per fruit** | **5 June** | **8.15** | **7.30** | **3.48** | **3.97** | **1.268** | **0.312** |
| | **19 July** | **1.15** | **0.94** | **3.20** | **0.68** | **1.436** | **0.262** |
| | **11 October** | **0** | **0** | **0.01** | **0.02** | **0.880** | **0.467** |
| **Parasitised mealybugs per fruit** | **5 June** | **0.13** | **0.09** | **0.07** | **0.05** | **0.778** | **0.520** |
| | **19 July** | **1.77** | **2.00** | **2.13** | **0.73** | **0.997** | **0.419** |
| | **11 October** | **0** | **0** | **0** | **0** | **1.667** | **0.413** |
| **% fruits damaged by fruit moths** | **5 June** | **0.33** | **0** | **0** | **0** | **0.166** | **0.413** |
| | **19 July** | **2.66** | **6.00** | **4.00** | **2.67** | **0.946** | **0.437** |
| | **11 October** | **5.66** | **15.67** | **28.33** | **20.33** | **0.903** | **0.457** |

Results on the recovery of *A. pseudococci* from 'potato-traps' during 1997 were fairly similar to 1996 (Fig. 2). On April 16, during the first two weeks after release, recovery of the parasitoids in the non-treated plots was 0.7 per trap whereas in the treated plots its average was 11.0. On May 15, the number of *A. pseudococci* increased to 58.0, while it only increased in the non-treated plots to 9.0 per trap. A month later, the numbers remained unchanged in the non-treated plots but had decreased in the treated plots. From August, a further decrease was observed in the numbers of *A. pseudococci*, which did not differ significantly between treated and non-treated plots. For all three sampling dates, live and parasitized mealybugs per fruits, as well as percentage fruits damaged by moths and/or cork rings did not differ significantly among treatments (Table 4).

## DISCUSSION

Periodic releases of natural enemies are a second choice after classical biological control (DeBach & Rosen, 1991). Israeli citrus groves constitute an unfavourable, disturbed environment for the major natural enemies of the citrus mealybug. Tingle and Copland (1988) showed that temperature has a major impact on parasitism of both *A. pseudococci* and *L. dactylopii*. For example, immature stages of the former species are susceptible to temperatures below 15°C (Battaglia & Tranfaglia, 1994; Krishnamoorthy, 1989) and, therefore, the low spring temperatures in Israel delay the population increase in the early season, thus affecting the establishment of naturally occurring *A. pseudococci*. Later in the season, the natural enemies are decimated by climatic extremes, the large fluctuations in the mealybug populations and the late summer aerial applications of malathion against the Mediterranean fruit fly. Under these conditions, which are common in Israeli groves, augmentative releases may be a feasible alternative (e.g., DeBach & Rosen, 1991).

Table 3. Mean number of live and parasitised citrus mealybugs in 1995 and 1996 (means from 2 locations: 1995: central coastal plain, Yezrae'el Valley; 1996: southern coastal plain, Yezrae'el Valley; for number of plots see below). Inundative releases of 5000 *Leptomastix dactylopii* per hectare in mid-May (1995) and of 10,000 *L. dactylopii* or 10,000 *A. pseudococci* or 7000 *L. dactylopii* + 3000 *A. pseudococci* released over a period of 10 days between mid- to late April, 1996. In 1995, there were 12 treated plots and 12 untreated plots of susceptible varieties (Sweetie, red grapefruit and Marsh grapefruit) and 12 untreated plots of non-susceptible varieties (Shamuti and Valencia orange); in 1996, there were 2 plots with *L. dactylopii*, 3 plots with *A. pseudococci* and 7 plots with mixed parasitoids. Five "potato-traps" per plot were put out from mid-April to mid-August 1996.



| Year & treatment | Variable | Treated plots | Untreated plots | *df* | *F* | *P* |
|---|---|---|---|---|---|---|
| 1995<br>*L. dactylopii*<br>(5000/hectare) | % heavily infested fruits | 34.08 | 37.55 | 1,26 | 0.000 | 0.991 |
| | live mealybugs per fruit | 1.33 | 2.06 | 1,26 | 1.038 | 0.318 |
| | parasitised mealybugs/fruit | 1.94 | 1.68 | 1,26 | 1.007 | 0.608 |
| | % fruit moth damage | 6.25 | 2.61 | 1,26 | 1.444 | 0.240 |
| 1996<br>*L. dactylopii, A. pseudococci* or both<br>(10000/hectare) | % heavily infested fruits | 45.30 | 44.83 | 1,22 | 0.003 | 0.874 |
| | live mealybugs per fruit | 5.47 | 5.71 | 1,22 | 0.002 | 0.958 |
| | parasitised mealybugs/fruit | 4.48 | 4.94 | 1,22 | 0.000 | 0.996 |
| | % fruit moth damage | 5.92 | 5.00 | 1,22 | 0.132 | 0.720 |

In the present study, therefore, augmentative releases were considered as an option due to the poor performance of the local natural enemies, the ineffectiveness of chemical control and the fact that all known potential candidates for classical biological control (e.g., Bartlett, 1978; Moore, 1988) have already been tested in Israel. Laboratory parameters characterizing parasitoid efficacy, are often unrealistic (Godfrey & Waage, 1991) and so our selection of *L. dactylopii* and *A. pseudococci* was based mainly on host suitability and environmental adaptation, and on positive results reported in previous studies on the release of *L. dactylopii* (Krishnamoorthy & Singh, 1987; Smith *et al.*, 1988; Spicciarelli *et al.*, 1994; Llorens, 1994).

Assessing the efficacy of inundative releases of a biological control agent can be done by a quantitative evaluation of the reduction of the targeted pest population and/or by the economic impact, based on comparison with plots to which additional natural enemies have not been applied (e.g., Bellows *et al.*, 1992). Based on such comparisons, our results under local conditions show that augmentation by *L. dactylopii* (with dosages of 5,000 and 10,000 individuals per hectare) or by *A. pseudococci* (with dosages of 10,000, 20,000 and 50,000 per hectare) did not improve citrus mealybug control on the tested citrus varieties.

Table 4. Mean number of live and parasitised citrus mealybugs in 1997 (Yezrae'el Valley); 3 plots for each of three dosages plus 9 control plots. Inundative releases of 10,000, 20,000 or 50,000 *A. pseudococci* per hectare released over a period of 10 days between mid- to late March. Five "potato-traps" per plot were put out from mid-April to early October (a total of 90 traps).

| Variable | Sampling date | Treatment | | | | Control vs all *A. pseudococci* treatments | |
|---|---|---|---|---|---|---|---|
| | | Untreated plots | *A. pseudococci* per ha¹ | | | F (1,16) | P |
| | | | 10,000 | 20,000 | 50,000 | | |
| Live mealybugs per fruit | early June | 0.27 | 0.55 | 0.32 | 0.65 | 0.210 | 0.653 |
| | mid-July | 1.56 | 0.80 | 0.41 | 0.26 | 1.490 | 0.240 |
| | late August | 0.17 | 0.16 | 0.23 | 0.12 | 0.710 | 0.412 |
| Parasitised mealybugs per fruit | early June | 0.03 | 0.08 | 0.13 | 0.09 | 1.226 | 0.285 |
| | mid-July | 0.34 | 0.53 | 0.46 | 0.68 | 0.347 | 0.544 |
| | late August | 0.41 | 0.59 | 0.60 | 0.80 | 0.002 | 0.789 |
| % fruits with cork ring/fruit moth damage | late August | 2.60 | 6.33 | 9.67 | 17.00 | 2.783 | 0.115 |

Only in 1993 did *L. dactylopii* form the majority of the recovered parasitoids. During that particular season, it also established itself in most of the non-treated plots. This was probably due to the unusually cold winter (which resulted in very low populations of the local natural enemies) and the release in June of *L. dactylopii* which contributed to the good establishment

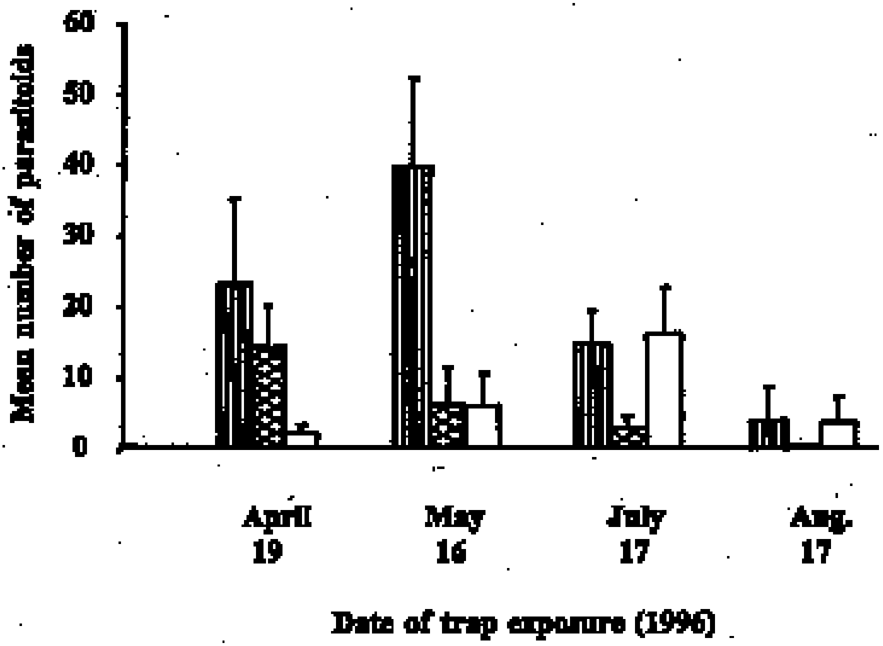


Figure 1. Mean number (+SE) of *Anagyrus pseudococci* (striped bars) and *Leptomastix dactylopii* (cross-hatched bars) that emerged from 'potato-traps_ per plot after being exposed for two weeks inside a crown of a citrus tree in treated and control plots (white bars). A total of 120 traps were activated in each sampling period, half of them in the control plots. In the treated plots release of the parasitoids was conducted in April 18, 1996, (10,000 *A. pseudococci*, 10,000 *L. dactylopii* or 3,000 *A. pseudococci* + 7,000 *L. dactylopii* per hectare).

of the parasitoid in the groves. These results encouraged us to locate the non-treated plots further away from the treated ones in 1994 and to establish additional controls consisting of netted trees. However, the recovery of *L. dactylopii* in 1994 was poor and the releases had no significant effect on the mealybug populations. Similar results were obtained in 1995.

Due to the poor recovery of *L. dactylopii* in 1994 and 1995, *A. pseudococci* was added to the experiment in 1996 as another treatment and the release dosage was increased to 10,000 individuals per ha. The releases were conducted a month earlier than in the previous years. Due to technical problems, releases consisted of only a single parasitoid species in five plots, whereas the other seven plots were treated with 7,000 *L. dactylopii* + 3,000 *A.*

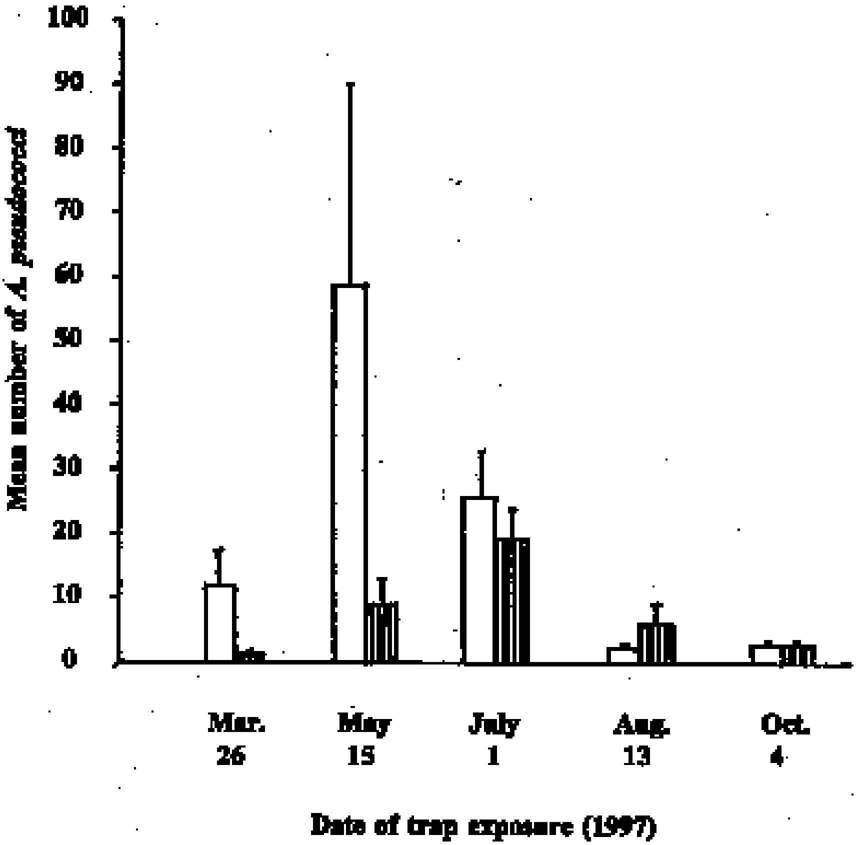


Figure 2. Mean number (+SE) of *Anagyrus pseudococci* that emerged per plot from 'potato-traps' after being exposed for two weeks inside a crown of a citrus tree in treated (white bars) and control (striped bars) plots. A total of 90 traps were activated in each sampling period, half of them in the control plots. In the treated plots release of the parasitoids was conducted in March 25, 1997 (10,000, 20,000 or 50,000 parasitoids per hectare).

*pseudococci* per ha. Even so, the inferiority of *L. dactylopii* to *A. pseudococci* could be observed soon after the release by its poor rate of recovery. Data obtained from the 'potato-traps' suggested that augmentation markedly improved parasitoid abundance during the first two months after the release but did not improve control of the mealybug.

In 1997, only *A. pseudococci* was tested, using additional high dosages of 20,000 and 50,000 per ha. The releases were conducted three weeks earlier than in the previous year in the hope of further improving the control. As in

1996, data obtained from the 'potato-traps' suggested that augmentation markedly improved the abundance of *A. pseudococci* during the first two months after its release. However, the release had no effect on the mealybug population nor on damage due to cork ring or on feeding damage by fruit moths. The somewhat low damage in the control plots, as compared to the non-treated plots, may be due to the use of several Marsh grapefruit and red grapefruit orchards. Feeding scars are rarely caused in grapefruit and, therefore, cork ring is rarely induced in the latter varieties.

Our results proved the better adaptability of *A. pseudococci* to local conditions compared with *L. dactylopii.* It is tempting to speculate that the poor establishment of *L. dactylopii* in 1994 and 1995 may have been the result of releasing poor quality parasitoids. Nevertheless, even increased dosages and earlier releases of *A. pseudococci* did not improve control of the mealybug. Moreover, even a rate of 50,000 parasitoids per ha was probably too little to control the mealybug, and the released parasitoids were unable to catch up with the rapid increase of the mealybug population during the critical period. In our case, the densities of released parasitoids may be considered as intermediate between inoculative and inundative releases (see Rosen, 1985). It was anticipated that the released parasitoids would establish their population in the first generation of the mealybug and, by the second or third parasitoid generation, would cause a reduction in the second mealybug generation. Therefore, the release of the parasitoids early in the season was expected to be an advantage. However, even the earliest releases, in mid-March, did not result in any significant reduction in the mealybug population. No information is available on the rate of migration of the released parasitoid from the relatively small treated plots to surrounding untreated groves, although such migration should be expected, especially early in the season when mealybug density is still low. Early releases face other problems - rain and cold periods. Hence, the low mealybug population and the extreme weather conditions probably hampered the establishment of the parasitoids at the release site.

Augmentative releases of parasitoids or predators may be effective against the citrus mealybug in areas where citrus varieties are not highly susceptible, where other mealybug species are not key problems, and where the growing period of the tree and the development of the mealybug population last well into the summer. This situation occurs in California, where inoculative releases of *C. montrouzieri* in the summer are able to reduce the mealybug population towards the end of the season (e.g., DeBach & Hagen, 1964). Sufficient control is achieved in California because their orchards are not injured by moderate populations of the mealybug and fruit moths are not a problem.

In Israel on the other hand, fruit infestation and damage occurs between May and mid- July. Soon after that, the mealybug population ceases to grow and feeding damage and sooty mould reach their peak. Although the natural enemies and intraspecific competition then destroy the stagnating population of the pest, much of the feeding injury by fruit moths has already been done. Fruit moths are attracted to infested fruits despite the absence of live mealybugs. Hence, the failure in the present study to reduce fruit moth damage by augmentative releases of parasitoids in orchards of red grapefruit and Sweetie was probably related to the rapid increase of the mealybug population. This rapid increase was the result of fast fruit development on these mealybug-susceptible varieties. We expected to achieve control by the release of large numbers of *A. pseudococci*, since these releases had a pronounced impact on the parasitoid density in the grove during the development of the first mealybug generation on fruit. However, it seemed that desirable levels of control could not be achieved because the build-up of the second mealybug generation, which causes the main damage to the fruits, was not prevented by release of parasitoids at any of the tested dosages.

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TAWFIK, M.H.; GHABBOUR, M.W.
*Plant Protection Research Institute, Agricultural Research Center, Dokki, Egypt*

# MONITORING CALIFORNIA RED SCALE AND ITS APHELINID PARASITOID USING YELLOW STICKY TRAPS.

## ABSTRACT

MONITORING CALIFORNIA RED SCALE AND ITS APHELINID PARASITOID USING YELLOW STICKY TRAPS.

Yellow sticky traps, which had been erected to monitor the dispersal of the sweet-potato whitefly, *Bemisia tabaci* Gennadius, from cotton fields to citrus orchards in Texas, also attracted adult male *Aonidiella aurantii* (Maskell) and its parasitoid *Aphytis* sp. Populations in three citrus orchards representing different host-plant varieties and maturity were studied and the effect of these and some environmental parameters on the numbers of male *A. aurantii* and of its parasitoid caught on the traps are described.

Key words: Rio Grand Valley, Aphelinidae, Diaspididae, flight periods, temperature, relative humidity, evaporation, wind speed, correlations

## INTRODUCTION

Recently (1990), *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodoidea), a major polyphagous pest on many crops, has invaded citrus in the Rio Grand Valley, Texas, where it infested young grapefruit, sweet orange, lemon and mandarin in a field nursery. It is considered that the whitefly disperses from local cotton crops into the nearby citrus orchards and, in order to monitor this movement, yellow sticky traps were used. Yellow sticky traps have been used commercially in the United States for several years to monitor the California red scale (*Aonidiella aurantii* (Maskell)) (Hemiptera: Coccoidea: Diaspididae) populations and so it was not surprising that these traps also caught adult male red scale. In addition, it also caught a species of *Aphytis* (Hymenoptera: Aphelinidae) which was believed to be a parasitoid of the red scale. *A. aurantii* is one of the most important pests of citrus in Texas, causing economic loss through a reduction in tree vitality and in a downgrading of infested fruits (Georgala, 1988).

Several species of *Aphytis* are important parasitoids in biocontrol programmes directed against serious diaspidid pests. Moreno *et al.* (1984) indicated that sticky yellow cards attracted *Aphytis melinus* but also showed that the number of male *A. aurantii* caught on the traps was not correlated with population declines of female scale caused by *Aphytis* sp.

This paper considers the use of yellow traps to monitor (a) peak flight periods of *A. aurantii* as a method of predicting populations on fruit and to assist in interpreting or facilitating pest management decisions in the orchards, and (b) populations of its parasitoid, *Aphytis* sp.

## MATERIALS AND METHODS

The following observations were made in three citrus orchards on the Texas Agricultural Experiment Station, Weslaco, Texas, between June and October, 1993 using rectangular yellow sticky traps (each side 7.5cm long x 1.5cm wide; 93.75cm$^2$ in area), placed in a horizontal position. Each trap was coated with a thin layer of insect trapping adhesive. The traps in the citrus orchards were inside the tree, pointing in a north-west direction. To count the insects captured on the traps, a fifth of one side of each trap (area of 18.75cm$^2$) was thoroughly examined. The sticky traps were replaced by fresh traps each week. Counting started on 14th June in the citrus orchards and lasted for 17 weeks. For this experiment, the three orchards used were as follows:

*Site 1*: old grapefruit, planted June 1985. Area 2.74 acres, with a total of 640 trees. Sixteen traps counted weekly.

*Site 2*: Old marrs-orange, planted June 1985. Area 1.5 acres, with a total of 154 trees. Six traps counted weekly.

*Site 3*: Rio-red young grapefruit, planted January 1993. Area 1.5 acres, with a total of 154 trees. Six traps counted weekly.

The effect of climatic factors (i.e. temperature, relative humidity, evaporation (in inches/day) and wind (in miles/h)) on the numbers of *A. aurantii* and *Aphytis* sp. caught on the traps (and therefore the effect of these factors on flight behaviour) was calculated using simple correlations to verify their influence.

## RESULTS AND DISCUSSION

The biological control of scale insects on citrus in the lower Rio Grand Valley, Texas, has been economically important for the past 23 years. Male flight patterns have been shown to reflect the development of the scale generations, with peaks in the number of males as shown by pheromone traps coinciding with peaks in the number of virgin females (Kennett & Hoffmann, 1985).

The mean number of adult male *A. aurantii* caught each week in the three citrus orchards is shown in Fig. 1. A few males were caught most weeks but

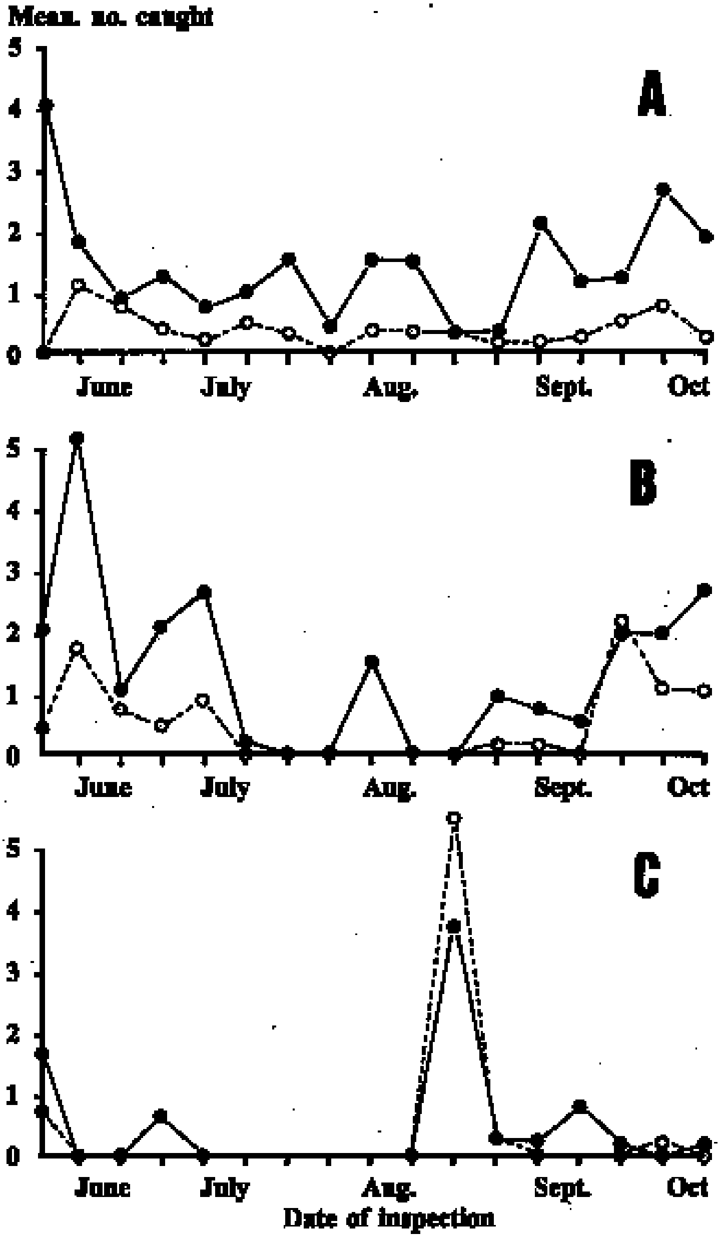


Fig. 1. Mean number of *Aphytis* sp. (•——•) and male *A. aurantii* (o—o) caught weekly on yellow sticky traps in three orchards in Texas: **A**. mature grapefruit orchard, **B**. mature orange orchard, and **C**. young grapefruit orchard.

there were slight peaks in June and September in the mature orchards but only one (quite distinct, in Aug.) in the younger orchard. Fig. 1 also shows the population fluctuations of *Aphytis* sp. The number of *Aphytis* sp. caught was generally greater than the number of male red scales caught.

Table 1 looks at the correlations between the number of male scales caught on the traps each week and the number of *Aphytis* caught. There were highly significant correlations in the orange and young grapefruit orchards but no clear correlation in the mature grapefruit orchard. As indicated above, the number of males caught on the trap will be closely correlated with the appearance of young virgin females in the orchards (Kennett & Hoffmann, 1985). The close correlation between the numbers of *Aphytus* sp. caught with that of the adult males shows that the parasitoid populations were also correlated with the appearance of the teneral adult female. Moreno *et al.* (1984) indicated that the number of male scales caught on the yellow cards was not correlated with population declines of female scale caused by *Aphytis* sp. In other words, because the parasitoid only attacks the female stages, quite large numbers of males may emerge even when the female population has been reduced by parasitism (Moreno & Luck, 1992). Nonetheless, the coincidence of male and parasitoid populations ensures that the parasitoids are around to attack the surviving females at the correct time. The close correlation between flight times of male diaspidid scales and their parasitoids was also found by Hippe & Mani (1995), who noted that the two main flight periods of male San José Scale, *Quadraspidiotus perniciosus* (Comstock), in May and September coincided with the appearance of its parasite, *Encarsia perniciosi* (Tower), captured on pheromone traps.

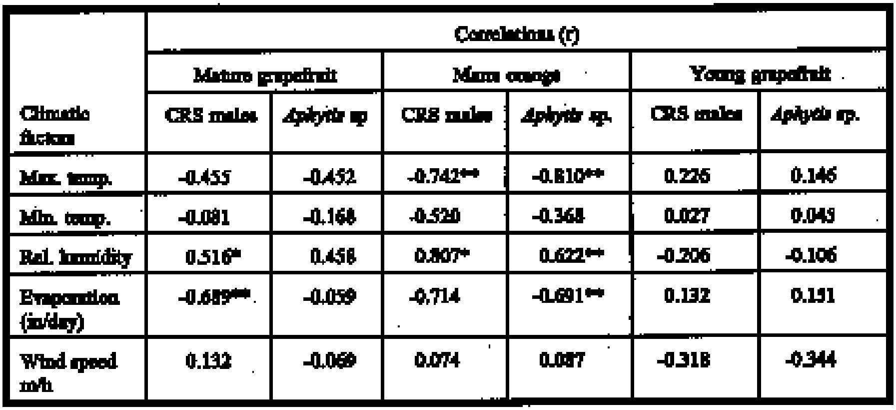
Table 1. Correlations between the number of male *A. aurantii* and its parasitoid *Aphytis* sp. caught on yellow sticky traps in three different citrus orchards in Texas, 1993.

| Correlations | mature grapefruit orchard | Marrs Orange orchard | Young grapefruit orchard |
|---|---|---|---|
| r | 0.051 | 0.782** | 0.922** |
| b | 0.018 | 0.393 | 1.922 |

These results confirm that male flight phenology can be used to time the chemical control of *A. aurantii*, when chemicals are being used. In addition, Walker *et al.* (1990) indicated that the optimal timing for the release of biological control agents for the control of red scale was 2-4 weeks after the peak of the second male flight period, which in our case was probably June. Using this information, release of *Aphytis melinus* when the virgin females were most abundant relative to other stages was found to reduce the percentage of scale-infested fruit (Moreno & Kennett, 1985).

The correlations between the numbers of male *A. aurantii* and its parasitoid *Aphytis* sp. caught on yellow sticky traps with certain climatic factors are shown in Table 2. The correlations for both insects with most of the climatic factors tested here were similar, with similar degrees of significance, especially on mature grapefruit and orange, both, for instance, responding negatively to maximum and minimum temperatures. These observations support the significant positive correlation between the numbers of male *A. aurantii* and *Aphytis* sp. caught on the traps noted in Table 1. These results also explain why so few were caught on August 2 when the temperature was over 99°F in all three orchards, a temperature which is presumably above the flight threshold of both species. Both male *A. aurantii* and *Aphytis* sp. also showed highly significant positive correlations with relative humidity, which might partially explain the peak on September 20 when the Relative Humidity reached its maximum (85.3% in the mature orange orchard, Fig. 1B). With regard to the young grapefruit data, there were slight positive correlations with maximum and minimum temperatures and a negative correlation to relative humidity - the reverse to that noted in

Table 2. Correlations of the number of male *A. aurantii* and its parasitoid *Aphytis* sp. caught on yellow sticky traps in three citrus orchard in Texas, 1993, with certain climatic factors.



| Climatic factors | Correlations (r) | | | | | |
|---|---|---|---|---|---|---|
| | Mature grapefruit | | Mature orange | | Young grapefruit | |
| | CRS males | *Aphytis* sp | CRS males | *Aphytis* sp. | CRS males | *Aphytis* sp. |
| Max. temp. | -0.455 | -0.452 | -0.742** | -0.810** | 0.226 | 0.146 |
| Min. temp. | -0.081 | -0.168 | -0.520 | -0.368 | 0.027 | 0.043 |
| Rel. humidity | 0.516* | 0.458 | 0.507* | 0.622** | -0.206 | -0.106 |
| Evaporation (in/day) | -0.689** | -0.059 | -0.714 | -0.691** | 0.132 | 0.151 |
| Wind speed m/h | 0.132 | -0.069 | 0.074 | 0.087 | -0.318 | -0.344 |

**where CRS = California red scale; * = significant at P<0.05 level; ** = significant at P<0.01 level.**

the more mature orchards. The reasons for this are unclear.

It is concluded that: i. yellow sticky traps could be a useful method of monitoring not only the flight periods of male *A. aurantii*, but also the activity of its parasitoid, *Aphytis* sp.; ii. there appears to be a good correlation between peak flight periods of male scales and of *Aphytis* sp. caught on the traps, and iii. that the flight activity of both the male scales and the parasitoid appear to be similarly affected by the climatic factors studied here.

## ACKNOWLEDGMENTS

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# BIOLOGICAL MONITORING, SAMPLING TECHNIQUES AND BIOLOGICAL AND CHEMICAL CONTROL: Posters and Abstracts:

## THE IMPORTANCE OF OILS IN THE INTEGRATED MANAGEMENT OF THE PYRIFORM SCALE IN AVOCADO ORCHARDS IN ISRAEL.

BEN-YEHUDA, S.[1]; HADAR, D. [2]; WYSOKY, M. [2]; IZHAR, Y.[2]; SWIRSKI, E. [2]
[1]*Plant Protection Division, The Extension Service, Ministry of Agriculture, Tel Aviv, 61070, Israel;*
[2]*Department of Entomology, Agricultural Research Organisation, Bet-Dagan, 50250, Israel*
*Email: zmendel@netvision.net.il*

The pyriform scale, *Protopulvinaria pyriformis* (Cockerell) (Hemiptera: Coccoidea: Coccidae) was discovered in Israel in 1980 and within a few years had spread to most of the avocado growing regions of the country. Several major avocado varieties (mainly Nabal) are highly susceptible to the pyriform scale. Other less susceptible avocado varieties, in the vicinity of the infected sites, can become damaged as well. The damage is caused by the secretion of large amounts of honeydew, resulting in a thick cover of sooty-mould on the leaves and on the fruit. Despite the large numbers of local natural enemies which accumulate in infested areas, as well as the establishment of the introduced encyrtid *Metaphycus stanleyi* Compere, which between them often cause high mortality of the scale, injury to susceptible avocado varieties has not been prevented. As a routine, application of synthetic insecticides in avocado orchards in Israel is avoided. Hence, to lower the pyriform scale populations with minimum negative consequences to the natural enemies, we studied the effect of several oils and a soap applications on the pyriform scale and the activity of the natural enemies. Several mineral oils ("mayonnaise-type" 1.75% (80% *A.I.*) and "stylet-oil" 1% (80% *A.I.*)) effectively controlled the scale nymphal stages. Therefore, oil application is conducted in the spring (February-April) and in the second half of the summer (July-October), when the population consists of mainly immature stages. Cotton oil and soap (potassium salt of fatty acids) were less effective. Application of the above mentioned compounds did not interfere with the activity of the natural enemies of the scale.

## A TECHNIQUE TO OBTAIN THE EGGS OF THE ARARAT COCHINEAL.

SARKISSOV, R.N.; MKRTCHIAN, L.P.; ZAKHARIAN, V.A.
*Institute of Zoology, Armenian NAS, Yereven, Armenia.*
*Email: aaa@triada.armenia.su*

Ararat cochineal (*Porphyrophora* sp.) produces a valuable, light-resistant red carmine dye. To protect this rare species and to increase its productivity, a technique for breeding it under artificial conditions has been developed. This has allowed a 5-6 times increase in body-mass yield and, therefore, of dye. The most laborious part of the technique is gathering the eggs during the spring and summer from wild plants for use in the greenhouse.

We have improved this technique. We now use wooden boxes (50 x 50 x 15 cms), with the bottom covered with gauze. The boxes are filled with 10 cm of soil derived from cochineal areas. Adult male and female cochineal insects are then placed in the boxes. Once fertilized, the females dig themselves into the soil, form the ovisac and lay their eggs. After 30-50 days, the boxes are transferred to cochineal natural areas and dug into the ground, level with the soil surface. The boxes are then maintained under these field conditions from November through to February, so that the eggs hibernate under natural conditions. The boxes are then collected and transferred to the laboratory, where the eggs are collected and are used either for the spring infection of plants or are kept in the refrigerator to infect plants in the summer. This has proved to be a very labour-saving technique.

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BOGO, A.[1]; WATSON, G.W.[2]; MANTLE, P.G.[1]; MOTTANA, G.M.[3]
*[1]Biochemistry Department, Imperial College of Science, Technology and Medicine, London, SW7 2AY, UK. [2]CABI BIOSCIENCE, c/o Entomology Department, The Natural History Museum, London, SW7 5BD, UK. [3]Department of Food Technology, Federal University of Santa Catarina, Florianopolis, Brazil.*

# HONEYDEW SUGARS ELIMINATED BY *STIGMACOCCUS* SP. NR. *ASPER* HEMPEL (HEMIPTERA: MARGARODIDAE) FEEDING ON LEGUMINOUS TREES IN BRAZIL.

## ABSTRACT

Honeydew sugars eliminated by *Stigmacoccus* sp. nr *asper* Hempel (Hemiptera: Margarodidae) feeding on leguminous trees in Brazil.

The sooty mould coating the trunks of mature trees of *Schizolobium excelsum* in Brazil was found to be associated with honeydew being eliminated by an undescribed species of margarodid near *Stigmacoccus asper* Hempel. Analysis of the honeydew sugars by paper chromatography revealed a complex composition. The principal sugar was sucrose, but there were significant amounts of fructose, glucose and three components identified as di-, tri- and tetrasaccharides. The disaccharides were maltose, trehalose, trehalulose and a hexose-hexitol. The other, apparently novel, pair of oligosaccharides were composed of glucose(s) 1,4 linked to the glucose of sucrose. The sugar composition of the tree sap was also determined and found to be glucose and sucrose only. The findings, therefore, imply significant and novel metabolic transformations of sugars by the scale insect and/or its microbial symbionts.

Key words: Xylococcinae, sexual reproduction, stigmatriose, stigmatetraose, Amazonia.

## INTRODUCTION

Black sooty moulds were noticed coating the trunks of mature trees of *Schizolobium excelsum* (Leguminosae). These trees are native to Amazonia, but have been planted in a small area of dense forest in the Botanic Garden of the Federal University of Santa Catarina, Florianopolis, Brazil. Closer investigation revealed frequent, hair-like, waxy, filamentous tubes protruding 5-8cm laterally from the bark, each bearing a clear honeydew droplet which was visited by flying insects. This striking phenomenon stimulated study of the scale insect involved and of the sugar composition of the tree sap and eliminated honeydew.

## MATERIALS AND METHODS

Honeydew (10-20µl) was collected from each wax filament separately by capillarity into a fine glass tube. Approximately 50 specimens of the honeydew-producing scale insects were collected by slicing beneath each insect to remove a thin layer of bark along with the specimen. This left the insect's severed stylets in the tree but insured that the clypeus and labium were undamaged. The insects were preserved in 80% ethanol before preparation as slide mounts, using the method in Williams & Watson (1988). Keys and descriptions in Morrison (1928) and Foldi (1995), and comparison with museum specimens of *S. asper* Hempel, were used to identify the slide-mounted insects on the basis of their morphology and collection data.

A few minutes after each scale insect had been excised from the tree bark, leaving the stylets *in situ*, small amounts of plant sap appeared and were absorbed into a piece of filter paper. The honeydew and the exuded plant sap were analysed by descending chromatography on Whatman 3MM paper in n-propanol:ethyl acetate:water (7:1:2). Sugars were visualised using aniline hydrogen phthalate reagent, and sucrose, fructose and glucose were recognized by reference compounds. Other sugars were isolated preparatively and their structures determined by a combination of FAB-MS analysis of permethylated derivatives and the standard methodology for polysaccharide linkage analysis by GC-MS (Biermann & McGinnis, 1989).

## RESULTS

The honeydew-producing insects were identified as pre-adult females of an undescribed species of scale insect near *Stigmacoccus asper* Hempel (Margarodidae: Xylococcinae). Immature males were also collected, implying that reproduction in this species is sexual.

Paper chromatography showed that the principal honeydew sugar was sucrose (Table 1). Fructose was also clearly evident. There were lesser amounts of glucose and sugars with chromatographic mobilities indicative of di- and tri-saccharides. A tetrasaccharide, with the lowest chromatographic mobility, was the least abundant component.

The composition of the disaccharide group was complex, FAB-MS data showing an approximately 2:1 ratio of di-hexoses (m/z 477) to hexose-hexitol (m/z 493). The composition of the latter was not defined further. However, rechromatography and subdivision of the disaccharide region into 3 regions according to mobility enabled an interpretation of the complex GC-MS data for sugar linkage analysis as indicating the presence of trehalose, trehalulose and maltose.

The molecular masses of the permethylated trisaccharide and tetrasaccharide confirmed that each was composed only of hexose units.

Linkage analysis for the trisaccharide clearly showed glucopyranose linked either in the 1 position or in both 1 and 4 positions, and fructofuranose linked in the 2 position. In the tetrasaccharide, the amount of 1,4 linked glucose was doubled. Consequently, the deduced structures are as in Table 1 and the two are structurally related.

Table 1. Sugar composition of honeydew eliminated by *Stigmacoccus* sp. on *Schizolobium excelsum* at Florianopolis, Brazil, June 1998, listed in decreasing order of abundance of the six chromatographically separated groups of sugars.

| Sugar | Relative order of abundance | FAB-MS* | Monosaccharide composition by GC-MS |
|---|---|---|---|
| SUCROSE | 1 | | $G_1 - {}_2F$ |
| FRUCTOSE | 2 | | F |
| GLUCOSE | 3 | 477 | G |
| DISACCHARIDE GROUP | 3 | 477 | $G_1 - {}_4G$ = MALTOSE |
| | | 477 | $G_1 - {}_1F$ = TREHALULOSE |
| | | 477 | $G_1 - {}_1G$ = TREHALOSE |
| | | 493 | HEXOSE-HEXITOL |
| TRISACCHARIDE | 3 | 681 | $G_1 - {}_4G_1 - {}_2F$<br>"STIGMATRIOSE" |
| TETRA-SACCHARIDE | 4 | 885 | $G_1 - {}_4G_1 - {}_4G_1 - {}_2F$<br>"STIGMATETRAOSE" |

* measured mass of the sodiated molecular ion of permethylated compound(s).

Analysis of the liquid collected from the severed insect mouthparts showed that sucrose and glucose were the only sugars in the plant sap. There was no evidence of any of the other oligosaccharides which have been recognised in the honeydew eliminated by the scale insect.

## DISCUSSION

Trehalose and trehalulose have already been described as components of scale insect honeydew (Fisher *et al.*, 1984; Bates *et al.*, 1990). However, the occurrence of a hexitol disaccharide, maltose and two oligosaccharides containing glucose connected by 1,4 links to the glucose of sucrose, appear to be novel findings. Predictably, maltose could arise from the trisaccharide by invertase cleavage of the sucrose bond. Since the oligosaccharides also appear to be novel sugars (Liptak *et al.*, 1991), the trivial names “Stigmatriose” and “Stigmatetraose” are proposed.

The significant difference between the carbohydrate composition of eliminated honeydew and the plant sap, implied by analysis of exudate from the severed insect mouthparts, is attributed to metabolism within the scale insect. At present, it is not possible to differentiate between activity by the insect's enzymes and those of any microbial symbionts, such as have been described for other "Homoptera" (Bates *et al.*, 1990; Tremblay, 1990). However, the present application of modern analytical techniques to very small amounts of natural material demonstrates the potential for novel compound discovery. It also emphasises the complex biotransformations within scale insects, which, in the present example, form an integral part of a food web involving a wide range of flying insects.

The undescribed species of scale insect will be described and named once adult specimens are obtained.

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GILLANI, W.A.; COPLAND, M.J.W.
*Wye College, University of London, Ashford, Kent, TN25 5AH*

# DEFENSIVE BEHAVIOUR OF THE LONGTAILED MEALYBUG *PSEUDOCOCCUS LONGISPINUS* (TARGIONI TOZZETTI) (HEMIPTERA: PSEUDOCOCCIDAE) AGAINST THE BROWN LACEWING *SYMPHEROBIUS FALLAX* NAVAS (NEUROPTERA: HEMEROBIIDAE).

## ABSTRACT

DEFENSIVE BEHAVIOUR OF THE LONGTAILED MEALYBUG *PSEUDOCOCCUS LONGISPINUS* (TARGIONI TOZZETTI) (HEMIPTERA: PSEUDOCOCCIDAE) AGAINST THE BROWN LACEWING *SYMPHEROBIUS FALLAX* NAVAS (NEUROPTERA: HEMEROBIIDAE).

The defensive tactics of 2nd- and 3rd-instar nymphal and adult *Pseudococcus longispinus* (Targioni Tozzetti) against larval *Sympherobius fallax* Navas were studied. When attacked by 1st- and 2nd-instar predators, these three mealybug stages were able to secrete ostiolar fluids which spread and hardened on the mouthparts of the predators; 1st-instar mealybugs appeared to be unable to secrete ostiolar fluids. Adult mealybugs also successfully defended themselves against 1st-instar predators by simply pushing them away with their cerarial wax fringe. Of the lacewing stages, 3rd-instar *S. fallax* larvae were the most successful at overcoming the defense tactics of *P. longispinus.*

Key words: lacewings, Chrysopidae, *Chrysoperla carnea*, behavioural defence, morphological defence, potato sprouts, haemolymph.

## INTRODUCTION

Adult female longtailed mealybug, *Pseudococcus longispinus* (Targioni Tozzetti), is a typical mealybug but has a particularly well-developed fringe of long, waxy filaments around the margin of the body associated with the cerarii, the hindmost two filaments being exceptionally long, so giving this mealybug its common name. As in other mealybugs, it has lateral pairs of transverse slit-like ostioles anteriorly, approximately on the head, and posteriorly on the VIth abdominal segment (Plates 1 & 2). When the mealybug is stimulated violently, a globule of fluid appears from one or more ostioles and this hardens quickly on exposure to the air.

Larvae of Neuroptera are usually predators and principally attack aphids, although they can also attack chermids, mealybugs, whiteflies and occasionally diaspidid scale insects (Clausen, 1972). Lacewings are widely distributed in both natural and agro-ecosystems in many parts of the world. Two families in particular, the Chrysopidae and Hemerobiidae, have attracted considerable attention as potential biological agents of small arthropod pests, both in the field and under glass. However, only a few species are widely distributed and have been seriously considered as biocontrol agents (New, 1975). One of these is the brown lacewing, *Sympherobius fallax* Navas (Hemerobiidae), where the adults are small and brown in colour, as the name indicates. The antennae are almost as long as the wings and tend to be held forwards. These insects are heterometabolous. Unlike the adults, the larvae have powerful mouthparts with which to suck fluids when inserted into the body of their prey. The adults have chewing mouthparts, are predatory and feed on similar food to the larvae.

Herbivorous insects vary enormously in their defensive behaviour against entomophagous insects. The anti-predatory mechanisms mostly involve behavioural and morphological defences (Gross, 1993) and thus, in the aphids, the tube-like cornicles (also known as siphunculi) have evolved as defensive structures which secrete a waxy fluid when the insect is alarmed. This has two functions: it contains an alarm pheromone and, on contact with a predator or parasite, the waxy fluid can dry quickly, incapacitating the enemy. Dixon (1958) observed that, if the larva of the coccinellid *Adalia decempunctata* (L) was smaller than the aphid (*Macrosiphum evansi* (Theobald)) it was attacking and seized an appendage, the aphid could escape by pulling the appendage free. However, if the coccinellid larva and aphid were about the same size, the aphid could escape if the cornicle nearest the appendage swung over and placed a drop of waxy liquid on the coccinellid's head where the wax could spread over the mouthparts and solidify. Similar observations were made by Canard & Principi (1984) with lacewing larvae, which died after their mouthparts had been smeared with cornicular fluid. Chrysopid larvae can also cause other escape reactions in aphids, which may drop off the plant in response to the presence of a larva of *Chrysoperla carnea* (Stephens) (Arzet, 1973). Perhaps similar behaviour occurs when mealybugs are attacked by natural enemies, as Williams (1978) considered that the posterior ostioles of mealybugs may be homologous with the cornicles of aphids.

The purpose of these observations was to look at the defence mechanisms of *P. longispinus* when attacked by various larval stages of *S. fallax* and to see how these were overcome by the lacewing larvae.

## MATERIALS AND METHODS

The defence behaviour of 2nd- and 3rd-instar nymphs and adult *P. longispinus* was tested against 1st-, 2nd- and 3rd-instar larvae of *S. fallax*. *P.*

*longispinus* and *S. fallax* were kept in cultures maintained on sprouting potatoes at about 27°C and 65% r.h. Prior to each trial, the larvae of *S. fallax* were starved by keeping them singly in 5ml glass vials for 24h. The three stages of *P. longispinus* were tested separately against each lacewing larval instar. The defensive behaviour of *P. longispinus* was studied against a background of green paper within a small cage. These cages were made of three pieces of perspex-glass, measuring 75x38x8mm; the middle piece of perspex had a 25mm diam. hole in the centre and this was sandwiched between the other two pieces. Ten mealybugs of a specific stage were offered at a time in the central cavity to a single larva of each stage of *S. fallax*. The behaviour of the predator and host were observed under a stereomicroscope for 20-90 mins from the time of introduction of the mealybugs into the arena. This was repeated at least 10 times for each *S. fallax* stage. The main purpose was to observe the defensive tactics of *P. longispinus* against the predatory larvae and, therefore, any feeding by *S. fallax* larvae was ignored. The results are based on individual observations on different nymphal stages of *P. longispinus* and no actual data were recorded. All these observations were made at about 26°C, 65% r.h. and 7.5 watts/m$^2$ light intensity. An S.L.R. camera fitted on a stand was used to take photographs *in situ*.

## RESULTS AND DISCUSSION

When a *S. fallax* larva encountered a longtailed mealybug, the mealybug did not present herself as an easy target to the predator, but utilised her morphological and behavioural abilities to the maximum to defend herself. On contact with a larva of *S. fallax* of any age, 3rd-instar and adult mealybugs raised the posterior end of their abdomens. This behaviour is similar to that when a male *P. longispinus* approaches a female and may be a signal that the female is ready for mating. Because all *S. fallax* larvae attacked *P. longispinus* from behind, the raising of the abdomen provided an apparently easy access to the underside of the abdomen. When a *S. fallax* larva began its attack (by grabbing at the underside of the mealybug's abdomen with its mandibles), the mealybug tried to get rid of the predator by one of the following ways:

a) Escape. This was generally successful with 3rd-instar mealybugs when attacked by 1st- and 2nd-instar *S. fallax*. Occasionally, the lacewing larva could be found still chasing an escaping mealybug, even 24h later.

b) Pushing the lacewing larva away. This was accomplished by the fringe of waxy filaments at each cerarius and by moving or twisting the abdomen.

Adult *P. longispinus* were always successful in pushing 1st-instar *S. fallax* larvae away, even after being attacked for 24h. However, this tactic by adult mealybugs was not successful against 3rd-instar *S. fallax* and was only partially successful against 2nd-instar larvae.

c) Ostiolar fluid secretion. Second- and 3rd-instar nymphs and young adult *P. longispinus* secreted shiny droplets of a waxy fluid from their posterior ostioles when attacked (1st-instar nymphs, and reproducing and spent females were never seen to produce droplets). The larvae of *S. fallax* always attacked the mealybugs from behind, close to the posterior ostioles. The ostiolar fluid solidified quickly in air (15 to 45 secs, depending on the size of the droplet). If the mealybug was lucky and the predator was not been able to grab it successfully, then the predator sometimes came into contact with the ostiolar fluid, which stuck to its mouthparts, solidified and caused death by starvation. Similar phenomena were observed by Dixon (1958) when larvae of the coccinellid *A. decempunctata* attacked the aphid *M. evansi*, and by Canard & Principi (1984) when chrysopid larvae attacked aphids. If a *S. fallax* larva was successful in grabbing a mealybug, the latter kept on secreting ostiolar droplets until the whole reserve of the fluid was exhausted, each successive droplet being smaller than the last. The available fluid appeared to be exhausted after 6 or 7 droplets had been produced. After 24h, most of the 1st-instar *S. fallax* were found to be victims of ostiolar fluid from adult female *P. longispinus*, but most 3rd-instar *S. fallax* successfully escaped from the ostiolar fluid of 3rd-instar nymphs and adult *P. longispinus*.

When 2nd-instar *S. fallax* had successfully pierced an adult mealybug, the latter would still try to escape and would continue to secrete ostiolar globules. On some occasions, one of these globules would engulf the predatory larva, resulting in it becoming stuck to the mealybug. On these occasions, the mealybug could be found walking about with the dead lacewing larva still attached to its posterior end, especially when the mealybug was large and the *S. fallax* larva was an early instar.

Some observations were also made on the source of the ostiolar fluid. It is considered here that it may be modified haemolymph because, when a mealybug was pricked with a needle, the body fluids exuded as droplets and solidified in the same way as the droplets from the ostioles (i.e. in 15-45 secs). The main difference was that the ostiolar fluid was clear and colourless while the haemolymph was opaque and buff-coloured.

Of the two stages of *P. longispinus* studied, it was the adult stage which was most capable of defending itself, whilst the 2nd-instar nymphs were the most vulnerable. Similarly, the 3rd-instar *S. fallax* was the most active in escaping from the ostiolar fluids produced by *P. longispinus,* while the 1st-instar was the least successful.

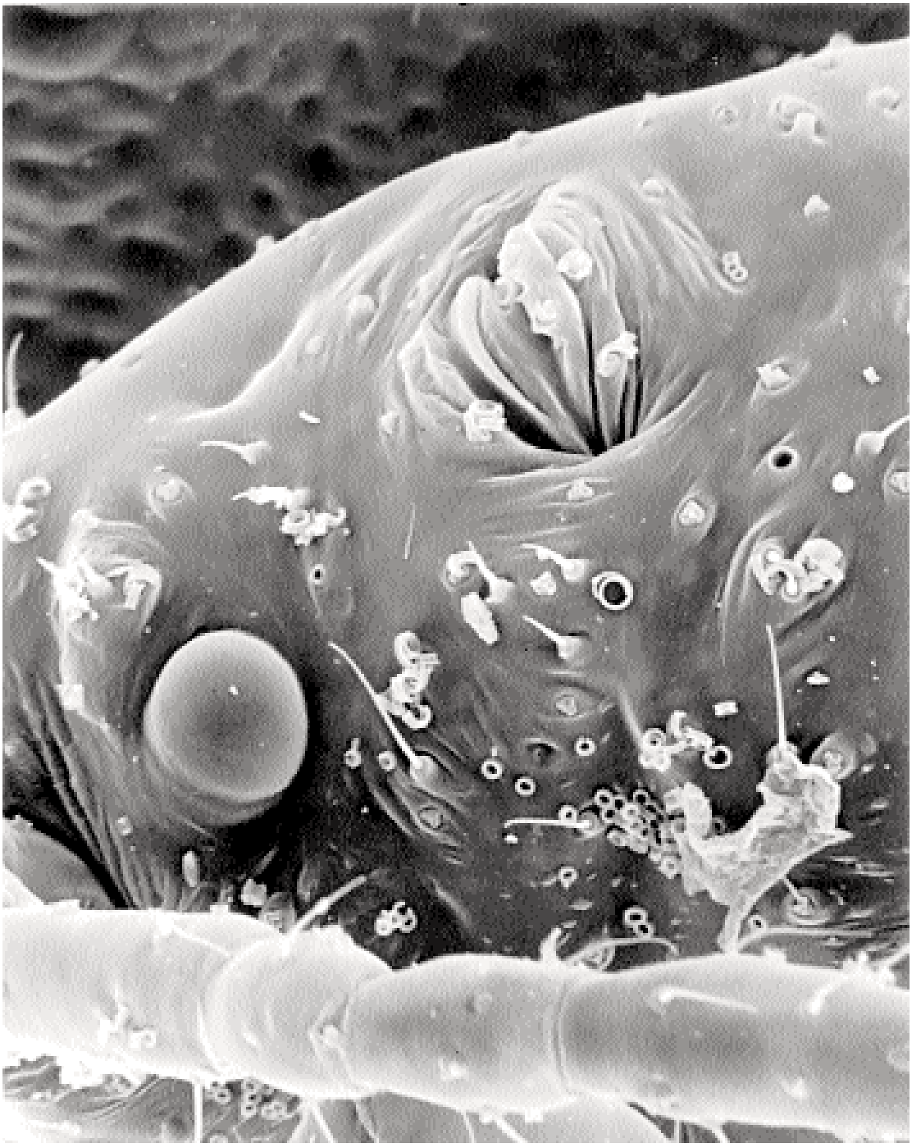

Plate 1: Scanning electron microscope study of anterior ostiole of *Pseudococcus longispinus.* x840

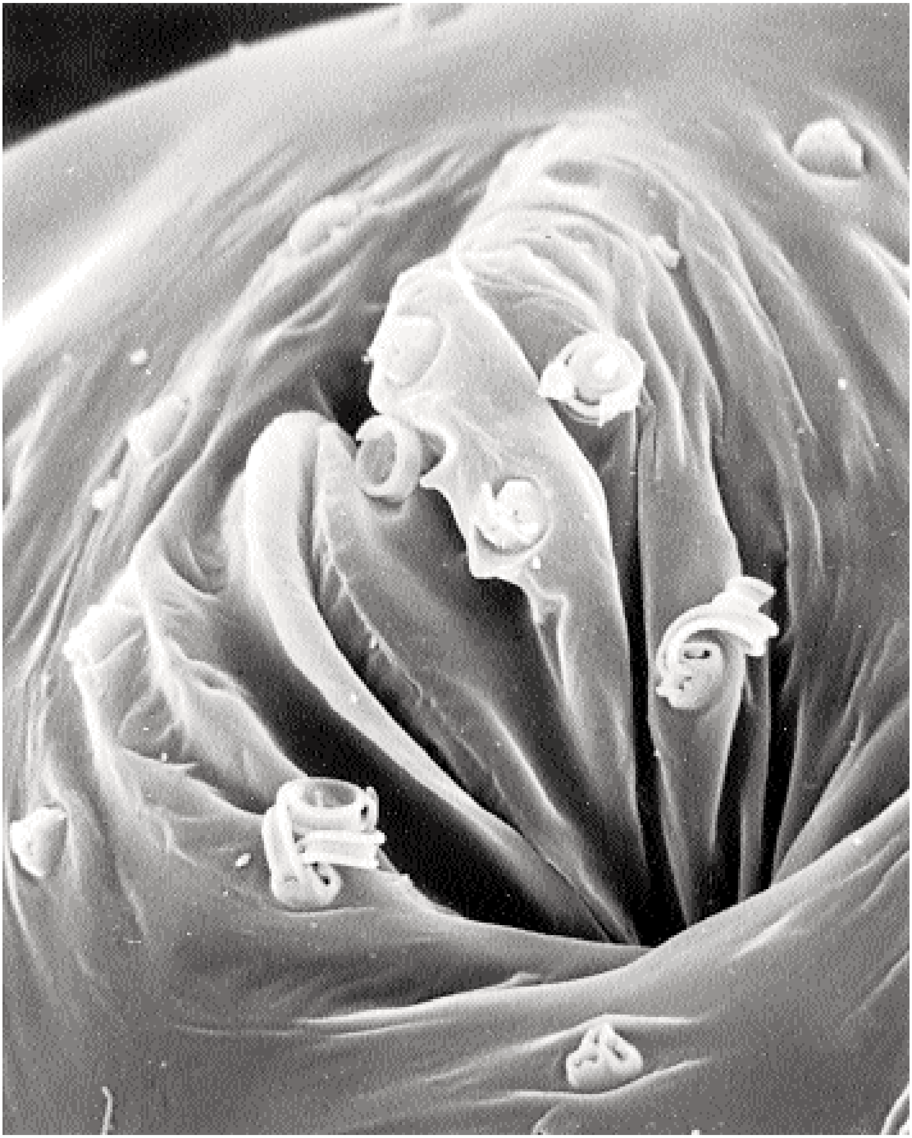

Plate 2: Scanning electron microscope study of anterior ostiole of *Pseudococcus longispinus*. x2500.

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HECKROTH, H.-P.[1]; FIALA, B.[2]; MASCHWITZ, U.[1]

[1]*AK Ethooekologie, Zoologisches Institut, Johann-Wolfgang Goethe-Universitaet,*
*Siesmayerstrasse 70, 60054 Frankfurt am Main, Germany.*
*2Theodor-Boveri-Institut, Zoologie III, Biozentrum, Am Hubland, D-97074 Würzburg, Germany.*

# INTEGRATION OF SCALE INSECTS (HEMIPTERA: COCCIDAE) IN THE SOUTH-EAST ASIAN ANT-PLANT (*CREMATOGASTER* (FORMICIDAE)-*MACARANGA* (EUPHORBIACEAE)) SYSTEM.

## ABSTRACT

Integration of scale insects (Hemiptera: Coccidae) in the South-East Asian ant-plant (*Crematogaster* (Formicidae)-*Macaranga* (Euphorbiaceae)) system.

The coccid colonisers of myrmecophytic *Macaranga* were tested for their trophic integration into the mutualistic *Crematogaster-Macaranga* ant-plant system. Honeydew secretion by these mostly endophytic scale insects was observed in *Coccus caviramicolus* Morrison, *C. penangensis* Morrison, *C. secretus* Morrison, *C. tumuliferus* Morrison, *C. tumuliferus* var. C.84 and in two other *Macaranga* coccid species. However, the use of coccids as protein-rich food by ants under normal and starvation conditions was not observed.

Key words: trophobiosis, ant nutrition, Myzolecaniinae, survival, dumping areas, *C. macarangae*, food-bodies, Pseudococcidae, Malaysia, *Macaranga bancana*, *M. hypoleuca*, *M. hullettii*, *M. winkleri*, *M. triloba*.

## INTRODUCTION

Ant-plant systems represent a common type of symbiosis in the tropics. The *Crematogaster-Macaranga* association is probably the most conspicuous ant-plant system in South-East Asia and includes more than 20 plant and at least 9 ant species. The plants provide food in the form of nutrient-rich food-bodies and nesting space for the ants, while the plant-specific ant colonisers defend their host-plant against herbivores and also gnaw off climbers, a behaviour called pruning (Fiala, 1989). The ants rely mainly on plant resources and do not hunt any prey on or around the plants (Fiala & Maschwitz, 1989, 1990, 1992; Fiala *et al.*, 1991). As in many other ant-plant-hemipteran systems (Gullan, 1997), scale insects are found inside almost all ant-inhabited *Macaranga* above a certain size (Heckroth *et al.*, 1998). An exception to this is the two-partner system *Camponotus-M. puncticulata* that can be found as a common understorey tree in peat swamp forests in the Malay Peninsula and Sumatra (Federle *et al.*, 1998). Also other ant-plant systems very often lack scale insects or other hemipterans as trophobiotic partners for the ants (summarised in Davidson & McKey, 1993).

Morrison (1921) and Takahashi (1951) described 6 species of coccids from *Macaranga* species in the Malay Peninsula. Recently, additional collections have been made from West and East Malaysia as well as from Sumatra and the Indonesian part of Borneo and their host-specificity investigated (Heckroth *et al.*, 1998). The *Macaranga* coccids all appear to belong to the Subfamily Myzolecaniinae (Heckroth *et al.*, 1998).

The coccids in the hollow stems of most *Macaranga* species are almost always present in this ant-plant symbiosis, but it is not known in what way they actually contribute to the ant-plant mutualism, since ant colonies can survive and grow without the presence of coccids on their host-plants (Heckroth, unpublished data). Honeydew is a common food source for ants (Davidson & McKey, 1993; Gullan, 1997; Hölldobler & Wilson, 1990). In addition, the use of these trophobionts as prey and, therefore, as a source of protein has been suggested (summarised in Gullan, 1997) because it had been found in non-specific associations (summarised in Gullan, 1997; Pontin, 1978; Way, 1954; 1955; 1963). The consumption of trophobionts by ants in these systems would be a particularly good and resource-saving way of gaining additional protein under normal or starvation conditions and would provide a way of controlling the trophobiont populations.

The aim of this study was to examine the rôle of coccids as a food source for ants in the *Crematogaster-Macaranga* mutualism. The major questions were: (1) do all common coccid species present in the hollow stems of myrmecophytic *Macaranga* provide honeydew for ant colonies; (2) is this honeydew a full diet for both the workers and/or the brood, and (3) are these coccids also used as prey by the ants?

## MATERIALS AND METHODS

### THE STUDY AREA

The study was conducted at the Ulu Gombak Field Study Centre in the Gombak Valley (Selangor, West Malaysia) and at Poring Hot Springs in Mt. Kinabalu National Park (Sabah; East Malaysia).

### 1. TROPHOBIOSIS

Because nearly all of ant-coccid interactions happen inside the plants, trophobiosis cannot usually be observed directly with *Macaranga* coccids. Nonetheless, observations were possible in the following experimental and natural situations, using a dissecting microscope or magnifying glass:

- stimulation of honeydew secretion with a hair: in cut and opened twigs after the removal of all ants (n=23);
- stimulation of coccids by ants: in cut and opened twigs (n=15);
- stimulation of *C. tumuliferus* Morrison (n=5) and morphospecies C.296* (n=6) by ants: in intact *Macaranga hypoleuca* with opened domatia (n=15);
- stimulation of *C. penangensis* Morrison by ants: in intact *Macaranga hullettii* with opened domatia (n=25);
- observations on the occasional aggregations of 1st- and 2nd-instar nymphs on the shoot-tip of *M. hypoleuca* (n=3) (also Khoo, S.G., personal communication) and of *Macaranga winkleri* (n=1).

### 2. REARING OF ANT WORKERS IN THE ABSENCE OF FOOD-BODIES AND WITH AND WITHOUT COCCIDS.

Sixteen *M. hypoleuca* plants with opened domatia, were each colonised with 15 worker ants, all the ants coming from a single ant colony. Eight of these plants were then also colonised with *C. tumuliferus* coccids *ad libidum*, the other eight plants being left as controls. The control plants were necessary to show whether ants could use any other food source on the plants, such as epiphylles, pollen or plant tissue. After one day, each shoot tip and petiole was covered with a sticky tangle trap (Tangle Foot Company©) to prevent the ants from collecting food-bodies. Dead ants were removed from the plants daily. All coccids were counted to exclude the possibility that they were consumed by the ants.

### 3. THE FEEDING ON SCALE INSECTS BY WORKERS AND BROOD

*i. Offering of coccids as protein-rich food for ant colonies of* Crematogaster *spec. 6*[1]:

Scale insects were offered to the ants to observe whether they were eaten, thrown from the plant or accepted as trophobionts under the following conditions:

- intact *C. tumuliferus* (n=25), morphospecies C.296 (n=23) and *C. penangensis* (n=28) were offered to ant-colonies that could obtain honeydew from coccids in an intact plant;
- intact *C. tumuliferus* (n=8), morphospecies C.296 (n=12) and *C.*

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*Morphospecies C. 296, C. 41 and C. 84 are undescribed species. These code number was used in Heckroth *et al.* 1998.

[1] *Crematogaster* species 6 and 8 are undescribed species. The *Crematogaster* colonisers of myrmecophytic *Macaranga* are separated into 9 species. These code numbers were use in Fiala *et al.* (1999).

*penangensis* (n=15) were offered to starving ant-colonies which were kept in a container;

- freshly damaged *C. tumuliferus* (n=5), morphospecies C.296 (n=7) and *C. penangensis* (n= 10) were offered to ant-colonies that could obtain honeydew from coccids in an intact plant;

- freshly damaged *C. tumuliferus* (n=5) were introduced to a group of coccids inside an intact plant of *M. hypoleuca* with opened domatia;

- freshly damaged *C. tumuliferus* (n=10), *C. penangensis* (n=15), morphospecies C. 296 (n=7) and C. 41 (n=4) were offered to starving ant colonies of *Crematogaster* species 6[1] and species 8[1], which were kept in a container.

*ii. Inspection of (a) dumping-grounds inside* Macaranga bancana† *and* M. hypoleuca *plants and (b) colony debris around the plants:*

Some internodes along the hollow twigs of myrmecophytic *Macaranga* are obviously used by ants as dumping areas, usually easily recognisable by a dark brown to blackish paste that is generally full of nematodes. In addition, discoloured food-bodies can be found there regularly. If scale insects were consumed by ants in substantial numbers, their antenna, legs, claws and other cuticular structures should be found in these dumping areas and, therefore, this debris was checked under the microscope.

In addition, some debris from the ant colonies was thrown off the plants. To study this, everything that fell from a 50cm high *M. hypoleuca* colonised with a complete ant colony plus 30 adult *C. tumuliferus* was collected in a box for 3 weeks. The box for collecting the debris was surrounded by an insect trap to prevent non-experimental ants from foraging this debris from the surrounding ground. The experiment was conducted indoors to protect the debris from weather conditions. The collected debris was inspected daily.

*iii. Observations on colonies in opened plants:*

All known typical *Macaranga* coccids can easily be obtained by cutting and splitting a twig of the host-plant and (with the exception of *C. secretus* Morrison) can then be transferred and established at new feeding sites. Once each coccid has withdrawn its stylets, it starts walking. Stylet withdrawal can take from 10 min (many *C. tumuliferus* and morphospecies C. 296) to several hours in *C. penangensis* and *C. macarangae*. Generally, to get a harvest of almost 100% of *C. tumuliferus* and morphospecies C. 296 and 40-60% in *C. penangensis*, live specimens should be kept in the shade under normal dry

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†*M. bancana* is now considered as the valid name for the common plant that is well-known as *M. triloba* (J.W.F. Silk, personal communication).

conditions. Sessile 1st-instar nymphs of *C. penangensis* do not remove their stylets and, consequently, cannot be used to colonise a second plant.

For these observations, two opened but living plants were colonised with ant workers and brood. In addition, nymphs of morphospecies C. 296 (n=17) and *C. penangensis* nymphs and adults (n=22) were placed in the internode of one plant. After two days, the leafstalks and shoot tip were covered with a sticky coating to stop the ants from collecting food-bodies. The number of ants, brood and coccids was recorded almost daily. When, after two weeks, the number of ants and brood had dropped to a very low level, fresh brood and ants were added from the original colony. The experiment was conducted for 44 days.

## RESULTS

### 1. TROPHOBIOSIS

Honeydew production in *Macaranga* coccids could be observed in all experimental set-ups. When artificially stimulated with a hair, honeydew production could be observed in *C. caviramicolus* Morrison, *C. macarangae* Morrison, *C. penangensis*, *C. secretus*, *C. tumuliferus*, *C. tumuliferus* var. C. 84, morphospecies C. 296 and morphospecies C. 41. In the absence of honeydew removal by either ants or the experimenter, both *C. penangensis* and *C. tumuliferus* were observed to retract the honeydew droplet after 1-3 minutes. Droplet production after antennation by ants was observed in *C. caviramicolus*, *C. penangensis*, *C. secretus*, *C. tumuliferus* and morphospecies C. 296. Honeydew secretion on the plant surface at the shoot-tip after antennating by ants could be observed in *C. tumuliferus* and morphospecies C. 41. In *C. tumuliferus*, the frequency of honeydew production by coccids on the plant surface was 5 droplets in 5 minutes on a sunny afternoon. On experimentally opened plants, the ants stayed near the coccids most of the time during the 21 days of observation. Honeydew was mostly produced with a frequency of 2-4 droplets per minute and, if not removed by ants or with a hair, was usually retracted after 1-3 minutes.

### 2. REARING OF WORKERS IN THE ABSENCE OF FOOD-BODIES AND WITH AND WITHOUT COCCIDS.

In the absence of food-bodies and without substitution of lost workers, all workers in plants without coccids had died after 6 days while two-thirds of the workers were still alive and showed no sign of starvation in plants with

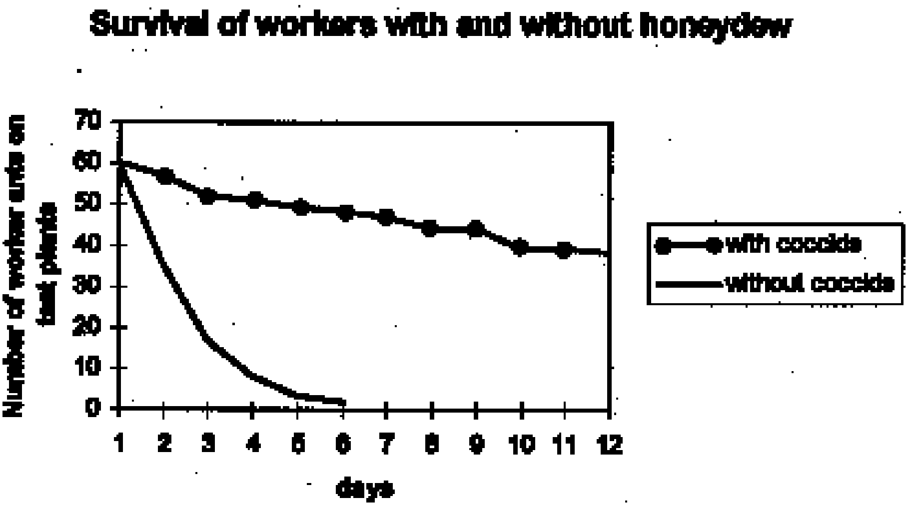

Fig. 1. Worker survival in test plants with (n=60) and without (n=60) coccids. The ants had no supply of food bodies.

coccids (Fig. 1). The loss of workers in plants with coccids was probably due to normal aging while some ants that died had been caught in the tangle trap. There were no hints that workers in the plants without coccids could use any other food source, such as plant tissue or epiphylles.

### 3. FEEDING ON SCALE INSECTS BY WORKERS AND BROOD.

#### *i. Offering coccids as food for ant colonies*

All offered coccids were either thrown off the plants immediately or were found in the experiment nest chambers. None of the surviving coccids showed any sign of damage by ants when checked under the microscope. The coccids that were damaged after they had become established on the plant were thrown off the plant. The development of ant larvae stopped and most of them were thrown off the plants once they had died and showed discolouration. All ants without honeydew died within a few days.

#### *ii. Inspection of (a) dumping-grounds inside* M. bancana *and* M. hypoleuca *plants and of (b) colony debris around the plants:*

Within the hollow twigs of *Macaranga*, no remains of arthropod origin could be found in the debris which consisted of an amorphous dark-brownish mass. With regard to the debris around the base of the tree, plant tissue from the boring of fresh entrance holes was found around the plant almost every day, especially when new internodes were opened the first time. Two ants and two coccids were found dead outside the plant. They had probably died inside the plant and were dumped by ant workers. Mature coccids can neither enter or leave the hollow twigs without the assistance of ant workers (Heckroth, unpublished data).

*iii. Observations on colonies in opened plants*

*C. tumuliferus* was mostly able to colonise the plants and in only a few cases was it thrown from the plant by ants. However, *C. penangensis* were always thrown from the plants by the ant workers. In the absence of food-bodies, the ant larva stopped development. The coccids developed well and produced offspring. A few ant workers survived the entire 44 days (which is approximately one-third of their life expectancy (Heckroth, unpublished data)) feeding on honeydew.

## DISCUSSION

As our results demonstrate, honeydew is a common food source for *Crematogaster* ants on myrmecophytic *Macaranga*. The coccids depend on the removal of this honeydew by the ants and retract the droplet when it is not removed. This shows the high degree of adaptation to life inside the hollow stems of living plants that is a common feature of members of the Subfamily Myzolecaniinae (Gullan & Buckley, 1993; Hodgson, 1994). Honeydew seems to be a full diet for ant workers, which are able to survive on an exclusive nutrition of honeydew for at least 40 days. In the absence of honeydew and without other food, the ants cannot survive longer than five days.

In contrast to our expectations, the coccids were not used as a protein source for the ant colony. Large numbers of coccids were thrown from the plant when they were offered in excess. Under our experimental conditions, *C. tumuliferus* was selectively accepted in the colonies but *C. penangensis* was generally thrown from the plants. This is in contrast to results of our former collections, where *C. penangensis* could be found regularly on *M. hypoleuca* plants although this plant species was most commonly colonised by *C. tumuliferus* (Heckroth *et al.*, 1998). Ants had to accept the loss of large numbers of the brood in the absence of food-bodies because of their inability to use coccids as a protein source. Food-bodies are believed to be the only food source on which an ant brood can be fed, even with coccids as honeydew providers (Heckroth, unpublished results).

In regular colony life, under conditions of food shortage and even when severely starved, no coccids were eaten by the ants. We cannot completely exclude the possibility that coccids are used as food sometimes but we have found no evidence that coccids are regularly fed on under normal or emergency conditions. Honeydew would appear to be unsuitable for rearing the brood, probably due to its general lack of protein (Crane, 1986a; 1986b; Ewart & Metcalf, 1956). Also, no honeydew producing Sternorrhyncha have been recorded as being eaten by ants in other specific trophobiont interactions, especially in plant-ants. Liefke *et al.* (1998) reported that the ant *Polyrhachis arachne*, which lives in the hollow internodes of bamboo, controls the density of *Kermicus wroughtoni* by either carrying them to other nests of the polydomous colonies or by throwing the crawlers out of the nest, while Moog *et al.* (1998 and pers. communication) found that members of the genus *Cladomyrma*, a common ant-plant genus which generally lives on host plants which do not provide food-bodies and only rarely extrafloral nectar for the ants, were not observed to use food sources other than scale insect honeydew. Preliminary results of J. Moog and H.-P. Heckroth (unpublished) show that the associated pseudococcids are not used as prey.

Further studies will focus on the effect of coccids on colony growth and on their other possible functions in the ant-plant system; this system will also be compared with other ant-plant systems and their scale insects.

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HEIDARI, M.
*Environment Department, Wye College, University of London, Wye, Ashford, Kent TN25 5AH, U.K.*

# THE INTRINSIC RATE OF INCREASE AND TEMPERATURE CO-EFFICIENTS OF THE COMSTOCK MEALYBUG, *PSEUDOCOCCUS COMSTOCKI* (KUWANA) (HEMIPTERA: COCCOIDEA: PSEUDOCOCCIDAE).

## ABSTRACT

THE INTRINSIC RATE OF INCREASE AND TEMPERATURE CO-EFFICIENTS OF THE COMSTOCK MEALYBUG, *PSEUDOCOCCUS COMSTOCKI* (KUWANA) (HEMIPTERA: COCCOIDEA: PSEUDOCOCCIDAE).

Life history studies on the development of *Pseudococcus comstocki* (Kuwana) were made under laboratory conditions at four constant temperatures, namely 18, 22, 26 and 30°C. Temperature proved to have a significant effect on development, survival, reproduction and longevity, and on the sex ratio of *P. comstocki*. Reproduction, survival and longevity were greatest at 22-26°C and lowest at 30°C, which was detrimental to the nymphs. It was also found that the sex ratio became female biased at 30°C. On the basis of these data, the intrinsic rate of natural increase ($r_m$) was computed to be 0.05, 0.07, 0.10 and 0.08 at the above temperatures and the gross reproduction rate (GRR) was also temperature dependent and was calculated to be 153, 249, 210 and 57. The lower temperature threshold for development (TL) was estimated to be 11.0°C and the time from birth to adulthood (K) 523 degree days.

Key words: potato sprouts, fecundity, weight gain, crowding, sex ratio, mortality.

## INTRODUCTION

*P. comstocki* (Kuwana) is a highly polyphagous, cosmopolitan pest of economic importance, and is a pest on citrus, many fruit trees and other ornamental plants, both in the field and under protected cultivation. It can cause severe damage to leaves, stems, fruits and roots (Miller & Kosztarab, 1979; Kosztarab, 1996). Plant damage can be caused directly by feeding and by the secretion of phytotoxic saliva, and indirectly through sooty moulds developing on the honeydew.

In the past, *P. comstocki* has been confused with several other mealybugs, particularly *P. cryptus* Hempel, but today these are fairly easily separated. However, because of the earlier problems with its identification, the biology of *P. comstocki* remains obscure. This study examines various life-history paramaters under four constant temperatures in the laboratory; in particular, it considers: i. the mortality of the immature stages, ii. the effect of body weight on fecundity, and iii. the intrinsic rate of increase.

## MATERIALS AND METHODS

Potato sprouts 5cm long, without a tuber, were placed in a culture of *P. comstocki* just before egg hatch at room temperature (approx. 22°C) for 5-6h to become infested with 1st-instar mealybugs. All but 10-20 crawlers were then removed from each sprout. The sprouts were then transferred to a ventilated plastic box (173 x 115 x 65mm) with two sprouting, soil-less potato tubers. Once the mealybugs had reached the 3rd or the beginning of the 4th female instar, 10 were kept on each potato and the rest were removed. Humidity in each box was kept at 60±5%. The box was then placed in a Gallenkamp compenstat incubator set at one of 4 temperatures and with continuous illumination provided by 6x8W fluorescent tubes. Five females per potato were carefully removed just after the last moult and weighed with a Sartorious electronic microbalance (0.005mg accuracy) and the other five were left in the box until oviposition was complete. As soon as the females started laying eggs, each insect was examined twice a day and all eggs were carefully removed and counted until the female died. The experiment was repeated at four experimental temperatures with 10 replications (100 female/treat.) in a completely randomised statistical design within each cabinet. The LSD technique (Clewer & Scarisbrick, 1991) was applied to contrast treatment means. The effect of crowding on egg production was also studied; uncrowded conditions were considered to be 5 adult females per sprout while crowded conditions were with 40-50 adult females per sprout.

In a second experiment, the effect of temperature on the survival of the immature stages was studied and the number of surviving individuals monitored. The experimental conditions were otherwise as above.

### Life history statistics:

The fecundity and longevity of *P. comstocki* were studied under four constant temperatures, each with 40 cohorts at the beginning of the experiment. The growth parameter was calculated from age-specific survival and fecundity schedules. For this, the following exponential model was applied: $dN/dt = rN$, where N is the number of individuals in the population at a given time $t$, $r$ is the intrinsic rate of natural increase and $d$ is a constant. $r_m$ was calculated by an iterative solution of the Lutka-Euler equation:

$\sum l_x m_x e^{-r\, mx} = 1$ (van den Bosch *et al.*, 1982)

where $x$ is the mid-point of the age intervals in days, $l_x$ is the probability of a female surviving to age *x*, $m_x$ is the mean number of female 'births' during age interval *x* per female aged *x*, and *e* is the base for the natural logarithms. Trial $r_m$ values were substituted into the above expression until the left hand side was arbitrarily close to 1. $l_x$ and $m_x$ were calculated by tabulating age-specific fecundity and age-specific survival data obtained from cohort fecundity and survival experiments. The lower theoretical development threshold (TL) and the time-to-adult in degree days (K) were estimated by linear regression analysis of the development rate (100/Y) on temperature (Campbell *et al.*, 1974). The total amount of thermal energy required for complete development, the thermal constant (K), can be calculated from the reciprocal of the slope of the regression line (1/b), while the lower temperature threshold for development may be calculated from TL = -a/b.

### INTRINSIC RATE OF NATURAL INCREASE (RM)

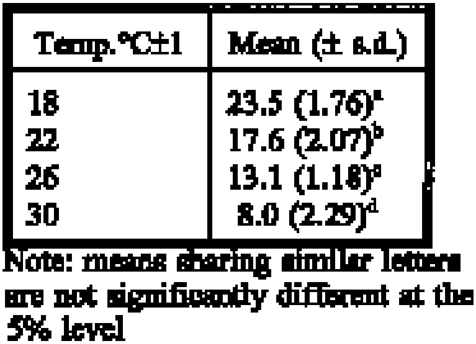
All parameters for the intrinsic rate of natural increase were calculated. Species with the greatest values of the intrinsic rate of natural increase are among the more abundant and this could be a desirable feature from the biological control point of view. However, $r_m$ is calculated by iteratively solving the above equation (Messenger, 1964).

## RESULTS

Temperature was found to have a significant effect on the weight gained by mealybugs (P<0.01), with the maximum weight gain at 18±1°C (4.7mg/adult female during the preoviposition period) and the minimum at 30°C (1.6mg/adult female during the preoviposition period) (Table 1).

Temperature and density were also found to have a significant influence

Table 1. Mean weight gain (mg ± s.d.) by adult female *P. comstocki* between the last moult and the start of egg-laying (n = 50).

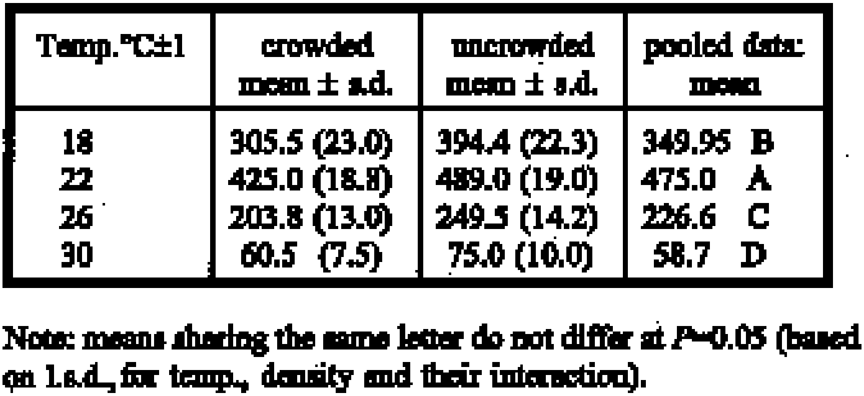


| Temp.°C±1 | Mean (± s.d.) |
|---|---|
| 18 | 23.5 (1.76)$^a$ |
| 22 | 17.6 (2.07)$^b$ |
| 26 | 13.1 (1.18)$^c$ |
| 30 | 8.0 (2.29)$^d$ |

Note: means sharing similar letters are not significantly different at the 5% level on the fecundity of *P. comstocki*. The most eggs/female were produced at 22±C, whilst at 30±C the mealybugs gained the least body weight and the oviposition rate was reduced to 60.5 ± 7.5 eggs/female (Table 2), clearly indicating the significant influence of temperature on population density of this pest.

The results obtained from this investigation also revealed a marked effect of temperature on development, survival, longevity and the sex ratio of *P. comstocki* (Tables 3 & 4). Temperatures around 28°C+ were fatal to the immature stages. Higher mortality occurred at 30°C (49%) (Table 4).

Table 2. Interaction of degree of crowding and four constant temperatures on the mean number of eggs laid per female *P. comstocki* (n=50).



| Temp.°C±1 | crowded mean ± s.d. | uncrowded mean ± s.d. | pooled data: mean |
|---|---|---|---|
| 18 | 305.5 (23.0) | 394.4 (22.3) | 349.95 B |
| 22 | 425.0 (18.8) | 489.0 (19.0) | 475.0 A |
| 26 | 203.8 (13.0) | 249.5 (14.2) | 226.6 C |
| 30 | 60.5 (7.5) | 75.0 (10.0) | 58.7 D |

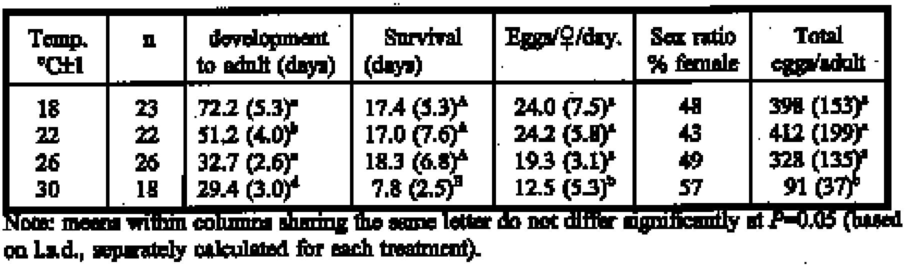
**Note: means sharing the same letter do not differ at $P$=0.05 (based on l.s.d., for temp., density and their interaction).**

The life-table (Table 5) parameters also show that 22°C and 26°C were the most favourable temperatures, with the greatest GRR and $R^O$, so that the greatest $r_m$ was at 26°C and the least at 18°C. However, the lower temperature threshold for development was calculated to be 11°C and the thermal constant (K) was calculated to be 325 degree-days (DD).

## DISCUSSION AND CONCLUSIONS

There was a direct correlation between temperature and body weight as well as between temperature and the number of eggs oviposited by each adult female, with lower body weights and reduced fecundity at higher temperatures. Similar results have been reported for *Phenacoccus manihoti* Matile-Ferrero (Iheagwam, 1981; Lema & Herren, 1985), *Planococcus citri* (Risso) (Bodenheimer, 1951; Tingle, 1985) and *Pseudococcus longispinus* (Targioni Tozzetti) (Guillani, 1999). These results explain why the winter generations are larger and heavier than later in the year and, perhaps, why

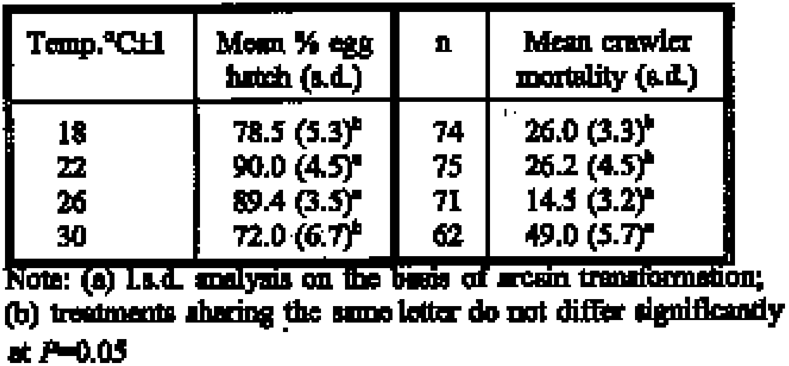
Table 3. Effect of temperature on rate of development (days), eggs per female per day (mean ± s.d.), and the sex ratio of *P. comstocki* at four constant temperatures.



| Temp. °C±1 | n | development to adult (days) | Survival (days) | Eggs/♀/day. | Sex ratio % female | Total eggs/adult |
|---|---|---|---|---|---|---|
| 18 | 23 | 72.2 (5.3)$^a$ | 17.4 (5.3)$^A$ | 24.0 (7.5)$^a$ | 48 | 398 (153)$^a$ |
| 22 | 22 | 51.2 (4.0)$^b$ | 17.0 (7.6)$^A$ | 24.2 (5.8)$^a$ | 43 | 412 (199)$^a$ |
| 26 | 26 | 32.7 (2.6)$^c$ | 18.3 (6.8)$^A$ | 19.3 (3.1)$^a$ | 49 | 328 (135)$^a$ |
| 30 | 18 | 29.4 (3.0)$^d$ | 7.8 (2.5)$^B$ | 12.5 (5.3)$^b$ | 57 | 91 (37)$^b$ |

Note: means within columns sharing the same letter do not differ significantly at $P$=0.05 (based on l.s.d., separately calculated for each treatment).

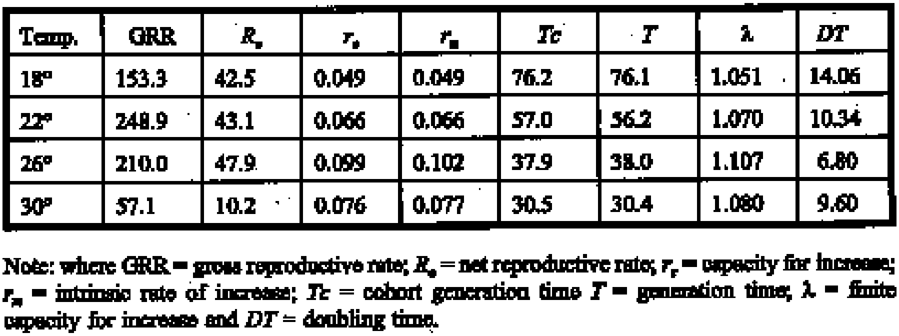
Table 4. Effect of temperature on % egg hatch and crawler mortality of *P. comstocki* (n=100).



| Temp.°C±1 | Mean % egg hatch (s.d.) | n | Mean crawler mortality (s.d.) |
|---|---|---|---|
| 18 | 78.5 (5.3)$^b$ | 74 | 26.0 (3.3)$^b$ |
| 22 | 90.0 (4.5)$^a$ | 75 | 26.2 (4.5)$^b$ |
| 26 | 89.4 (3.5)$^a$ | 71 | 14.5 (3.2)$^a$ |
| 30 | 72.0 (6.7)$^b$ | 62 | 49.0 (5.7)$^c$ |

Note: (a) l.s.d. analysis on the basis of arcsin transformation; (b) treatments sharing the same letter do not differ significantly at $P$=0.05

Table 5. Life-table parameters of *P. comstocki* at four temperatures.



| Temp. | GRR | $R_o$ | $r_c$ | $r_m$ | $Tc$ | $T$ | λ | $DT$ |
|---|---|---|---|---|---|---|---|---|
| 18° | 153.3 | 42.5 | 0.049 | 0.049 | 76.2 | 76.1 | 1.051 | 14.06 |
| 22° | 248.9 | 43.1 | 0.066 | 0.066 | 57.0 | 56.2 | 1.070 | 10.34 |
| 26° | 210.0 | 47.9 | 0.099 | 0.102 | 37.9 | 38.0 | 1.107 | 6.80 |
| 30° | 57.1 | 10.2 | 0.076 | 0.077 | 30.5 | 30.4 | 1.080 | 9.60 |

Note: where GRR = gross reproductive rate; $R_o$ = net reproductive rate; $r_c$ = capacity for increase; $r_m$ = intrinsic rate of increase; $Tc$ = cohort generation time $T$ = generation time; λ = finite capacity for increase and $DT$ = doubling time.

fecundity is greatest in the spring. The results also show that constant temperatures over 30°C are probably detrimental to the nymphs of *P. comstocki* but that temperatures ranging between 18-26°C were optimal. Bodenheimer (1951) reported that spring and autumn were the most favourable seasons for crawler development in Palestine and that juvenile mortality fluctuated between 10-32%, with temperatures above 26°C being unfavourable, particularly in combination with low humidity. Similar observations have been reported with *Planococcus ficus* (Signoret) and *P. citri* by Sayed *et al.* (1962). However, the above results were obtained with constant temperatures in the laboratory and it should be born in mind that survival etc. under oscillating temperatures and other humidities might be very different under field conditions.

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HIPPE, C.; FREY, J.E.
*Swiss Federal Research Station for Fruit-Growing, Viticulture and Horticulture, CH-8820 Wädenswil, Switzerland*

# BIOLOGY OF THE HORSE CHESTNUT SCALE, *PULVINARIA REGALIS* CANARD (HEMIPTERA: COCCOIDEA: COCCIDAE), IN SWITZERLAND.

## ABSTRACT

BIOLOGY OF THE HORSE CHESTNUT SCALE, *PULVINARIA REGALIS* CANARD (HEMIPTERA: COCCOIDEA: COCCIDAE), IN SWITZERLAND.

In 1997, many lime (*Tilia* spp.) and horse chestnut (*Aesculus hippocastanum*) trees in the centre of Zurich were found to be heavily infested by the horse chestnut scale, *Pulvinaria regalis* Canard. The biology of this introduced coccid was studied for one year. Crawlers hatched from the end of May and moved to the leaves of their host plants. There the nymphs settled and fed until Sept./Oct., when they migrated to adjacent twigs to overwinter as the 3rd-instar females. After the final nymphal moult in the spring, the adult female went through a period of rapid growth. Adult males appeared for a short period at the beginning of May but were rare. At this time, the females began to move to the main branches and the trunk of the tree, where they secreted a white ovisac consisting of wax filaments. Shortly after oviposition, the females died but remained attached to the ovisac. Two species of aphelinid (*Coccophagus lycimnia* (Walker) and, much less commonly, *C. semicircularis* (Förster)) emerged from parasitised scale nymphs in May (on twigs) and at the beginning of September (on leaves). The average rate of parasitisation of *P. regalis* was low (≤5%). No dipteran and only a few coccinellid predators were found during the sampling period.

Key words: sex ratio, plant stress, *Pseudaulacaspis pentagona*, *Coccophagus obscurus*, *C. scutellaris*, *Exochomus quadripustulatus*, *Leucopis silesiaca*, urban environment, parasitoids.

## INTRODUCTION

The horse chestnut scale was recorded for the first time in the Greater London area in 1964 (Harris, 1970). One year later, it was noticed near Paris and described as a new species, *Pulvinaria regalis* (Canard, 1968). Since then, it has spread not only within the United Kingdom and France but has also been reported from Belgium (in 1981; Merlin & Pasteels, 1990), the Netherlands (in 1988; Jansen, 1996), Germany (in 1989; Sengonca & Faber, 1995) and Switzerland (in 1992; Kozár *et al.*, 1994).

*P. regalis* infests at least 61 plant species belonging to 24 families (Schmitz, 1997). This host range suggests that *P. regalis* might have originated from the Far East (Harris, 1970) but it has only so far been found in Europe. It predominantly infests trees within towns and cities, often along roadsides or in car-parking areas. Trees already suffering from stress symptoms are preferred and show the highest infestation levels (Speight, 1986; Speight *et al.*, 1998).

In the centre of Zurich, heavy infestations on lime (*Tilia* spp) and horse chestnut trees (*Aesculus hippocastanum*) were observed in 1997. Interestingly, an outbreak of another introduced scale insect, *Pseudaulacaspis pentagona* (Targioni-Tozzetti), had occurred there five years previously on *Sophora* sp. (Mani *et al.* 1997). This diaspidid, like *P. regalis*, also seems to thrive in urban environments (Hanks & Denno, 1993).

## MATERIALS AND METHODS

Lime and horse chestnut trees infested by *P. regalis* were selected in July 1997 in the centre of Zurich. Samples were collected from these trees at intervals (at least fortnightly) between July 1997 and June 1998, the number of samples on each occasion depending on the level of infestation but sufficient to produce more than 300 scales per visit. In addition, the trunks of the trees were checked for the occurrence of adult females, ovisacs, crawlers and predators.

The collected samples were studied in the laboratory. The average mortality in the overwintering stage of *P. regalis* was established by determining the percentage of dead scales on twig samples between the beginning of March and the beginning of May (seven replicates of 300 scales each). The percentage of males was assessed by counting male developmental stages between the first week of April and the first week of May (four replicates of 300 scales each), while the average rate of parasitisation was evaluated by counting parasitised scales on leaves in September and on twigs between the third week of April and the first week of May (three replicates of 300 scales each).

Parasitised *P. regalis* were isolated from leaf and twig samples in the laboratory to ensure that the adult parasitoids emerged only from this host. Between mid-Sept. and mid-Oct., 177 parasitoids were collected from scales on the leaves while, between the second week of May and the beginning of June, 87 parasitoids were examined from scales on the twigs. Voucher specimens of the parasitoids were deposited in the collection of the Natural History Museum, London.

## RESULTS AND DISCUSSION

In Zurich, mainly lime and horse chestnut trees were infested by *P. regalis*. The crawlers hatched from the end of May, left the ovisacs on the trunks and main branches of the host plants and moved to the leaves. There they settled, often on the undersurface next to the leaf veins, feeding until Sept./Oct. Prior to leaf fall, the nymphs migrated to adjacent twigs on which they overwintered (females as the third-instar (Sengonca & Faber, 1996)). The mean mortality in 1998 during this overwintering stage was 10.0%. In spring, the final moult of the female nymphs was followed by a period of rapid growth, the largest females growing to >6mm. Adult males appeared for a short period at the beginning of May but were rare (2.3% of the total population). At this time, the females began to move from the twigs downwards to the main branches and the trunk of the trees, where white wax filaments were secreted to form the ovisacs. Female *P. regalis* are known to lay up to 3000 eggs (Speight, 1994). Shortly after oviposition, the females died but remained attached to the ovisac, forming a protective cover for the eggs and the offspring. On hatching, the new generation of crawlers dispersed to the leaves again. During this dispersal, the nymphs are easily carried away by the wind and about 99.5% of them die before settling on a leaf (Merlin *et al.*, 1988). However, some crawlers might get blown onto previously uninfested trees and thus spread the infestation.

Although infestations by the horse chestnut scale can have a considerable impact on the growth of the trees (Speight, 1991), the primary “damage” caused by the coccid seems to be of a cosmetic nature. The conspicuous white ovisacs of the adult females cover the trunks and main branches of the trees and are often mistaken for a fungal disease. Amenity trees in towns are supposed to look nice, and infested trees apparently do not fulfil these requirements. The use of insecticides in urban areas, however, is problematic and usually unwanted. In Zurich, therefore, an environmentally harmless method was tested on selected trees: the unsightly ovisacs on the trunks and main branches were washed off with water using a high-pressure cleaner. When carried out just before egg hatch, this washing should also control the pest. Although the washing procedure proved to be difficult and time consuming when the trees were high, it may be an interesting approach especially for younger trees.

Heavy infestations in other cities are known to have subsided after some years but the reasons for this decline are not understood. Native natural enemies do not seem to have a decisive impact on the populations of *P. regalis* in urban areas, maybe because of a low abundance of parasitoids and predators in this environment. Two aphelinid species belonging to the genus *Coccophagus* have previously been described as parasitoids of the horse chestnut scale: *C. obscurus* Westwood in England (Speight & Nicol, 1984) and *C. scutellaris* (Dalman) in Germany (Faber & Sengonca, 1997). In Zurich, however, two other species in this genus were found: *C. lycimnia*

(Walker) and *C. semicircularis* (Förster), which started to emerge from the scales in May (on twigs) and at the beginning of September (on leaves). Of the parasitoids collected, 97.3% were *C. lycimnia*.

According to Speight & Nicol (1984), the parasitoids overwinter as pupae in their hosts fixed to the leaves, so that the parasitoids end up on the ground after leaf fall. As the fallen leaves get removed by the local street cleaners in towns, this would prevent a build-up of the parasitoid population in the following year. However, in Zurich, only a few parasitoid pupae were found in scales on leaves in late October and it is thought that these had probably failed to emerge and died later on. The remaining parasitoids overwintered in an early developmental stage in their hosts on the twigs, indicating that the migration of the parasitised nymphs from the leaves in the autumn had not been suppressed.

All those parasitoids collected from the overwintering scales in the spring were females but 22.9% of the adult *C. lycimnia* in the autumn were males. Blahutiak (1972) found a similar phenomenon in a population of *C. lycimnia* parasitising the European fruit scale, *Parthenolecanium corni* (Bouché), which also occurs in small numbers on the trees in central Zurich. Since *P. corni* is known to be a host of both *C. lycimnia* and *C. semicircularis* (Hayat, 1997), these aphelinids were probably already present when the trees became infested with the horse chestnut scale. However, the rate of parasitisation of *P. regalis* on the leaf and twig samples was low (≤5%).

Coccinellid predators (e.g., *Exochomus quadripustulatus* Linnaeus) were also rare and no potential dipteran predators (e.g., the chamaemyiid *Leucopis silesiaca* Egger) were encountered in the scales' ovisacs.

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LIT, I.L. Jr[1]; CAASI-LIT, M.[2]; TALIDONG, C.V. Jr[2]
[1]*Entomology Section, Museum of Natural History, University of the Philippines Los Baños (UPLB), College, Laguna 4031, Philippines.*
[2]*Entomology Laboratory, Institute of Plant Breeding, College of Agriculture, UPLB, College, Laguna 4031, Philippines.*

# THE PRODUCTION OF LONG ANAL FILAMENTS BY THE BAMBOO NODE MEALYBUG, *ANTONINA* SP. (HEMIPTERA: COCCOIDEA: PSEUDOCOCCIDAE), AS A RESPONSE TO LACK OF ATTENDING ANTS.

## ABSTRACT

The production of long anal filaments by the bamboo node mealybug, *Antonina* sp. (Hemiptera: Coccoidea: Pseudococcidae), as a response to lack of attending ants.

Bamboo node mealybugs, *Antonina* sp., in the absence of attending ants, were observed to produce long waxy filaments both in the field and in the greenhouse. In contrast, ant-attended mealybugs had only very short filaments or none at all. Ant exclusion experiments confirmed the field observations. The available data suggest that the long filaments are an adaptation for the dispersal of honeydew in the absence of solicitous ants, so as to avoid drowning in the accumulating honeydew or suffocation due to development of sooty moulds.

Key words: Poaceae, Gramineae, *Bambusa*, damage, filament structure, Sternorrhyncha, *Anoplolepis longipes*, *Dolichoderus*, *Oecophylla smaragdina*, *Polyrhachis*, *Solenopsis geminata*, *Monomorium*.

## INTRODUCTION

Mealybugs of the genus *Antonina* Signoret are legless and normally sclerotised in the adult stage. They are usually globose and enclosed in a felt-like waxy sac, with only the mouthparts, spiracles and the anal-vulva area exposed. This group has been known to occur almost exclusively on species of Poaceae (= Gramineae) (Ben-Dov, 1994; Hendricks & Kosztarab, 1999).

We have observed one species to seriously affect new propagules and young bamboo plants of several species, particularly *Bambusa tuldoides* Munro, *B. vulgaris* var. *vulgaris* Schrader ex Wendland, *B. v.* cv. *vittata* A. Riviere (= *B. v.* var. *striata* (Lodd ex Lindley) Gamble), *B. philippinensis* (Gamble) McClure (= *Sphaerobambos philippinensis* (Gamble) S. Dransfield) and *B. multiplex* (Lour.) Raeuschel ex J.A. & J.H. Schultes. This *Antonina* species fixes itself on the nodes, forming colonies of as many as 15 adult females on a single node and hence we have called it the bamboo node mealybug.

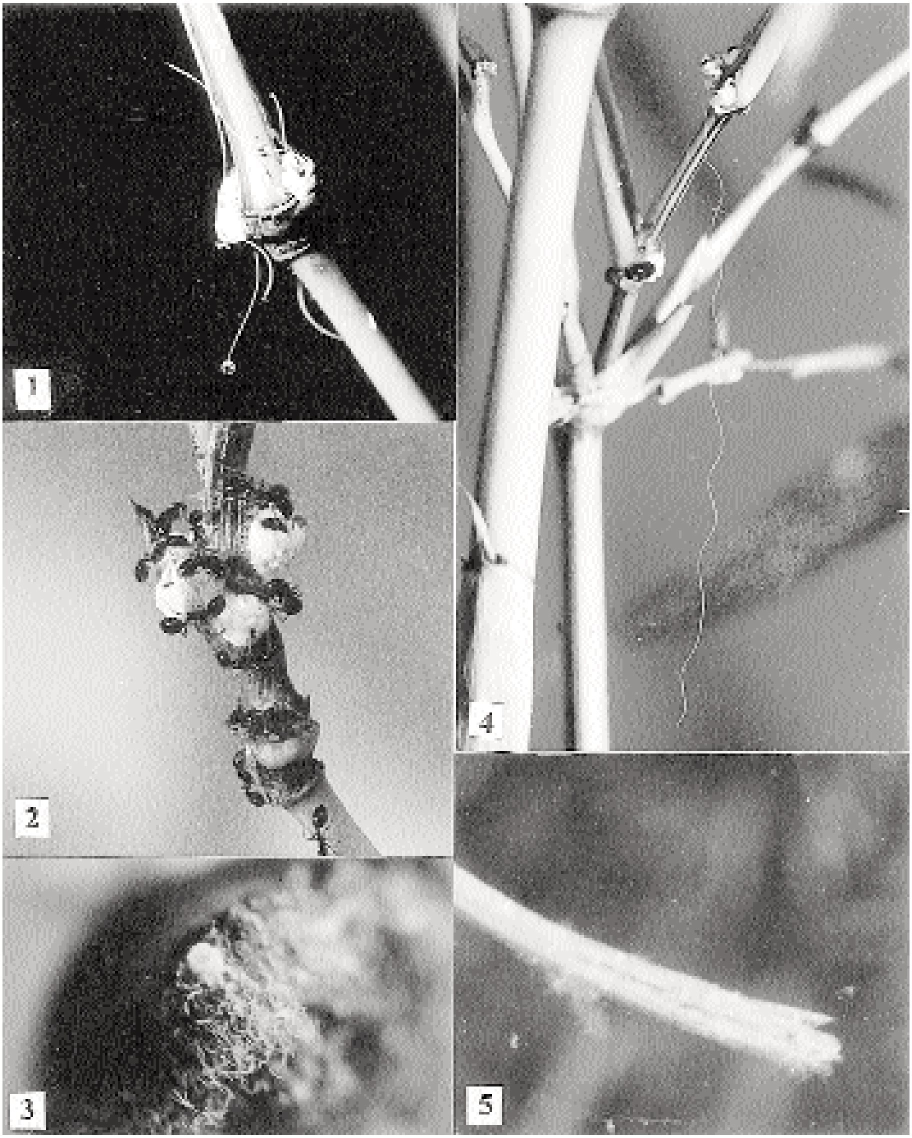
Both in the field and in the greenhouse, the bamboo node mealybug causes yellowing of leaves, stunted growth and, if kept unchecked, eventually the death of young bamboo plants. In the field, these insects apparently benefit from the attendance of various ant species which protect them from most natural enemies and also disperse them, especially the first-instar crawlers, from their maternal or hatching site to other favourable areas or plants. In this mutualistic relationship, the ants are provided with honeydew. This type of classic mutualistic relationship between ants and honeydew-producing Sternorrhyncha has been reviewed many times (e.g., Nixon, 1951; Way, 1963; McKenzie, 1967; Gullan, 1997).

However, in the absence of ants, the accumulation of honeydew can drown the honeydew-producer or they can become suffocated by sooty moulds that can develop on the uncollected honeydew. In addition, the development of the sooty moulds on the leaves can also affect the photosynthetic activity and, therefore, the health of the host plant. Therefore, honeydew needs to be removed by the ants or expelled as far as possible away from the mealybugs and the host plant (Malumphy, 1997). Adaptations of facultatively myrmecophilous mealybugs and other scale insects for the expulsion of honeydew in the absence of solicitous ants have also been documented in previous papers and reviews (e.g., Williams & Williams, 1980). All examples of these adaptations essentially involve active propulsion of honeydew away from the body with the aid of the anal ring setae and/or the anal tube.

In our on-going study of arthropods associated with bamboo, we have observed that the bamboo node mealybugs, in the absence of attending ants, produce long, waxy filaments both in the field and in the greenhouse (Fig. 1). In contrast, those that were ant attended had only very short filaments or none at all (Fig. 2). This phenomenon has not been documented nor studied before in mealybugs but is well-known in some margarodids (e.g., Bhatti, 1990; Morales, 1991) and a few eriococcids, such as *Ourococcus* Fuller (Fuller, 1899). At the same time, the possibility that this could involve adaptations to dispose of honeydew in the absence of attending ants led us to conduct ant exclusion experiments to test our hypothesis, i.e. that bamboo node mealybugs produce long anal filaments in response to lack of attending ants.

## MATERIALS AND METHODS

Young bamboo plants propagated from culm cuttings were examined for the presence of ants and mealybugs. Bamboo node mealybugs with and



**Figures 1-5:** The bamboo node mealybug, *Antonina* sp., and its anal filaments.
**1**. Unattended mealybugs with long filaments, showing honeydew droplet. **2**. Mealybugs without filaments attended by *Solenopsis* ants. **3**. Anal region of a mealybug (sac removed) with filament starting to form less than 24h after ant exclusion. **4**. Longest filament, 80mm. **5**. Mounted filament showing strands of wax fibres.

without filaments and those found to be with or without attending ants were collected separately, preserved and identified to determine whether they belonged to the same species. In addition, live specimens were observed to establish whether the long, waxy filaments were really of anal origin.

Two ant exclusion trials were conducted. The first trial used a single potted plant (Buddha's belly bamboo, *B. tuldoides*) with many branches, nearly all of which were infested with the bamboo node mealybug attended by the ant *Anoplolepis longipes* Jerdon. Ten branches were selected, each with 2 colonies of 3-6 mealybugs. Ants were removed from half of these branches, after which the basal nodes were coated with petroleum jelly to keep the branches ant free. Daily observations were made for 5 days, starting 24h after isolation from the ants. After this time, the petroleum jelly coatings were removed, allowing the ants to return, and observations were then continued for another 5 days.

In the second trial, 10 similarly propagated, plastic-potted, young plants of the yellow striated variety (yellow common bamboo, *B. v.* cv. *vittata*) were taken from the field where their resident mealybug fauna were also attended by *A. longipes.* The ants were removed and the plants then kept ant-free by applying a repellent chalk around the platform where the plants were placed. Ten colonies, each with about 5 adult female mealybugs, were randomly selected and marked. The lengths of anal filaments were then measured daily using a flexible metre rule. Observations were made for 10 days, starting 24h after isolation from the ants.

While these trials were being conducted, field observations were continued, with an emphasis on the other ant species that attend this mealybug and on any peculiar behaviour on the part of either the ant or the mealybug. All important observations were photographed and voucher specimens collected where applicable. Voucher specimens have been deposited in the Entomology Section of the UPLB Museum of Natural History.

## RESULTS AND DISCUSSION

All specimens of the bamboo node mealybug belonged to the same species of *Antonina.* Observations on live mealybugs under the stereo-zoom microscope confirmed that the long, waxy filaments were of anal origin (Fig. 3). In the field, the other ant species attending the mealybug were *Dolichoderus* sp., *Oecophylla smaragdina smaragdina* (Fabricius), *Polyrhachis* sp., *Solenopsis geminata geminata* (Fabricius) and *S. g. rufa* (Jerdon). In both the greenhouse and in the laboratory, the mealybug colonies were also attended by *Monomorium* sp. but this ant not only fed on the honeydew and the waxy filaments but also on the mealybugs themselves.

In both ant-exclusion trials, the mealybugs started producing anal filaments within 24h of the removal of the ants. The daily increase in length of the anal filaments ranged from zero in a few individuals to 8mm, with an average of 2.9mm and a modal value of 3.0mm. In the first trial, the returning ants did not cut off the filaments but were still able to collect globules of honeydew from the tips of the relatively short filaments. There was no further increase in filament length once the ants had returned.

Each mealybug produced only one anal filament at a time, which became either spiral or kinky as it grew. After 10 days, the average length of an anal filament reached 34.9mm. However, the longest recorded was from a specimen reared in the greenhouse before this study, which had a filament 80mm long (Fig. 4). Using the modal value of 3mm increase in length per day, we estimate that this particular mealybug had been isolated from ants for at least 26 days. Mealybugs with very long filaments were not attended by ants. What happens to these mealybugs needs further study.

It is clear that the role of the long anal filament is to dispose of the honeydew. We have observed honeydew droplets accumulating on the distal end of each filament (Fig. 1), regardless of the angle or orientation of the mealybug to the stem or node. Each filament is actually made up of closely packed, minute, wax fibres, which form a microtube or capillary (Fig. 5), through which honeydew droplets are actively eliminated. With regard to the spiral or kinky filaments, there is probably some physical explanation why a spiral microtube or capillary would be more favoured than a straight one (e.g., perhaps related to the fluid mechanics of honeydew). Nevertheless, it will definitely have something to do with the chemical structure of the wax as well as the arrangement of the wax secreting pores or ducts around the anal ring or anal ring setae.

These ant exclusion experiments confirmed the field observations. There still remains, however, the alternative hypothesis that the production of the long, anal filaments may not be a response to lack of attending ants but that the presence of ants inhibits the development of anal filaments, possibly including the cutting of the filaments by the ants. However, it was observed that isolated mealybugs or those that were almost completely covered by the culm sheaths, still developed filaments, even in the presence of attending ants, although not as long as when the mealybugs were entirely unattended. It appears that, with these occasional cases, the filaments were ignored by the ants (except *Monomorium* sp.).

In summary, the available data suggest that the long anal filaments are an adaptation to dispose of the honeydew in the absence of solicitous ants so as to avoid drowning in the accumulating honeydew or suffocation due to the development of sooty moulds. This ability to dispose of honeydew in the absence of ants may partly explain the relative success of these mealybugs in colonising bamboo plants, both in the field and in the greenhouse.

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ÖZGÖKÇE, M.S.[1]; YASAR, B.[1]; KARACA, I.[2]
[1]*Department of Plant Protection, University of Yuzuncuyil, 65080 Van, Turkey.*
*2Department of Plant Protection, University of Çukurova, 01330 Adana, Turkey.*

# LIFE TABLES OF *LEPIDOSAPHES ULMI* (L.) AND *PALAEOLECANIUM BITUBERCULATUM* (TARGIONI TOZZETTI) (HEMIPTERA: COCCOIDEA) ON APPLE TREES IN VAN PROVINCE, TURKEY.

## ABSTRACT

Life tables of *Lepidosaphes ulmi* (L.) and *Palaeolecanium bituberculatum* (Targioni Tozzetti) (Hemiptera: Coccoidea) on apple trees in Van Province, Turkey.

Apples are the most important cultivated crop in Van Province in Eastern Anatolia Region, Turkey, where *Lepidosaphes ulmi* (L.) and *Palaeolecanium bituberculatum* (Targioni Tozzetti) (Hemiptera: Coccoidea) are amongst the most economically important pest species. Life-table data were collected in the field for these two species in two different apple orchards. The development time for each stage was recorded once a month in the Winter and every fortnight during the Spring, Summer and Autumn. In each orchard, both shoots and leaves of five randomly selected trees were sampled and each stage of the two scale species was counted. The life-table data were analyzed with regard to the age of the insects and the season, and it was found that *L. ulmi* and *P. bituberculatum* had one generation a year. Of several mortality factors, parasitisation was the most important (25.8% for *L. ulmi* and 23.8% for *P. bituberculatum*).

Key words: *Aphytis mytilaspidis*, aphelinid, *Coccophagus palaeolecanii.*

## INTRODUCTION

Horticulture is very important in the Van Province of Turkey, where apple production is the most important fruit crop. This is due to the special microclimate in the area around Van Lake, which is surrounded by mountains. Of the pests which attack apple in this area, two coccid species are economically important, namely *Lepidosaphes ulmi* (L.) and *Palaeolecanium bituberculatum* (Targioni Tozzetti) (Erol & Yasar, 1994). There has been no detailed study of these species in the Van Region and this paper presents the life tables of these two species in order to provide basic background knowledge for further research.

## MATERIALS AND METHODS

The studies were carried out between 1994 and 1995 in two unsprayed apple orchards in Van Province, one which had an infestation of *L. ulmi* and the other *P. bituberculatum*. Samples were collected monthly during the winter and every fortnight during the rest of the year (April to October inclusive). For samples of both species, five trees approximately 1.5-2.0m tall in each orchard were randomly chosen, from each of which five 20cm shoots (one from the four sides of the tree and another from the centre) and 25 leaves were collected. The number of scales on 10 cm of each shoot and on the lower surface of each leaf were counted and placed in the following categories: egg, 1st-instar nymph, 2nd-instar nymph, young female, mature female and parasitized individuals. No male stages were found. When each scale was counted, they were dissected so that the presence of parasitoids could be detected.

The following life table data were calculated (Morris, 1963; Morris & Miller, 1954; Harcourt, 1969; Krebs, 1972):

| | |
|---|---|
| x | age interval at which the sample was taken. |
| lx | the number of scales alive at the start of each stage noted in the x column. |
| dx | the mortality within the age interval stated in the x column. |
| dxF | the mortality factor responsible for dx. |
| 100qx | percentage mortality. |
| Sx | survival rate within x. |

## RESULTS AND DISCUSSION

### *Lepidosaphes ulmi*

*L. ulmi* had one generation a year in Van Province, overwintering in the egg stage beneath the scale cover. One generation a year is normal for Europe (Bodenheimer, 1949; Çanakçioglu (1977), but two generations have been recorded on apple and pear in the Aegean and Mediterranean regions of Turkey (Nizamlioglu, 1957; Okul *et al.,* 1978).

Although some biological races are known to have males (Ferris, 1937; Kosztarab & Kozár, 1988; Gerson, 1990; Kozár, 1990), no males were found during this study and so it is likely that this species is parthenogenetic in Van Province. The overwintering eggs hatch in May and the crawlers settle on 1st- and 2nd-year old shoots, although, when particularly abundant, they can settle elsewhere (Samarasinghe & LeRoux, 1966).

The life cycle of the scale and the number of scales parasitised by its parasitoid are shown in Fig. 1. The 1st-instar nymphs completed their development by mid-July and the next generation of adult females

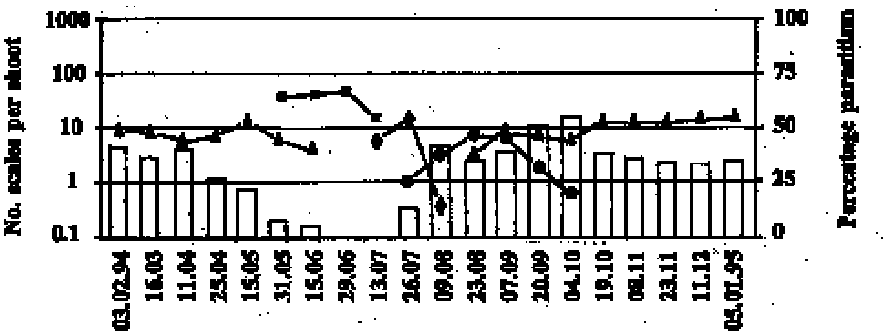


**Fig. 1.** **Number of each stage of *Lepidosaphes ulmi* per 10cm length of shoot (——) and percentage parasitism (bars) by *Aphytis mytilaspidis* in Van province in 1994-1995 (left y-axis = log scale). Where -▲- = egg data; -•- = nymphal data; -♦- = data for immature adult females and -●- = data for mature adult females.**

commenced egg laying towards the end of July. One of the main mortality factors was parasitisation by the aphelinid *Aphytis mytilaspidis* (Le Baron) which attacks mainly the egg stage but can also be found in the adult females. Thus, the percentage mortality became much reduced on hatching. However, when the new generation of eggs was laid in August, the mortality rate rose again sharply. During the egg stage, the percentage parasitism ranged between 22 and 36%. Parasitisation of the new generation was seen at the end of July. The life table data (which refer to field conditions) are given in Table 1. Here, the initial population was calculated theoretically, based on

Table 1. Life table for *Lepidosaphes ulmi*.

| x | lx | dxF | dx | $100qx_1$ | $100qx^1$ | Sx |
|---|---|---|---|---|---|---|
| Eggs (N) | 11,650.6 | Parasites<br>"Others"<br>Total | 4305.56<br>7111.07<br>11,416.63 | 36.96<br>61.04 | 36.96<br>61.04 | 0.020 |
| Larvae | 233.98 | Parasites<br>"Others"<br>Total | 0.00<br>151.20<br>151.20 | 0.00<br>64.62 | 0.00<br>1.30 | 0.354 |
| Young adult females | 82.78 | Parasites<br>"Others"<br>Total | 4.90<br>22.04<br>26.94 | 5.92<br>26.62 | 0.04<br>0.19 | 0.675 |
| Mature adult females | 55.84 | Parasites<br>"Others"<br>Total | 35.19<br>20.65<br>55.84 | 63.02<br>36.98 | 0.30<br>0.18 | |

the number of females in the previous years population, as follows: the mean number of eggs per female was 39.8 and this was multiplied by the number of adult female scales on the shoots on the first counting date in May. Thus, the initial estimated population of eggs was 11,650.6 per 10cm shoot. However, as almost 37% were parasitised by *A. mytilaspidis* and a further 61% died due to unknown factors, only 2% of the eggs were still alive in the Spring. Thus, about 234 eggs were able to hatch but of these 64.6% died due to unknown factors, so that only 35.4% of the 234 eggs became adult females. Of these adult females, 55.8% produced eggs but not all adults survived for the full egg-laying period because 63% of the adult scales were parasitised. Thus, the next generation eggs were laid by the 37% surviving adult females. It is clear from Table 1 that mortality was high in the egg and nymphal stages. It can be shown that natural mortality factors were the cause of this high mortality. The high rate of parasitism is thought to be because the orchards had been unsprayed in the two years prior to the study.

## *Palaeolecanium bituberculatum*

*P. bituberculatum* also has only one generation a year in Van Province and overwinters as an egg beneath the female scale cover. Hatching occurs at the beginning of May and the crawlers settle on the leaves (Özgökçe, 1995) where they remain until adult. Once mated at the end of June, the adult

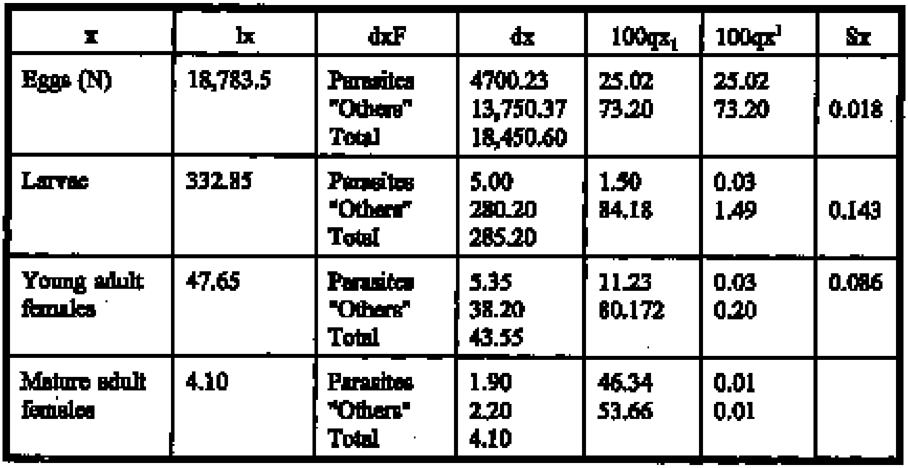
Fig. 2. Number of each stage of *Palaeolecanium bituberculatum* per 10cm length of shoot or per leaf (——) and percentage parasitism (bars) by *Coccophagus palaeolecanii* in Van province in 1994-1995 (left y-axis = log scale). Where white bars = parasitism on shoots and hatched bars = parasitism on leaves; and -▲- = egg data (on twigs); -■- = nymphal data (on leaves); -◆- = data for immature adult females on leaves; -●- = data for immature adult females on twigs, and -○- = data for mature adult females on twigs.

females move (preferably) onto the young shoots and shoot tips but they can also settle on the branches of the tree. They do no move again. The survivorship curve and life cycle of the scale and the number of scales parasitised are shown in Fig. 2. The mature adult females commence laying the eggs of the next generation towards the end of October.

The main parasite attacking *P. bituberculatum* is the aphelinid parasitoid *Coccophagus palaeolecanii* Jasnosh, which mainly attacks the adult stage but can also parasitise the egg and the nymphal stages. Parasitisation was lowest at the end of June, when the larval population was highest but, by the end of October, when the eggs of the next generation had been laid, the percentage parasitism rose again.

The percentage parasitism was calculated in the same manner as for *L. ulmi*, and ranged between 17 and 41%. This high percentage parasitism may have been indirectly due to *Hyponomeuta malinellus* Zell (Lepidoptera: Hyponomeutidae) which caused much damage to the leaves and thus a reduction in the number of scales for the available parasitoids. The initial estimated population (see under *L. ulmi*) started with 18,783.5 eggs per 10cm shoot or one leaf, but there was very high mortality, with 25% being lost through parasitism and 73.2% due to unknown factors (Table 2), so that only 1.8% hatched to become crawlers. Thus, a mean of 332.9 individuals hatched, of which 1.5% were lost through parasitism and a further 84.2% through other factors. Thus, only 14.3% of the eggs that hatched actually became adult

Table 2. Life table for *Palaeolecanium bituberculatum*.



| x | lx | dxF | dx | $100qx_1$ | $100qx^1$ | Sx |
|---|---|---|---|---|---|---|
| **Eggs (N)** | **18,783.5** | **Parasites**<br>**"Others"**<br>**Total** | **4700.23**<br>**13,750.37**<br>**18,450.60** | **25.02**<br>**73.20** | **25.02**<br>**73.20** | **0.018** |
| **Larvae** | **332.85** | **Parasites**<br>**"Others"**<br>**Total** | **5.00**<br>**280.20**<br>**285.20** | **1.50**<br>**84.18** | **0.03**<br>**1.49** | **0.143** |
| **Young adult females** | **47.65** | **Parasites**<br>**"Others"**<br>**Total** | **5.35**<br>**38.20**<br>**43.55** | **11.23**<br>**80.172** | **0.03**<br>**0.20** | **0.086** |
| **Mature adult females** | **4.10** | **Parasites**<br>**"Others"**<br>**Total** | **1.90**<br>**2.20**<br>**4.10** | **46.34**<br>**53.66** | **0.01**<br>**0.01** | |

females; of these, 11.2% were parasitised and a further 80.2% were killed by other factors, leaving only 8.6% of the original adults to lay eggs for the next generation. Of these next generation eggs, it was found that 46.3% were parasitised, leaving 53.7% to found the next generation.

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PELLIZZARI, G.; FONTANA, P.
*Università di Padova, Istituto di Entomologia Agraria*
*Agripolis, via Romea 16 - 35020 Legnaro PD, Italy*

# A STUDY ON THE LIFE HISTORY OF *LECANOPSIS CLODIENSIS* (PELLIZZARI) N. COMB. (HEMIPTERA: COCCOIDEA: COCCIDAE).

## ABSTRACT

A study on the life history of *Lecanopsis clodiensis* (Pellizzari) n. comb.
(Hemiptera: Coccoidea: Coccidae).

The biology of *Lecanopsis clodiensis* (Pellizzari) has been studied in Italy, where the species is widespread and lives on Gramineae. The species has one generation/year. Adult emergence takes places in April-May, depending on the meteorological conditions. After mating, the females lay eggs and the crawlers hatch within a month and disperse to the root-crowns of the host plant (a Gramineae) and settle under the leaf-sheath in very protected positions. The 3rd-instar female nymphs and 2nd-instar male nymphs overwinter. All nymphal stages are covered by a glassy wax test. Some aspects of its life history have been investigated in their natural environments (a sandy beach and a meadow) and in the laboratory, particularly its reproductive behaviour, the behaviour of both fertilised and virgin females, its mating behaviour and the dispersal of the adult female. Other observations on the remarkable biology of this species are reported.

Key words: voltinism, sex ratio, eggsac, pupa, phototaxis, host plants, sex pheromones.

## INTRODUCTION

The first brief account on the biology of a *Lecanopsis* species was by Green (1921), who made several observations on the unusual life history of *L. formicarum* Newstead. Thirty years later, Schmutterer (1952) added further biological information (overwintering stage and possible presence of the male). It was only in 1982 that Boratynski *et al.* (1982) presented a comprehensive work on the biology of the same species. In their excellent paper, the authors also clarified for the first time the morphology of the different male and female nymphal stages of *Lecanopsis formicarum.*

Little is known about the biology and even less about the ethology of the other *Lecanopsis* species. Generally, researchers report only the date of collection, the different stages collected and the host plant (Borchsenius, 1957; Tereznikova, 1981; Kosztarab & Kozár, 1988). Moreover, the identity of some species is somewhat obscure.

This paper is part of a larger study devoted to the revision of the genus *Lecanopsis* and highlights some biological aspects of a recently described species, *Lecanopsis clodiensis* (Pellizzari) **n. comb**. (Pellizzari, 1995).

## DISTRIBUTION

*L. clodiensis* was discovered in 1985 on a sandy beach facing the Adriatic sea in the district of Venice, living on Gramineae. Investigations carried out over the following years led to the discovery of numerous biotopes where this species is present in Italy.

So far *L. clodiensis* has been found only in Italy, where it appears to be widespread throughout the peninsula. It colonises, sometimes with large populations, different environments and has been recorded in North-Eastern Italy on the sandy beaches and in the hills, in the Apennine meadows, and in the South on rocks near the sea and in arid areas.

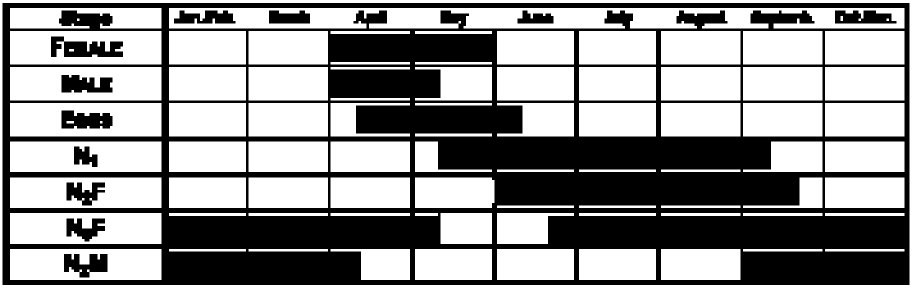
## LIFE CYCLE

The biology of *L. clodiensis* has been studied since 1994 on a sandy beach near Venice, where this species lives on *Agropyron pungens*. Occasional observations have also been carried out in other natural environments in Central and Southern Italy. Further observations have also been made in the laboratory, with the purpose of studying particular aspects of the behaviour of this species.

As previously mentioned, the life cycle of a *Lecanopsis* was highlighted for the first time by Boratynski *et al.* (1982), who studied the biology of *L. formicarum* in the field and in the laboratory. The biology of *L. clodiensis* appears to be very similar (Table 1). The female of *L. clodiensis* develops through three instars. The 2nd- and 3rd-instar females are characterised by a considerable reduction in the size of the legs and antennae, which is usual in this genus. The male has two nymphal stages and then passes through the prepupal and pupal stages, finally becoming an winged adult male. The 2nd-instar male differs from the 2nd-instar female in having well-developed legs and antennae. The nymphs of both sexes are enclosed within a thin, transparent, waxy test.

*Lecanopsis clodiensis* has one generation/year. The adult males and females emerge between the second half of April and the first half of May, depending on the meteorological conditions and localities. A few days after fertilisation, the females start to secrete a loose, white eggsac, that encloses part of the female body, and she then lays her eggs. Each female lays an average of 670 eggs (minimum 280; maximum 1350). Virgin females do not lay eggs but do usually produce an empty eggsac. The eggs hatch after 15-30 days and the crawlers try to reach the root-crown of the host plant, where they settle under the leaf-sheath, in very protected positions.

Table 1: Life cycle of *Lecanopsis clodiensis* (Pellizzari) on *Agropyron pungens* on a beach on the Adriatic Coast near Venice, 1994.
Where: Female = adult female; Male = winged male; Eggs = eggs and eggsacs; $N^1$ = first-instar nymphs; $N_2F$ = second-instar female; $N_3F$ = third-instar female, and $N_2M$ = second-instar male.



| Stage | Jan-Feb | March | April | May | June | July | August | Septemb. | Oct-Dec |
|---|---|---|---|---|---|---|---|---|---|
| FEMALE | | | ■ | ■ | | | | | |
| MALE | | | ■ | ■ | | | | | |
| EGGS | | | ■ | ■ | ■ | | | | |
| $N_1$ | | | | ■ | ■ | ■ | ■ | ■ | |
| $N_2F$ | | | | | ■ | ■ | ■ | ■ | |
| $N_3F$ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| $N_2M$ | ■ | ■ | ■ | | | | | ■ | ■ |

Settled 1st-instar females are present on the plants until September, although 2nd-instar females appear in June and are present until September. Rare 3rd-instar females can be found at the end of June, but their number increases later and from September until the following spring they are the only female stage present on the plants (Fig. 2a).

The 2nd-instar males occur from the end of August until April-May of the following year, but then, within a few days, they all move from the crown of the host plant in search for a suitable place to secrete a puparium and then moult to prepupa, pupa and adult male.

The peak of emergence of the adult females takes place within a few days in any particular locality, so that the simultaneous appearance of the females in places where a large population is present assumes the characteristics of an outbreak. We observed one of these outbreaks on 11 April 1997, when we found thousands of adult females on the beach, far from their host plants, wandering singly on the sand or forming groups (Fig 1a). All of these wandering females were without an eggsac. Several groups of egg-laying females were found only in the shade, under plants or in other protected places. As females with eggsacs were found only in shady or protected locations, we hypothesised that, after mating, the females move again towards shaded areas. Because of the high number of females present on the beach, we were able to collect several living specimens to perform laboratory tests for confirmation of our hypothesis.

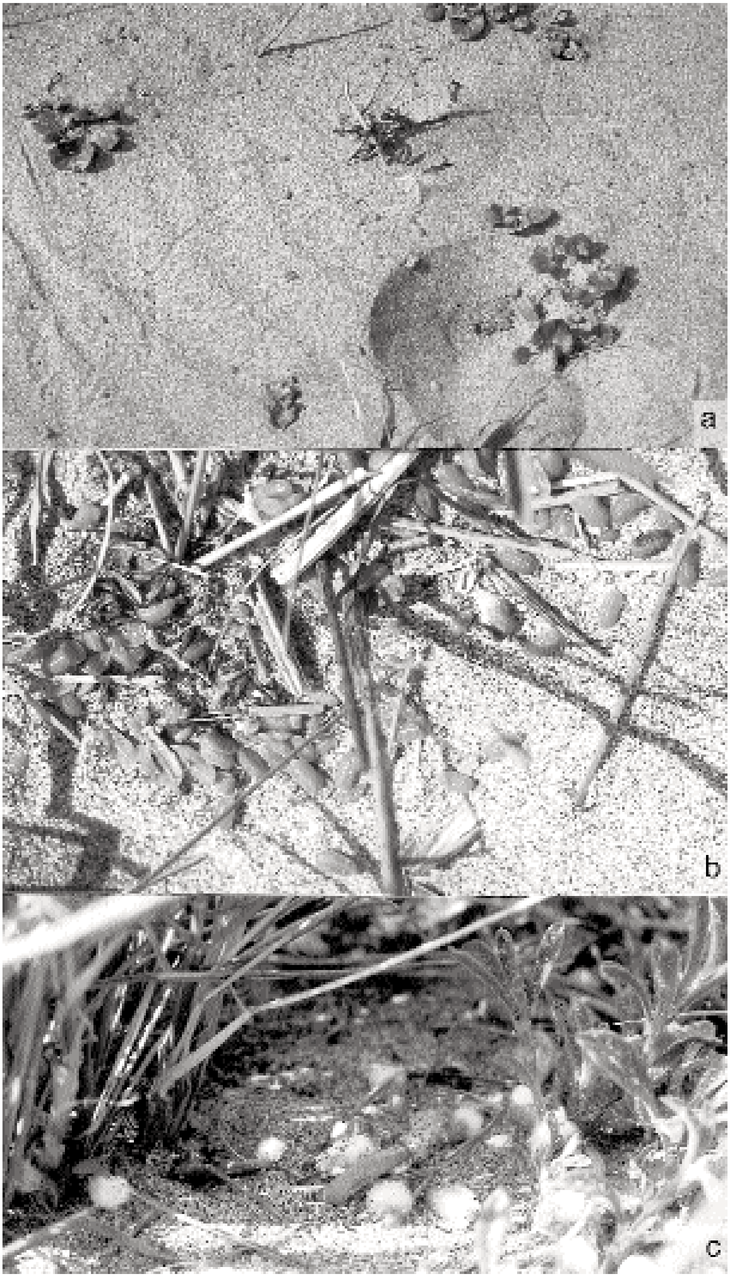


Fig. 1a: adult virgin females wandering on the sand; Fig. 1b,c: aggregations of adult virgin females.

### LABORATORY TESTS

Tests in the laboratory were performed in April 1997, to verify the ability of the adult females to move and to evaluate the preference of fertilised females for protected or exposed places for egg-laying. Other tests were performed in February, 1998, to observe their reproductive behaviour.

1. *Capacity to move*: a group of 34 females without eggsacs, collected in the field in April 1997, were divided into two groups and put on a sheet of polystyrene for ten minutes. Their start and final positions were marked with pins. During the experiment, only two females did not move. The others covered a distance varying from 0.5 to 12cm, with an average of 4.5cm in the 10 minutes, i.e. an average speed of 27cm/h with a maximum of 72cm/h. In this test, the adult females of *L. clodiensis* showed that they could move easily and, therefore, could colonise new plants and new territories.

2. *Behaviour of fertilised females*: this test was designed to verify in the laboratory a hypothesis based on field observation, that ovipositing females laid eggs in shady, protected places. Only fertilised females lay eggs, virgin females only producing empty egg-sacs. A group of 125 females without eggsacs were collected in the field in April, 1997. They were divided into groups of 25 individuals in 14cm diam. petri-dishes, the bottoms of which were covered with blotting-paper. Into each petri-dish was placed a 4x4cm piece of dark, thin, folded card as a shelter. We therefore gave each female the choice between an open or a sheltered place in which to lay her eggs. A total of 76 females laid eggs. Of these, 66 (87%) laid eggs under the dark, folded card or under the blotting-paper. A total of 46 females did not lay eggs, but produced empty egg-sacs. Of these, only 11 (23%) were recovered under the shelter. This test, therefore, demonstrated that the fertilised females tended to search for protected places in order to lay their eggs.

3. *Reproductive behaviour of* L. clodiensis *under laboratory conditions*: on the 11th December 1997, several plants of *Agropyron* with 3rd-instar females and 2nd-instar males on the crown were collected in the field, put in small pots and brought to the laboratory with the purpose of obtaining adult males and adult virgin females so as to observe mating and the behaviour of the virgin females. Before putting the plants in the laboratory, four plants were carefully checked to verify the sex ratio, which was about 1:1 on this date.

One month after the plants were brought into the laboratory, where the average temperature was 20°C, we noticed the emergence of the adult females. Just after the last moult, they broke through the glassy test and emerged into the open by moving backwards among the leaf-sheaths. After emergence, most females climbed the leaf blades, reaching the top where they stopped. Other females stayed on the ground, without any great possibility of moving because of the small dimension of the pot. Some of them were transferred to petri-dishes where they continued to move. After a period of 12-15 days, all of the virgin females had secreted a white, loose eggsac but none had laid eggs.

A few days after the emergence of the females, the 2nd-instar males left the crown of the host plant and started to wander to find a place to secrete the puparium. A very few climbed the green leaves of the host plant and here secreted the puparium (Fig. 2b). After about a week, they moulted to prepupa, pupa and finally to winged adult male. However, many 2nd-instar males moved towards the saucers under the pots but they all died without secreting the puparium or failed to secrete it. No puparia were observed on the soil, although we cannot exclude this possibility - because of their small size, they could have escaped our observation. On the contrary, Boratynski *et al.* (1982) reported that the male nymphs of *L. formicarum* formed puparia on the soil and these authors specified that they had never seen them on plants.

The leaves with the puparia were cut from the plants and preserved in a small cage to perform mating tests. One male puparium with a male inside was put in a small plastic cage with a virgin female to observe the mating behaviour. Just after emerging, the male started to move quickly and, on reaching the female, mounted the dorsum, walked over her whilst vibrating the antennae rapidly, and then inserted his aedeagus into the genital opening through the anal cleft, at the same time raising the caudal filaments upwards (Fig. 2e). The mating lasted a few seconds after which the male quickly left the female to wander in the cage but he promptly mated again when he met the female during his rapid exploration of the cage. In the observed situation, the male mated 17 times with the same female, but then became inactive and died within a few hours. The female started to lay eggs a few days after copulation.

The other 5 male puparia were kept in small boxes, each with several virgin females (from 5 to 30 females) in order to ascertain how many females could be fertilised by one male. The best performance was 7 females fertilised by one male but two of the seven females laid only a few eggs. Altogether 5 males fertilised 12 females; two males failed to fertilise any females. From the results of this test, we can infer that a male can mate with several females. Besides, it seems likely that subsequent copulations by a male result in progressively lower fecundity of the females, probably because

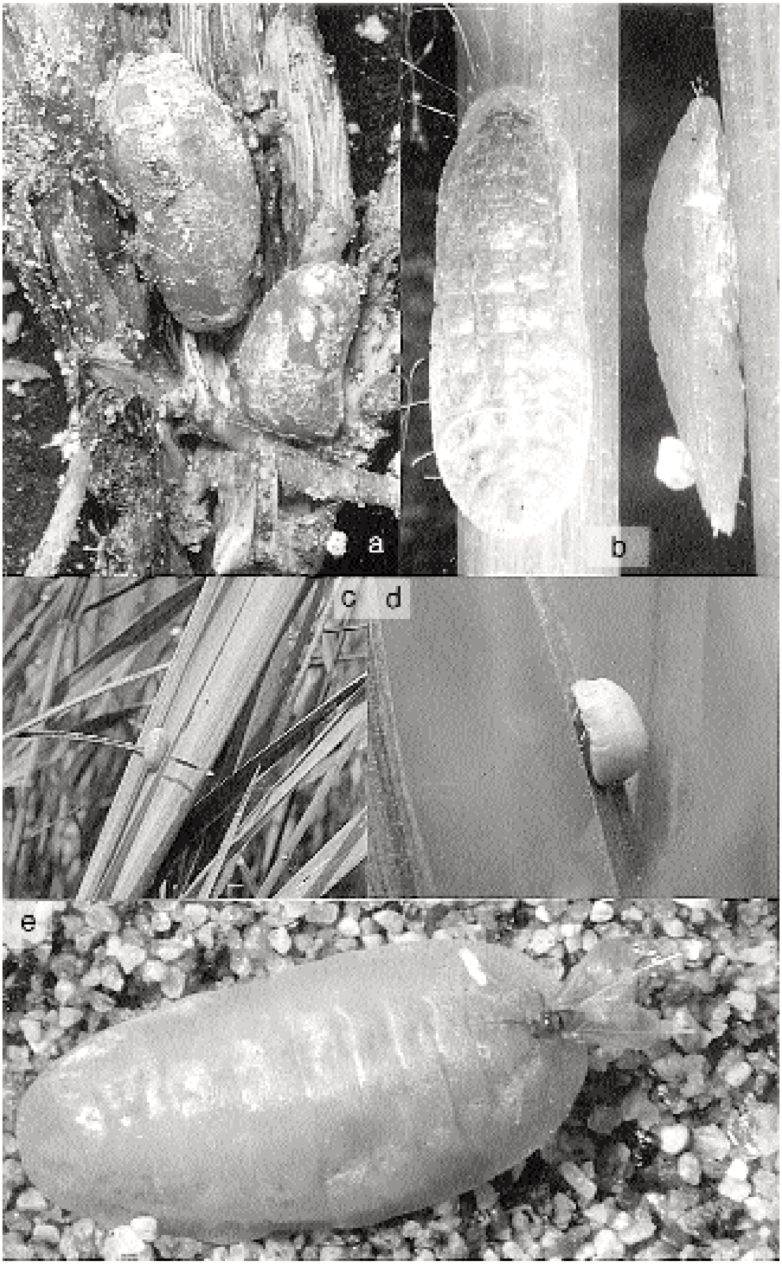


Fig. 2a: 3rd-instar females settled on the crown of *Agropyron pungens*; Fig. 2b: puparia of males; Fig. 2c, d: virgin females climbing the leaf blades; Fig. 2e: mating.

of the lesser amount of spermatozoa they receive. These tests need to be repeated.

Under laboratory conditions, 123 females emerged from the infested plants but only 7 males, giving a sex ratio of 18:1.

### REPRODUCTIVE BEHAVIOUR

These observations, which were carried out under natural environmental conditions and in the laboratory, allowed us to clarify the reproductive behaviour of *L. clodiensis.*

The adult virgin females are apparently positively phototactic. After emergence, they exhibited two different types of behaviour, probably depending on the environment in which they lived. Those living amid the grass of meadows usually climbed to the top of the leaf blades just after emergence (Fig. 2c,d), where they stayed waiting for the male. After mating, they descended and started to lay eggs on the ground or under stones or moss. In several cases, unfertilised females remained on the top of blades and here produced their empty eggsac. This behaviour was also recorded by Green (1917, 1921) for *L. formicarum*, but not by Boratynski *et al.* (1982), who cast doubt on Green's observation.

The females which lived on the beach, where the host plants are scattered, generally moved to open, sunny places on the sand, where they formed groups of tens of individuals (Fig. 1b,c). After mating, they moved from these sunny sites to shady places, usually the base of grasses or under stones (although unusual protected places were also chosen by the wandering females, such as pieces of plywood, polystyrene, and so on) and here they stopped moving and started to lay eggs. It is the crawlers who have the task of finding the host plant.

Unfertilised females usually did not exhibit any preference for shady, protected places but remained for a long time in sunny or exposed sites such as the top of leaves or stems, presumably waiting for the male, eventually secreting an eggsac but never laying eggs. In several cases, the empty eggsacs of these virgin females were longer than those with eggs because the virgin females continued to move, thus changing the shape of the eggsac.

### COMMENTS

In the life history of *L. clodiensis,* we can recognise several interesting peculiarities, some of which were also pointed out by Boratynski *et al.* (l.c.) for *L. formicarum.*

The adult females varied considerably in size, from 3 to 8mm. The dimensions attained by the adult females were similar to those of the 3rd-instar female before the last moult, the size of the latter clearly depending on their feeding position, which is chosen by the crawler. In fact, we have found 3rd-instars in very different positions and sizes on the host plant on the same date, with some nymphs squeezed by the growth of the plant and consequently with a misshapen and dwarf body.

Adult females have no connection with the host plant and do not feed. Just after emergence from the last moult, each female leaves the host plant and wanders on the ground or climbs up blades of grass. During these wanderings, they stop near different plants. However, finding a female, with or without an eggsac, near a plant does not mean that the plant is the scale's host. The only true host plants of *Lecanopsis* are those on which nymphal stages have been collected.

We make the following speculations about the behaviour of *L. clodiensis*. The congregation of the females into groups on the beach could favour mating, where the greater amount of sex pheromone secreted by the group of females could help males to locate them. In addition, it was noted that each male was able to fertilise several females without any new, hazardous search. In a meadow, the fact that the females remain on the leaf blades rather than on the ground would also facilitate location by the males.

Several questions still remain unsolved: i.e. 1. What is the sex ratio of the species in natural environments? The sex ratio of the nymphal instars on the host plants in December was 1:1, but in the laboratory, at the end of metamorphosis, we obtained 123 females and only 7 males, with a sex ratio strongly in favour of females (18:1). 2. Where are the puparia secreted in the field? On the plants or on the soil surface? We were not able to locate them on the beach. 3. Why did we find adult females on the beach so far from their host plant? This behaviour appears highly risky, even though it could be partly explained by the attempt to colonise new plants.

These and several other open questions (i.e. the factors involved in ending diapause) will be the stimulus for further studies on the behaviour of species in this fascinating genus.

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RUSSO, A.; MAZZEO, G.; SUMA, P.; LONGO, S.
*Università di Catania, Istituto di Entomologia Agraria,*
*Via Valdisavoia 5, 95123 Catania, Italy*

# BIONOMICS OF *DACTYLOPIUS COCCUS* COSTA (HEMIPTERA: COCCOIDEA) IN A GREENHOUSE IN SICILY.

## ABSTRACT

Bionomics of *Dactylopius coccus* Costa (Hemiptera: Coccoidea) in a greenhouse in Sicily.

A study on the biology of *Dactylopius coccus* Costa was undertaken to evaluate the possibility of mass-rearing it commercially in Sicily. The colonies of *D. coccus* were maintained on 2-3 years old cladophylls of *Opuntia ficus indica,* rooted in plant pots, in a greenhouse near the Faculty of Agricultural Sciences, the University of Catania. Almost daily observations were made between April 1995 and August 1996. Three reproductive cycles of the scale insect were observed; the duration of each instar, the length of each life cycle, female fecundity and the effects of the biotic factors have been studied.

Key words: mass rearing, *Opuntia*, biology, Dactylopiidae, fecundity, environmental conditions, Canary Islands, Mexico, Peru, Bolivia, Chile, Sardinia, dye, *Exochomus flavipes*, mortality, phototaxis, temperature, humidity.

## INTRODUCTION

Among the scale insects used by man commercially, *Dactylopius coccus* Costa (Hemiptera: Coccoidea: Dactylopiidae) is probably the species which has been of the greatest interest. The Incas reared it and used the acidic dye, which they extracted from the scale-insect bodies, as goods of exchange (Donkin, 1977). Today, with the coming of synthetic dyes, the production and use of these natural dyes has suffered a considerable reduction. For this reason, *D. coccus* is now only bred commercially in Central America (Mexico), South America (Peru, Bolivia, Chile) and the Canary Islands (Flores-Flores & Tekelenburg, 1995), even though it may be present in almost all continents.

During the last century, several unsuccessful attempts to breed *D. coccus* in Italy were made by introducing specimens of various strains into areas of Sardinia (Blanchard, 1883) and Sicily (Inzenga, 1861) which have a particularly mild climate. More recently, as part of a European Union Demonstrative Project for alternative production, attempts to mass rear *D. coccus* under controlled conditions have been started in Sicily. Some reports on this research have already been published (Russo & Mazzeo, 1996; Mazzeo *et al.*, 1998) and they are summarized in the present paper.

## MATERIALS AND METHODS

These observations were made between April 1995 and August 1996 in a glasshouse in the Institute of Agricultural Entomology, University of Catania, using specimens kindly sent from the mass breeding cultures in the Canary Islands. The cultures of *D. coccus* were maintained on 2-3 year old cladophylls of *Opuntia ficus indica*, rooted in plant pots. According to Flores-Flores & Tekelenburg (1995), the inoculation should be made by placing 20-25 ovipositing females in a tulle bag fixed to the cladophylls with cactus thorns. This technique, widely employed in South America, allows the crawlers to disperse over the host but prevents the feeding activity of the ladybird *Exochomus flavipes* ab. *nigripennis* Erichson, an effective predator of *D. coccus* that has been found in the original colonies. When the crawlers have settled on the cladophylls and have started to produce the characteristic white wax filaments, the surrounding area of the cladophyll was marked using a felt pen. These individuals of *D. coccus* were monitored almost daily. Moults were recorded by counting and removing the exuviae. The wax filaments were partially removed each day to facilitate observation. Males were not disturbed after they had begun to form their cocoons.

The behaviour, duration and survival of each life stage was recorded. Whenever possible, fecundity was studied by dissecting single mated females under a stereomicroscope.

## RESULTS

Climatic factors have a marked influence on the biology of *D. coccus*. The 1st-instar nymphs are strongly negatively phototactic and so sunlight causes them to settle in areas on the cladophylls protected from direct solar radiation. Temperature and humidity also affect the length of each instar and its mortality (Figs 1 & 2). There were two generations a year and the length of each instar is shown in Fig. 1. The following minimum and maximum values were found: N1 - from about 20 days (Spring-Summer generation) to 38 days (Winter-Spring generation); N2 - from about 12 (Spring-Summer generations, 1995) to 25 days (Spring-Summer, 1996); adult female - from 21 (Winter-Spring generation) to 36 days (Spring-Summer, 1995). The length of the male nymphal instars was almost identical to those of the female and the average length of the pupal and prepupal stage was 22 days. The adult male survived for 2 to 6 days.

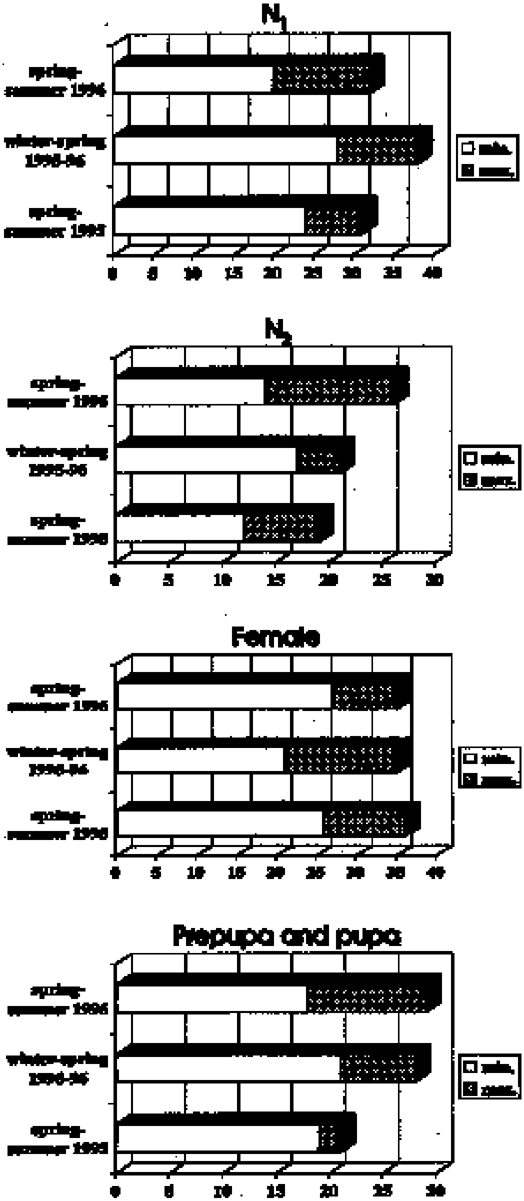

Fig. 1. Length of the N1, N2, adult female and prepupa + pupal stages of *Dactylopius coccus* Costa in a greenhouse in Sicily.

The greater length of the nymphal instars of the Winter-Spring generation was due to the low temperatures which, even in the protected environment of the greenhouse, went down to 12°C during this period. The average length of the female life cycle was 74 days for the Spring-Summer generation and 85 days for the Winter-Spring generation (Fig. 2), while that of the male was from 45 in the Spring-Summer generation to 56 days in the Winter-Spring generation.

First- and 2nd-instar mortality (Fig. 2) was highest during the Spring-Summer, 1995 (the first period of observations) (1st = 15.8%; 2nd = 16.7%). The mortality of the adult female was only 3.6% during the same period and was practically nil during the Winter-Spring generation, 1996. However, in the Spring-Summer 1996 generation, adult female mortality was over 90% (Fig. 2). This extremely high mortality was correlated with the extreme temperatures and humidity: the latter was nearly 100% and was associated with temperatures over 50°C, with a daily range of about 20°C. These conditions were lethal for the adult *D. coccus* which, like its host, prefers temperatures between 24 and 28°C and a lower relative humidity (Flores-Flores & Tekelenburg, 1995).

The fertility, evaluated as number of eggs produced per female, averaged only about 251, whereas Perez Guerra & Kosztarab (1992) reported a mean of about 430/female. However, there was considerable variability in the Sicilian specimens (min. 62, max 459) and this was considered to be due to such factors as the size of the ovary, which itself may have been related to the physiological condition of the host plant and the position in which the female had settled.

## DISCUSSION

These results clearly show that *D. coccus* requires particular conditions for growth and reproduction and that these will have to be taken into consideration for commercial production. It is also clear that some degree of temperature and humidity control will be required in Mediterranean areas if the insect is to survive the hot summers under greenhouse conditions.

This implies that a close look will need to be taken at the economics of such a commercial enterprise, because the market for natural dyes in Europe is small due to the production of cheaper synthetic products. As the natural dyes can also contain human pathogenic microorganisms, the synthetic dyes are also more hygienic.

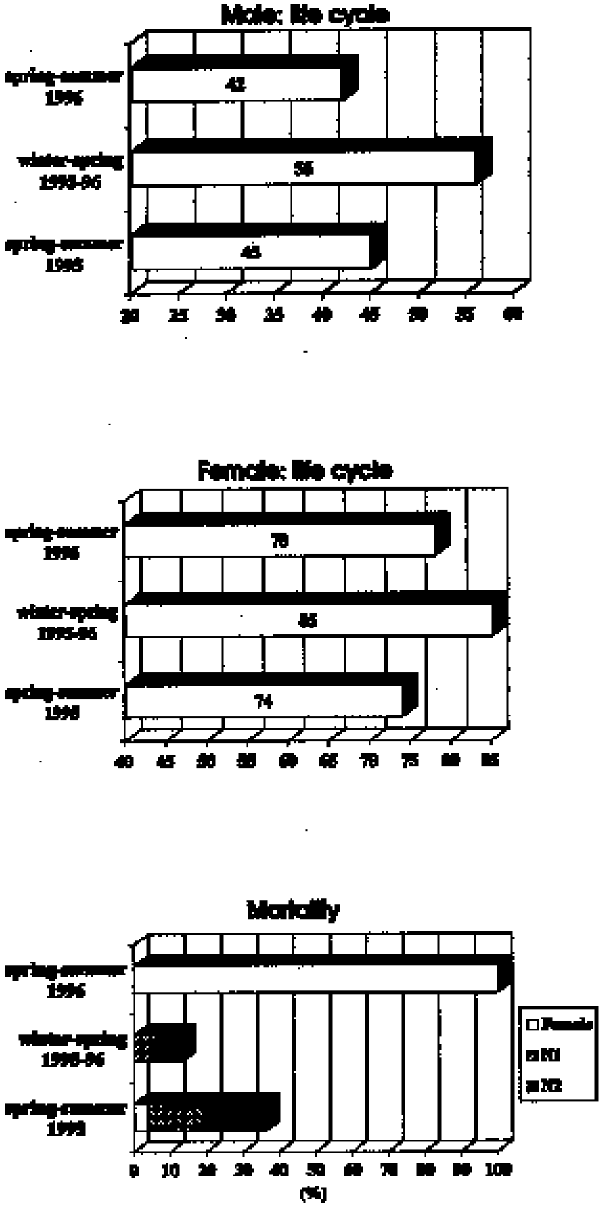

Fig. 2. Length of the female and male life cycle and mortality of *Dactylopius coccus* Costa in a greenhouse in Sicily.

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SCHMUTTERER, H.
*Institute of Phytopathology and Applied Zoology, University of Giessen, Germany*

# THE SCALE INSECTS, WHITEFLIES, APHIDS AND PSYLLIDS OF THE NEEM TREE, *AZADIRACHTA INDICA* (MELIACEAE).

## ABSTRACT

THE SCALE INSECTS, WHITEFLIES, APHIDS AND PSYLLIDS OF THE NEEM TREE, *AZADIRACHTA INDICA* (MELIACEAE).

The neem tree, *Azadirachta indica* (Meliaceae), is attacked by numerous scale insect species, mainly diaspidids, coccids and pseudococcids, as well as a few species belonging to other families in the Sternorrhyncha. *Aonidiella orientalis* (Newstead) is the most important pest of neem; others such as *Pinnaspis strachani* (Cooley), *Chrysomphalus aonidum* (L.) and *Pulvinarisca jacksoni* (Newstead) are minor pests of local importance. Water stress or unsuitable soil conditions in Africa and elsewhere may reduce the resistance of the trees and, therefore, increase the probability of outbreaks. Most scale insects attacking neem are more or less polyphagous species. The closely-related chinaberry tree, *Melia azedarach*, is also attacked by many scale insect species, suggesting that neither of these closely related plants can protect themselves against those scale insects species which can either avoid the tissues containing the active ingredients or are naturally resistant to them.

Key words: Indian lilac, Persian lilac, azadirachtin, antifeedant, Africa, Asia, South Pacific, tropical America, *Oryzaephilus surinamensis*. damage, pest status, *Oecophylla smaragdina*, Aleyrodoidea, Psylloidea, Aphidoidea.

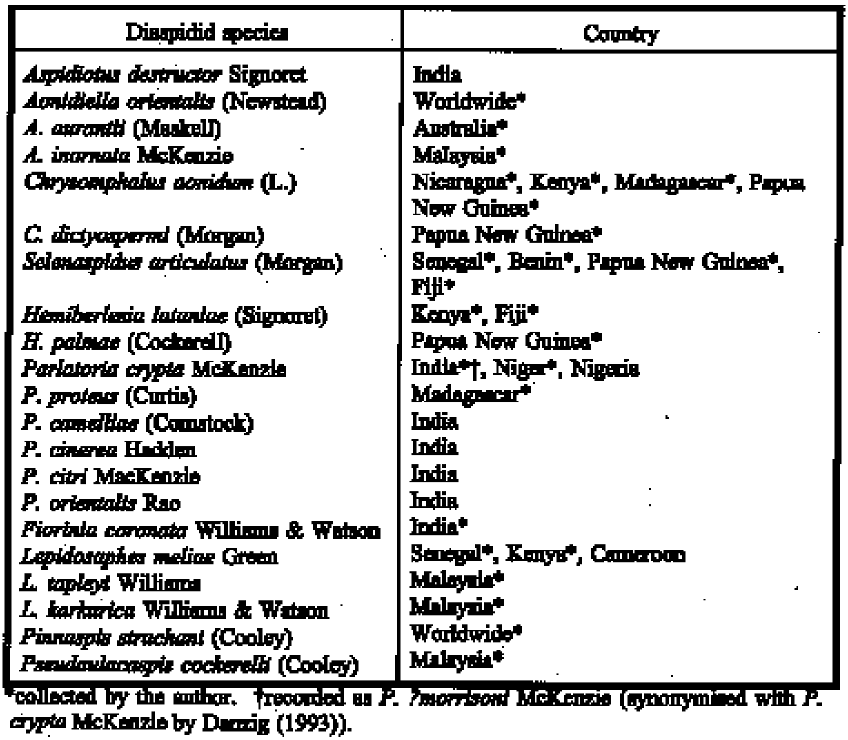
## INTRODUCTION

The Indian lilac or neem tree, *Azadirachta indica* (Meliaceae), has attracted much attention from research workers during the last 20-30 years, mainly because it contains a highly active secondary plant chemical, the tetranortriterpenoid azadirachtin, which has insect antifeedant, growth disrupting and sterilising properties, as well as other effects on insects. Based on extracts of neem seed kernels, various pesticides have been developed, suitable for integrated pest management in tropical and temperate climates.

It might have been expected that only a few insect species would attack plants which contain such highly effective insecticidal ingredients. However, with regard to the neem tree, numerous insects have been recorded (Boa, 1995; Schmutterer, 1995; Tewari, 1992) although most cause no obvious damage. The number of Coccoidea recorded from neem is quite high, about 40 species, but the numbers of other Sternorrhyncha is much lower, with few whitefly species and even fewer aphids and psyllids.

The most important species of the various superfamilies in the Sternorrhyncha attacking *A. indica* will be discussed below.

Table 1. Armoured scales (Diaspididae) infesting neem trees.



| Diaspidid species | Country |
|---|---|
| *Aspidiotus destructor* Signoret | India |
| *Aonidiella orientalis* (Newstead) | Worldwide* |
| *A. aurantii* (Maskell) | Australia* |
| *A. inornata* McKenzie | Malaysia* |
| *Chrysomphalus aonidum* (L.) | Nicaragua*, Kenya*, Madagascar*, Papua New Guinea* |
| *C. dictyospermi* (Morgan) | Papua New Guinea* |
| *Selenaspidus articulatus* (Morgan) | Senegal*, Benin*, Papua New Guinea*, Fiji* |
| *Hemiberlesia lataniae* (Signoret) | Kenya*, Fiji* |
| *H. palmae* (Cockerell) | Papua New Guinea* |
| *Parlatoria crypta* McKenzie | India*†, Niger*, Nigeria |
| *P. proteus* (Curtis) | Madagascar* |
| *P. camelliae* (Comstock) | India |
| *P. cinerea* Hadden | India |
| *P. citri* MacKenzie | India |
| *P. orientalis* Rao | India |
| *Fiorinia coronata* Williams & Watson | India* |
| *Lepidosaphes meliae* Green | Senegal*, Kenya*, Cameroon |
| *L. tapleyi* Williams | Malaysia* |
| *L. karkarica* Williams & Watson | Malaysia* |
| *Pinnaspis strachani* (Cooley) | Worldwide* |
| *Pseudaulacaspis cockerelli* (Cooley) | Malaysia* |

*collected by the author. †recorded as *P. ?morrisoni* McKenzie (synonymised with *P. crypta* McKenzie by Danzig (1993)).

SCALE INSECTS (COCCOIDEA).

The dominant family of scale insects on *A. indica* is the Diaspididae (Table 1). At present, 22 species have been recorded, most of them from Asia (the source of origin of the neem tree), but with a few from the South Pacific, Africa and from tropical America. A few diaspidid species have an almost worldwide distribution on neem, e.g., *Pinnaspis strachani* (Cooley).

*Aonidiella orientalis* (Newstead) (Fig. 1) is the most serious pest of neem and outbreaks have been observed in parts of Africa, especially in countries around Lake Chad (Niger, Nigeria and Cameroon). The main reason is thought to be water stress. Heavy infestations on the leaves and shoots result in dieback, even sometimes in the death of heavily infested trees. In large areas of East Africa and Asia, *A. orientalis* is common but almost never reaches pest populations, most probably because it is well controlled by natural enemies, such as coccinellids and parasitoids.

*P. strachani* and *Chrysomphalus aonidum* (L.) are widespread minor pests of neem, although they occasionally cause local outbreaks which lead to leaf

Fig. 1. *Aonidiella orientalis* on the upper surface of leaflets of *Azadirachta indica.*

shedding and dieback of branches. In southwestern Madagascar, it was considered that the unfavourable limestone soil conditions may have been the main contributory reason for some damage caused by *C. aonidum.*

Five species of *Parlatoria* attack neem in India (*P. camelliae* Comstock, *P. orientalis* Rao, *P. crypta* McKenzie (as *P. morrisoni* McKenzie), *P. cinerea* Hadden and *P. citri* McKenzie (Suresh, 1995)), while *Parlatoria crypta* McKenzie is very common in parts of sub-sahelian Africa, such as Niger. Large populations of the latter species were seen on the upper surface of leaflets but the damage caused was apparently limited. The same applied to *Lepidosaphes tapleyi* Williams. Both *P. crypta* and *L. tapleyi* were also common on mango (*Mangifera indica*).

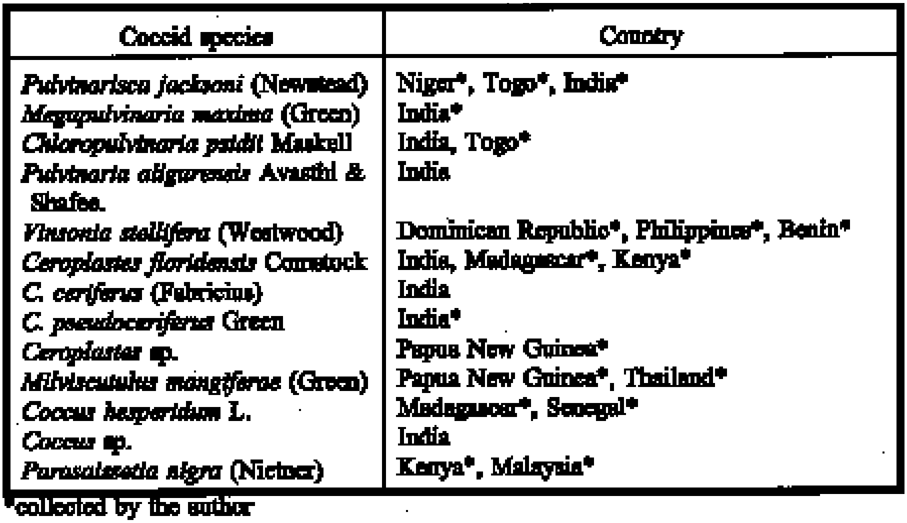
Altogether 13 species of soft scales (Coccidae) have been recorded attacking *A. indica* (Table 2). From the economic point of view, *Pulvinarisca jacksoni* (Newstead) (Africa, India) and *Megapulvinaria maxima* (Green)

(India) seem to be important. Local outbreaks of these species have been recorded several times and these two coccids, along with the occasional *Chloropulvinaria psidii* (Maskell), produce large amounts of honeydew which quickly become covered by sooty mould.

Four species of *Ceroplastes* have been recorded from Asia (mainly India) but they seem to play no role as pests. *Milviscutulus mangiferae* (Green) was collected in Thailand and in Papua New Guinea where, in the Markham Valley, it attacked the youngest shoot-tip leaves, where it was attended by the weaver ant, *Oecophylla smaragdina* (Fabricius), in its leaf nests.

Only five species of mealybugs (Pseudococcidae) have been collected on neem trees, some in Asia, others in Africa (Table 3). In addition, *Kerria lacca* (Kerr) (Lacciferidae) attacks neem in India (Tewari, 1992) while, a few years ago, the author found an asterolecaniid (probably a *Planchonia* sp.) infesting petioles near Mombasa, Kenya.

Table 2. Soft scales (Coccidae) infesting neem trees



| Coccid species | Country |
|---|---|
| *Pulvinarisca jacksoni* (Newstead) | Niger*, Togo*, India* |
| *Megapulvinaria maxima* (Green) | India* |
| *Chloropulvinaria psidii* Maskell | India, Togo* |
| *Pulvinaria aligarensis* Avasthi & Shafee. | India |
| *Vinsonia stellifera* (Westwood) | Dominican Republic*, Philippines*, Benin* |
| *Ceroplastes floridensis* Comstock | India, Madagascar*, Kenya* |
| *C. ceriferus* (Fabricius) | India |
| *C. pseudoceriferus* Green | India* |
| *Ceroplastes* sp. | Papua New Guinea* |
| *Milviscutulus mangiferae* (Green) | Papua New Guinea*, Thailand* |
| *Coccus hesperidum* L. | Madagascar*, Senegal* |
| *Coccus* sp. | India |
| *Parasaissetia nigra* (Nietner) | Kenya*, Malaysia* |

*collected by the author

WHITEFLIES, APHIDS AND PSYLLIDS

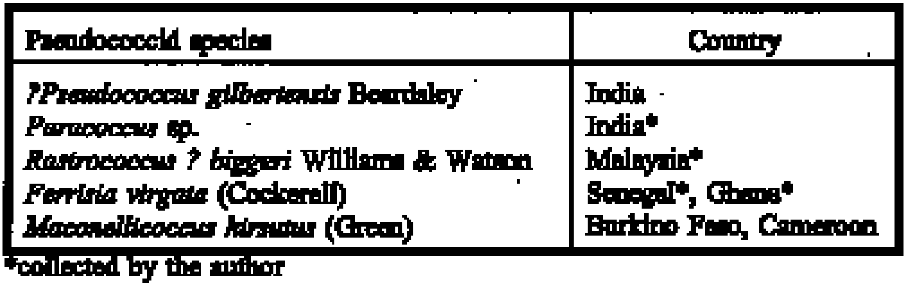
Little can be said regarding the occurrence of whiteflies, aphids and psyllids on neem trees but the four species of whiteflies recorded are listed in Table 4. These include the well-known citrus pest *Aleurothrixus floccosus* (Maskell) which was collected on Gran Canaria, Canary Islands; a small colony of *Aleurocanthus woglumi* Ashby, also a widespread pest of citrus, in

Melaka, Malaysia, and a few specimens of an *Aleuroplatus* sp. in Toliara, southwestern Madagascar.

Two species of aphids, namely *Aphis spiraecola* Patch and *A. gossypii* Glover, have been recorded on seedlings and young shoots and leaves, mainly from the Caribbean. However, the colonies were destroyed by coccinellids within a few days and it seems unlikely that aphids can utilise neem for a longer period.

The psyllid *Diaphorina aegyptiaca* Puton seems to be the only species of jumping lice recorded from neem (India) (Boa, 1995). Schmutterer (1998) reported that females of the leucaena psyllid, *Heteropsylla cubana* (Crawford), laid eggs on the young shoots and leaves but the first-instar nymphs could not moult to the next instar. The same applied to the spiralling whitefly, *Aleurodicus dispersus* Russel, in Senegal.

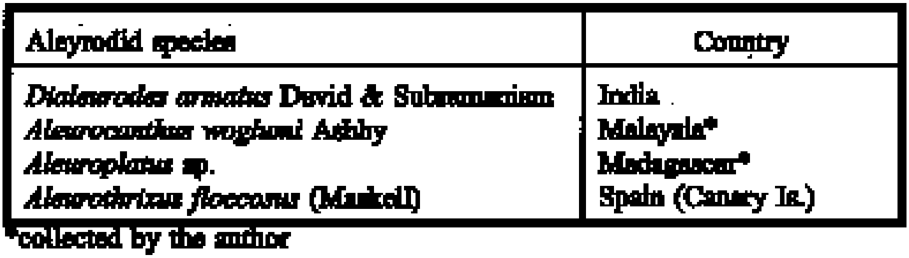
Table 3. Mealybugs (Pseudococcidae) infesting neem trees



| Pseudococcid species | Country |
|---|---|
| *?Pseudococcus gilbertensis* Beardsley | India |
| *Paracoccus* sp. | India* |
| *Rastrococcus ? biggeri* Williams & Watson | Malaysia* |
| *Ferrisia virgata* (Cockerell) | Senegal*, Ghana* |
| *Maconellicoccus hirsutus* (Green) | Burkino Faso, Cameroon |

*collected by the author

Table 4. Whiteflies (Aleyrodidae) infesting neem trees.



| Aleyrodid species | Country |
|---|---|
| *Dialeurodes armatus* David & Subramaniam | India |
| *Aleurocanthus woglumi* Ashby | Malaysia* |
| *Aleuroplatus* sp. | Madagascar* |
| *Aleurothrixus floccosus* (Maskell) | Spain (Canary Is.) |

*collected by the author

The few species of whiteflies, aphids and psyllids found on *A. indica* suggest that this plant is, in general, an unsuitable host for these groups of sternorrhynchid insects.

## WHY IS NEEM ATTACKED BY NUMEROUS SCALE INSECTS?

It is difficult to answer this question satisfactorily. No trials have been carried out to assess the $LC_{50}$ values using pure azadirachtin and scale insects. With aphids, very obvious differences regarding susceptibility were found, ranging from 3ppm to >150ppm (Feng & Isman, 1995). The silvaniid beetle, *Oryzaephilus surinamensis* (L.), a well-known pest of stored products, can breed successfully in neem seed kernels that contain the highest concentration of azadirachtin on the neem tree.

One reason for the ability of scale insect species to live on neem could also be that they do not feed on plant tissues containing the active ingredients. However, Ossiewatsch (1999) showed that azadirachtin was translocated in the phloem of neem-treated cabbage plants and that the triterpenoid was also detected in the honeydew of the cabbage aphid.

There seem to be no scale insect species confined to neem alone. Most of the recorded species are more or less polyphagous, attacking a wide range of tropical plants from different families. Rather few, little-known species with a narrow host range (for instance, *Fiorinia coronata* Williams & Watson and *Lepidosaphes karkarica* Williams & Watson) have been recorded.

A close relative of the neem tree, the chinaberry tree or Persian lilac, *Melia azedarach*, contains active principles in its seed kernels which resemble those of *A. indica.* Chinaberry is also attacked by an array of scale insects (Kozár, 1992), some of which occur on neem, others not. *Pseudaulacaspis pentagona* (Targioni Tozzetti), for instance, is a pest of *M. azedarach* in the Mediterranean and in the South Pacific but has not been recorded on *A. indica.* From the above discussion, it would appear that the insecticidal and other active ingredients found in neem and chinaberry do not protect these trees against many scale insect species, which appear to be either resistant to the active ingredient or are able to avoid tissues with the active ingredients, whereas these chemicals can be rather effective against other sternorrhynchid insects, such as aphids, whiteflies and psyllids.

## ACKNOWLEDGEMENTS

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SILVA, E.M.B.; MEXIA, A.
*Secçao Proteccao Integrada, Departamento de Proteccao das Plantas e de Fitoecologia, Instituto Superior de Agronomia, Tapada da Ajuda, 1399 Lisboa Codex, Portugal*

# HISTOLOGICAL STUDIES ON THE STYLET PATHWAY, FEEDING SITES AND NATURE OF FEEDING DAMAGE BY *PLANOCOCCUS CITRI* (RISSO) (HOMOPTERA: PSEUDOCOCCIDAE) IN SWEET ORANGE.

## ABSTRACT

HISTOLOGICAL STUDIES ON THE STYLET PATHWAY, FEEDING SITES AND NATURE OF FEEDING DAMAGE BY *PLANOCOCCUS CITRI* (RISSO) (HOMOPTERA: PSEUDOCOCCIDAE) IN SWEET ORANGE.

Histological studies on the stylet pathway, feeding sites and cell damage caused by the citrus mealybug, *Planococcus citri* (Risso), on sweet orange (*Citrus sinensis* (L.) Osbeck) fruit and leaves are described. The frequency of stylet pathways that were exclusively intercellular did not differ significantly from those that were both inter- and intracellular. Stylet track terminations were significantly more frequent in the phloem and its proximity than elsewhere, indicating that the phloem was the preferred feeding site in both fruits and leaves. None of the observed stylet tracks had multiple branches. The majority of plant cells surrounding the stylet tracks showed no detectable damage; only in the fruit did some cells appear slightly enlarged and had a different pigmentation, suggesting that the damage was caused by diffusion of saliva from the stylet. The pierced cells appeared otherwise healthy.

Key words: feeding behaviour

## INTRODUCTION

The citrus mealybug, *Planococcus citri* (Risso) (Homoptera: Pseudococcidae), is a world-wide polyphagous insect, considered to be a key pest of citrus in many countries. Feeding injuries caused by *P. citri* on citrus include chlorotic spots on fruit and leaves, deformation of the peel and fruit splitting (Silva, 1994, 1998; Silva & Mexia, 1997). Despite the importance of the damage caused by *P. citri* on citrus, there are no studies of its feeding behaviour on citrus and the physiological damage caused by this species is poorly understood.

The present study was developed to study the feeding behaviour (i.e., stylet pathway, stylet track terminations and proximity to phloem) of *P. citri* and the nature of any cell damage caused by it to sweet orange fruit and leaves. This study adds to the present understanding of the histology and damage already outlined in previous studies (Silva, 1994, 1998; Silva & Mexia, 1997).

## MATERIALS AND METHODS

*Selection of experimental units.* Fruit and leaves were collected from 10-year old, sweet orange trees (cultivar "Navelina") budded on to Citrange Troyer rootstock, in a grove with an area of 3600m$^2$, in Setubal (38° 33' N, 8° 53' W; 28m altitude), Portugal.

Before the fruit and leaves were used in the experimental study, they were submitted to a phase of isolation and infestation in cages, as described previously (Silva, 1994; Silva & Mexia, 1997). All fruits and leaves were harvested on the 12 November 1996, during the normal harvesting period. A total of 10 fruits with feeding injury (i.e. chlorotic spots and peel deformation) and 10 healthy fruits (i.e. without any injury and with characteristic orange colouration) and a total of 10 leaves with and without feeding injury caused by *P. citri* (i.e. with chlorotic spots) were harvested from the grove.

*Fixation and sectioning.* Small pieces (approximately 1cm$^2$) of citrus peel and leaf tissue were removed, with those from the infected samples being taken from selected chlorotic areas within a *P. citri* colony while the uninfected leaves were from healthy, green regions.

The method of Graça & Pereira (1990) was slightly modified for fixation and sectioning. The samples were fixed in FAA (10 parts 95% ethanol, 1 part glacial acetic acid, 2 parts formaldehyde [37-40%], 7 parts distilled water), according to the formula presented by Washington & Walker (1990) for 2 days at laboratory temperature. After fixation, the samples were washed in distilled water several times for 24 hours and then were gradually embedded in polietilenoglicol (1,500 g/mol) (PEG), first with 20% PEG for 24 h at 60°C and then each sample was placed in an appropriate mould and a solution of 100% PEG was added. The pieces were sectioned (0.8µm) at right-angles to the surface of fruits and leaves, with an appropriate adhesive ribbon, using a hand microtome. The sections were stained with toluidine blue (0.05%). Prior to mounting on microscope slides, each section was separated from the adhesive ribbon with gelatinous glycerine and xylol. All the sections were carefully examined under the light microscope (1000x) for (i) stylets or stylets sheaths (i.e. the stylet pathway and termination of stylets at feeding sites) and (ii) the condition of the chlorotic cells (e.g., cell appearance, cell size, alterations of chloroplast number and aspect) and whether these cells surrounded the stylet tracks or were some distance away, when compared with healthy cells.

*Statistical analysis.* Chi-square analyses ($P<0.01$) (Zar, 1984) were used to compare frequencies of stylet pathways, stylet tracks terminations and their proximity to phloem in the fruits and leaves.

## RESULTS AND DISCUSSION

### STYLET TRACK PATHWAYS.

There was no significant difference in the frequency of stylet pathways that were exclusively intercellular and those that were both inter- and intracellular in either fruits (53% as compared with 45.2%; $\chi^2=0.62$, df=1, $P>0.01$) or leaves (42.4% as compared with 57.5%; $\chi^2=1.22$, df=1, $P>0.01$)). Stylet pathways that were exclusively intracellular occurred rarely in the fruit (1.8%) and never in the leaves.

These observations suggest that *P. citri* stylets tend to follow a mixed inter- and intracellular pathway or an exclusively intercellular pathway. No stylet track had multiple branches, suggesting considerable ability by *P. citri* to locate the feeding sites.

### *Stylet track terminations and proximity to phloem.*

Stylet-track termination was as follows: (a) in the proximity of vascular bundles: 49.6% in fruits and 72.7% in leaves, (b) in the phloem: 10.4% in the fruits and 6.1% in the leaves, and (c) in the mesophyll, distant from the vascular bundles, 40.0% in fruits and 21.2% in the leaves. The percentage of the stylet tracks that reached the phloem or were located near the vascular bundles was 60.0% in the fruit, 78.8% in the leaves, significantly more frequent than other stylet terminations distant from vascular bundle (fruits: $\chi^2=4.0$, df=1, $P<0.05$; leaves: $\chi^2=33.29$, df=1, $P<0.01$). Thus, the phloem is apparently the preferred feeding site in both the fruits and leaves of sweet orange, as suggested by Silva (in press).

### *Nature of cell damage caused by stylets.*

The majority of plant cells surrounding the stylet tracks showed no detectable damage, suggesting that the cellular contents were not removed or that there was little or no saliva injection into these cells. This is similar to observations with other scale species, e.g., *Aonidiella aurantii* (Homoptera: Diaspididae) (Washington & Walker, 1990), *Unaspis citri* (Comstock) (Homoptera: Diaspididae) (Albrigo & Brooks, 1977) and *Phenacoccus manihoti* Matile-Ferrero (Homoptera: Pseudococcidae) (Calatayud *et al.*, 1994). However, some cells distant from stylet tracks appeared slightly enlarged within the fruits (32.2%) and had different pigmentation (5.2%). Because there was no detectable damage to cells pierced by *P. citri* stylets during penetration, it is suggested that the damage (i.e. chlorotic spots on the fruit and leaves and the citrus peel deformation) may be caused by diffusion of saliva away from the stylet. In addition, the toxicity of saliva may be enhanced by the high population densities of *P. citri* on sweet orange. However, it was not possible to detect any changes in the number and appearance of chloroplasts within the chlorotic cells (Silva, in press).

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ÜLGENTÜRK, S.; TOROS, S.
*University of Ankara, Faculty of Agriculture, Department of Plant Protection, Diskapi 06110, Ankara, Turkey*

# STUDIES ON THE BIOLOGY OF *EULECANIUM CILIATUM* (DOUGLAS) (HEMIPTERA: COCCIDAE) IN ANKARA, TURKEY.

## ABSTRACT

STUDIES ON THE BIOLOGY OF *EULECANIUM CILIATUM* (DOUGLAS) (HEMIPTERA: COCCIDAE) IN ANKARA, TURKEY.

*Eulecanium ciliatum* Douglas is a common pest species on Aceraceae and Rosaceae in Ankara province, Turkey. Its biology was investigated on *Acer campestre, A. pseudoplatanus, Crataegus monogyna* and *C. oxyacantha* in 1995-1996. *E. ciliatum* had one generation a year and overwintered as the $2^{nd}$-instar nymph. The number of eggs laid per female depended on the host, with the greatest number of eggs being laid on *A. pseudoplatanus*, on which it had the densest populations. The $1^{st}$-instar nymphs were found on both leaf surfaces but they preferred the upper surface. The $2^{nd}$-instar nymphs preferred sites on branches on the north-east side of the host trees. The sex ratio varied between 1.5 and 3.8♂:1♀.

Key words: Palaearctic, life cycle, ecology, host plants, settling sites, migration, *Formica cunicularia*, *Camponatus aethiops*, *Plagiolepis vindobonensis*, *Anthribus fasciatus*, urban entomology, Brunton compass, predator.

## INTRODUCTION

*Eulecanium ciliatum* (Douglas) (Coccidae) is a widespread species in the Palaearctic region (Ben-Dov, 1993) and was recorded in Ankara by Bodenheimer (1953). There is only limited information on the biology of *E. ciliatum* in the literature, although Newstead (1903), Borchsenius (1957) and Kosztarab & Kozár (1988) give some data on its distribution and host plants.

During surveys of the Coccoidea in Ankara carried out between 1992-1994, *E. ciliatum* had been found to be harmful to some species of Aceraceae and Rosaceae common in parks and gardens. Following heavy infestations, the tips of the branches dried up and sometimes the whole tree died. Its biology in Turkey is poorly known and the aim of this study was to rectify this.

## MATERIALS AND METHODS

The life cycle, growth patterns and population changes of *E. ciliatum* were studied between 1994 and 1996 on three of each of the following host plants: *Acer campestre* and *A. pseudoplatanus* (Aceraceae) and *Crataegus monogyna* and *C. oxyacantha* (Rosaceae). Samples were collected once a month between November and April, and once a week or once a fortnight between April and October. From each host tree, four 10cm long, one year old or older shoots were collected from the four sides of each tree, giving a total of 48 samples (4 replicates x 3 trees x 4 sides). The number of 1st- and 2nd-instar nymphs, prepupae, pupae, empty tests and adult female (young without eggs or with eggs) stages were counted for each twig. The time of the appearance of each stage, its duration, the sex ratio, changes in the populations and the overwintering stage were determined under natural conditions. For confirmation of particular instars, individuals were transferred to 70% alcohol and mounted as described by Wilkey (1962). The number of eggs per female was determined by counting the number of eggs beneath 150 adult females on each host species in the last quarter of May.

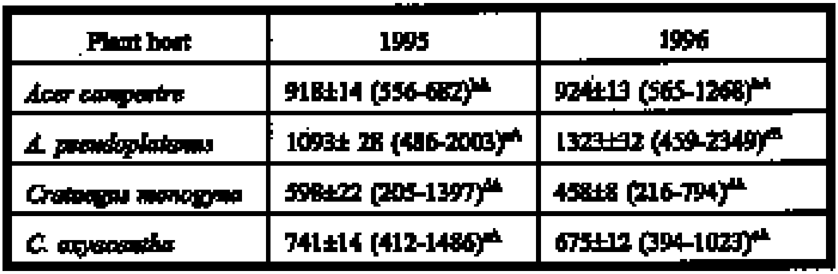
The number of crawlers hatching each day was determined by counting the number emerging from beneath 20 females from each host tree. For this, twig samples from the four hosts, each with a single adult female, were maintained in closed vials in the laboratory and observed daily; all emerged crawlers were removed. The preferred settling sites for the 1st-instar nymphs was determined by counting the number of crawlers on both leaf surfaces of 48 leaves collected from 10cm long shoots off each of the four host plants. The preferences of the adult females were determined by measuring the compass direction of the infected branches on each of the four host species, using a Brunton compass. A total of 30 measurements were made for *A. campestre* and *C. monogyna* and 32 measurements were made for *A. pseudoplantanus* and *C. oxyacantha.*

## RESULTS AND DISCUSSION

In both years, the first eggs were observed on *A. campestre* in the last week of April, followed by *A. pseudoplatanus,* while they appeared in the first week of May on the two *Crataegus* sp.; in Germany, Schmutterer (1952) found that *E. ciliatum* started oviposition in the second week of May and that it was complete within 15 days. The eggs were deposited within a brood chamber beneath the abdomen of the adult females and were elliptic in shape, pink when fresh but turning brownish-pink as the embryo developed.

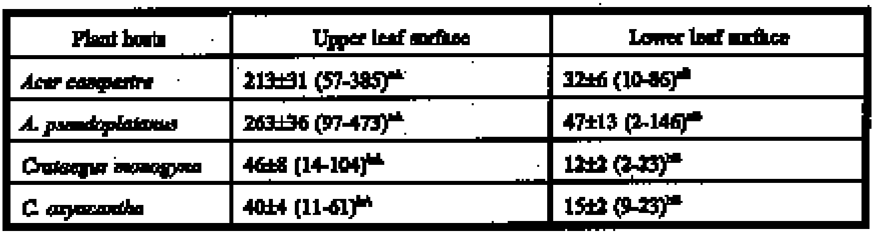
The number of eggs laid per female varied greatly between host plants (Table 1), with significantly more eggs being laid on *A. pseudoplatanus* than on the other three host plants. The first crawlers appeared 39 days after first oviposition in 1995 and 31 days in 1996. However, under laboratory conditions (25±2°C, 60±5% relative humidity), maximum crawler hatch occurred after only 5-8 days and hatching lasted 15-20 days (Fig. 1).

Table 1. Mean no. (± s.e.) and range of eggs laid by *Eulecanium ciliatum* on four host plants in Ankara province, Turkey in 1995 and 1996.



| Plant host | 1995 | 1996 |
|---|---|---|
| *Acer campestre* | 918±14 (556-682)[illegible] | 924±13 (565-1268)[illegible] |
| *A. pseudoplatanus* | 1093± 28 (486-2003)[illegible] | 1323±32 (459-2349)[illegible] |
| *Crataegus monogyna* | 598±22 (205-1397)[illegible] | 458±8 (216-794)[illegible] |
| *C. oxyacantha* | 741±14 (412-1486)[illegible] | 675±12 (394-1023)[illegible] |

Table 2. Mean no. (± s.e.) and range of 1st-instar nymphs of *Eulecanium ciliatum* which had settled on the lower and upper leaf surfaces of leaves of four host species in Ankara province (data/leaf).



| Plant hosts | Upper leaf surface | Lower leaf surface |
|---|---|---|
| *Acer campestre* | 213±31 (57-385)[illegible] | 32±6 (10-86)[illegible] |
| *A. pseudoplatanus* | 263±36 (97-473)[illegible] | 47±13 (2-146)[illegible] |
| *Crataegus monogyna* | 46±8 (14-104)[illegible] | 12±2 (2-23)[illegible] |
| *C. oxyacantha* | 40±4 (11-61)[illegible] | 15±2 (9-23)[illegible] |

where: capital letters indicate differences between surfaces and small letters differences between host plants; and where data sharing the same letter do not differ statistically (P<0.01).

where: capital letters indicate differences between years and small letters differences between hosts within years; and where data sharing the same letter do not differ statistically (P<0.01).

The crawlers remained under the parental abdomen for some time before dispersing to the young shoots and leaves, where they settled on the midrib and veins of both leaf surfaces. This behaviour is influenced by innate behaviour patterns, availability of acceptable settling sites and ambient

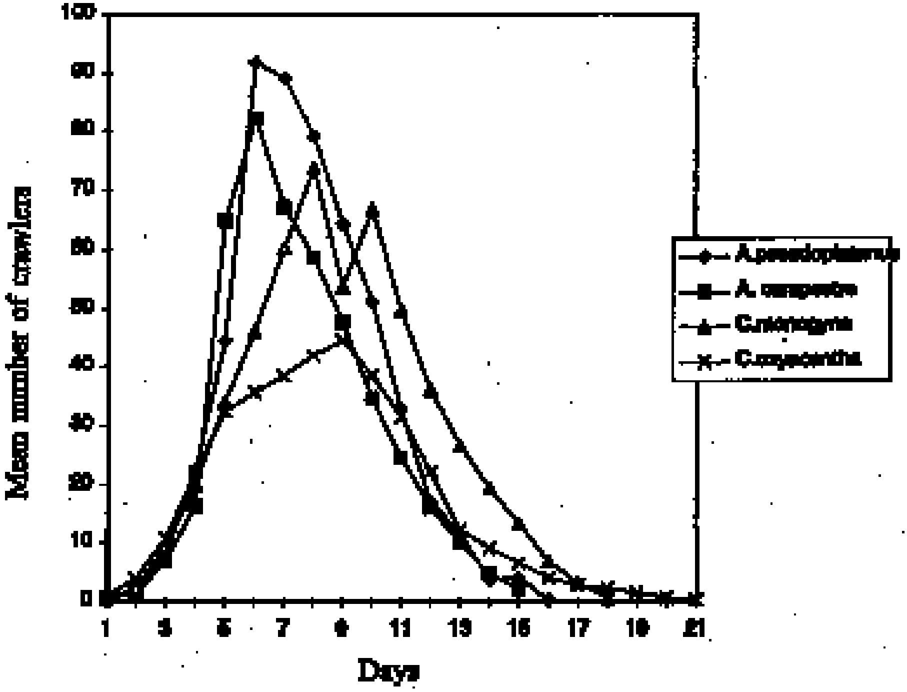


Figure 1. The number of crawlers of *E. ciliatum* emerging each day once hatching had started on the twigs of four host species under laboratory conditions (25±2°C; 60±5% RH).

environmental conditions (Beardsley & Gonzáles, 1975). Schmutterer (1952) reported that the larvae colonised the lower surface but, in our study, they showed a strong preference for the upper surface (Table 2).

The greatest populations of $1^{st}$-instar nymphs were found in July. These nymphs grew slowly until mid-September, when they started to moult. Thus, the $1^{st}$ instar lasted 93-103 days. Newstead (1903) noted the appearance of the first crawlers of *E. ciliatum* at the end of July and found that they moulted before overwintering, while, on the other hand, Schmutterer (1952) found that the first moult occurred between the end of August and mid-September in Germany.

The first $2^{nd}$-instar nymphs were found on the leaves on the $8^{th}$ Sept. in 1995 and on the 15th September in 1996. There was then a rapid increase in the number of $2^{nd}$-instar nymphs until the leaves started to senesce and the mean temperature to fall, when the nymphs migrated to the branches and stems, where they settled beneath the branches or on the more sunny sides of the trees. During this migration, it is believed that many nymphs die due to unfavourable environmental conditions, such as high winds and heavy rain. This migration was complete by the beginning of November and the numbers settling on the four host plants were different, with the largest populations on *A. pseudoplatanus* with 221 nymphs per branch. This migration from the leaves to the branches or stems to overwinter is a common behaviour for scale insects which feed on the leaves of perennial host plants (Hamon & Williams, 1984). This migration of *E. ciliatum* nymphs was also noted by Schmutterer (1952). *E. ciliatum*, therefore, overwinter as the 2nd-instar nymph and this stage lasted about 118-226 days. Little parasitisation of nymphs was noted at this stage.

Schmutterer (1952) reported the first prepupae of *E. ciliatum* at the end of April in Germany, the pupae at the beginning of May and the appearance and flight of the adult males in the second week of May. In the present study, the first prepupal + pupal stages were noted in the second week of April, when the majority of males were at this stage under their glassy, translucent test. The density of the prepupal + pupal populations varied depending on the hosts and the year, with the greatest populations on *A. pseudoplatanus* (means: 94.5±5.5 (range 61-124) in 1995; 122.5±5.3 (range 102-136) in 1996). The first empty pupal test was found in the first week of May on *A. campestre*. The prepupal + pupal stages lasted 36-46 days.

Adult females have a very thin, smooth skin immediately after moulting and, at this stage, were observed to secrete large amounts of honeydew. This was visited by several species of ants (Hymenoptera; Formicidae): *Formica cunicularia* Latreille, *Camponatus aethiops* (Latreille) and *Plagiolepis vindobonensis* Lomnicki. Later, the dorsum of these females became rather convex and sclerotised. Honeydew secretion by the females decreased gradually as they became convex and sclerotised, finally ceasing when this process was complete. The population densities of the adult females (both pre- and post-oviposition) was different on the various hosts, with the largest numbers on *A. pseudoplatanus* in 1996 (30.0±1.2 (range 22-37) per branch). The first eggs were found on *A. campestre* and *A. pseudoplatanus* in the first week in May. The adult females survived for 28-38 days in 1995 and 27-46 days in 1996 respectively. The size of the adult females varied depending on the host species, the largest individuals being on *A. pseudoplatanus* and the smallest on *C. monogyna*.

It was noted that the adult females did not appear to be randomly distributed on the trees but appeared to favour the more N and NE-SW-facing parts of the trees. The position of *E. ciliatum* on the four host plants was therefore evaluated. This showed a strong preference for the north-eastern and south-western parts of trees. Schmutterer (1952) reported that *E. ciliatum* preferred to settle on trees in the sunshine in the warmer parts of parks.

During the adult stage, there was a significant amount of parasitisation and predation, the latter particularly by *Anthribus fasciatus* (Förster) (Coleoptera: Anthribidae), which was rather effective.

*E. ciliatum* has 1 generation a year in Ankara, similar to that in Central Europe (Kosztarab & Kozár, 1988). The sex ratio varied according to the host plant but ranged from 1.5 to 3.8♂:1♀.

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VAHEDI, H.A.
*Environment Dept., University of London, Wye College, Ashford, Kent, CT12 4BX, UK*

# THE BIOLOGY OF *PORPHYROPHORA TRITICI* (HEMIPTERA: COCCOIDEA: MARGARODIDAE) AND THE EFFECT OF SOME FARMING PRACTICES ON ITS POPULATIONS IN KERMANSHAH, IRAN.

## ABSTRACT

THE BIOLOGY OF *PORPHYROPHORA TRITICI* (HEMIPTERA: COCCOIDEA: MARGARODIDAE) AND THE EFFECT OF SOME FARMING PRACTICES ON ITS POPULATIONS IN KERMANSHAH, IRAN.

This paper describes the life cycle of *Porphyrophora tritici* Bodenheimer on wheat in the Kermanshah region of Iran, and the effect of various farming practices (irrigation, harvesting, rotations and time of ploughing) on its survival. It is concluded that the manipulation of the time of ploughing may be the most economical management method of those tried.

Key words: barley, control, weeding, natural enemies, *Lithophylus* sp., ground pearls, damage, grazing.

## INTRODUCTION

*Porphyrophora tritici* Bodenheimer (Hemiptera: Coccoidea: Margarodidae) is one of the “ground pearls”, a name which refers to the 2nd-instar nymph which forms a protective cyst (the “pearl”) on the root-collar of plants. *P. tritici* is a pest of wheat and barley in the Mediterranean, North Africa and Western Asia and is particularly important in Iran, Turkey and Syria, where, in some years, it causes stunting or death of shoots of wheat and barley grown on non-irrigated fields (Borchsenius, 1973; Duran, 1971; Miller, 1992; Shojaei & Bahador, 1987; Vahedi, 1992). *P. tritici* infests 95% of the barley in Syria and sometimes causes losses of more than 40% in winter wheat (grain and forage) in Iran (Safar-Alizadae & Bahador, 1987), where it has spread across the arid wheat and barley growing areas in the West (Vahedi, 1992).

Infestations of *P. tritici* are highly unpredictable, both between fields and between localities, with widespread heavy infestations in some years while, in other years, very limited and isolated populations have been found (Miller & Jones, 1998; Vahedi, 1992). Cultivation using disc-harrows has been found to decrease infestations by 95% (Miller & Jones, 1998). Crop rotation has also been found to reduce populations (Miller *et al.*, 1994).

## LIFE CYCLE

*P. tritici* is a univoltine species. It overwinters as crawlers within the dry body of the adult female in a ovisac in the subsoil at a depth of about 4cm. Early in the spring (generally in late March in Iran), the crawlers emerge from the ovisac and disperse to the soil surface, where they settle at the base of the root-collar between the leaf-sheaths of seedlings of some grass and weed species and start feeding. At this stage, the wheat is near the end of the tillering stage and stem extension is just starting. As the 1st-instar nymphs feed, they becomes paler. By late April, the female nymphs have moulted to form the 2nd-instar cyst stage, which initially has well-developed legs and antennae but these appear to shrink with age. The cyst is covered in a thin, shiny brown wax, and is rather brittle and easily crushed. The emergence of the adults is closely linked to plant phenology, with maximum growth of the cyst-stage occurring when the cereal hosts are entering the milk-ripening stage. Thus, in grassland where the plants develop rather earlier, the emergence of the adults is also earlier. The reddish adult females emerge from the cyst stage in late April or early May and lack mouthparts and so they cannot feed. Thus, there appears to be three female stages.

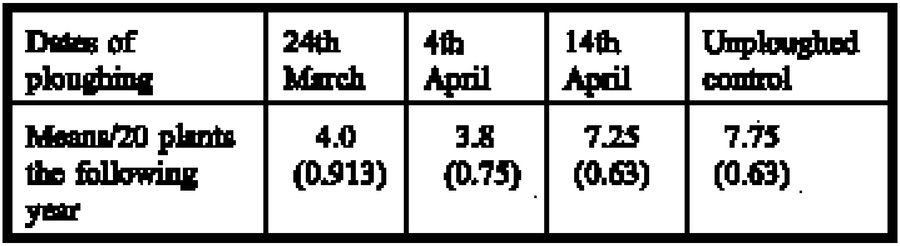
During male development, only the 1st- and 2nd-instars feed, all later stages lacking mouthparts. Two to three days after forming the glassy puparium some 3-4cm down in the soil near the roots, the 2nd-instar males moult to form the prepupa and then, after a further 2-3 days, they again moult to give the pupa. The adult males emerge 2 to 3 days later and thus there are 5 male stages. The red adult males are weak fliers and live for about 3-4 days. The mature adults (male and female) usually appear in early May prior to the ripening of the wheat.

Shortly after mating, the female retreats underground to a depth of about 4cm, where she produces white wax filaments to form an ovisac into which the eggs are laid (mean preoviposition period 7 days; mean oviposition period 8 days). Each female lays about 200 eggs. Sandy-clay or light soils are preferred for egg-laying. The eggs hatch after about 3-4 months and the reddish, first-stage nymphs then overwinter within the ovisac and in the space made free by the shrinking of the abdomen of the dead female. Young wheat plants or tillers become stunted if initially infected by more than two nymphs but appear unaffected by a single nymph. Maximum damage is done at the seedling stage by the 2nd-instar cyst and plants at the third-leaf stage may be killed outright. Heavily infested fields have reduced yields, with poor quality grain.

### TIME OF PLOUGHING

Because the crawlers which emerge in the spring quickly colonise suitable plants, any crop or volunteer hosts which are present at this time quickly become infected. Therefore, this experiment looked at the time of ploughing on the survival of the crawlers. The trial had three ploughing dates and a control (unploughed). After ploughing, the ground was left fallow until the following autumn, when it was planted to wheat. In the spring of the following year (about 12 months after ploughing), five plants from each of four $1m^2$ plots from each treatment were sampled and the number of *P. tritici* counted.

Table 1. Mean ± SE *P. tritici* per 20 plants/treatment on winter wheat approximately one year after ploughing on three dates and an unploughed control.



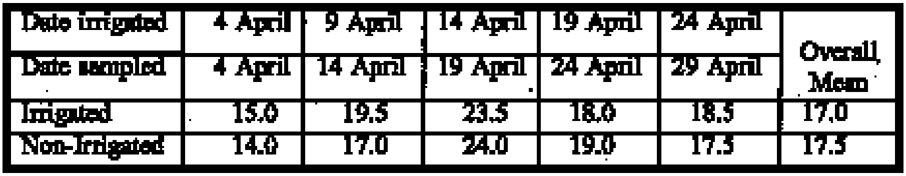
| Dates of ploughing | 24th March | 4th April | 14th April | Unploughed control |
|---|---|---|---|---|
| Means/20 plants the following year | 4.0 (0.913) | 3.8 (0.75) | 7.25 (0.63) | 7.75 (0.63) |

Table 1 summarises the results. There was a significant ($P<0.01$) increase in the number of *P. tritici* present on the plants when ploughed after the 4th April, suggesting that early ploughing, followed by a fallow period, could substantially reduce the population. In addition, it is considered that delaying ploughing until late April (i.e. until later than the latest date in Table 1) might allow the crawlers to colonise volunteer plants and to moult to the cyst stage before being ploughed in, again providing good potential control through starvation as the cyst-stage cannot move.

### IRRIGATION

Because some winter wheat crops in Iran are irrigated, this experiment was designed to see what effect irrigation might have on the *P. tritici* populations. Ten $1m^2$ plots were marked out, five in an area which was flood irrigated along furrows, so that the soil was wet to about 10cm, and five in a non-irrigated area nearby. All irrigated plots were irrigated on the 4th April and then 10 plants were sampled from plot 1 and from a control plot; plots 2-5 were then irrigated a second time on 9th April and plot 2 (and the corresponding control plot) sampled on 14th April; plots 3-5 were then irrigated a third time on 14th April and sampled on the 19th April, and so on (see Table 2).

Table 2. Number of *P. tritici* cysts per 10 winter wheat plants (at the end of tillering stage) in five irrigated and five non-irrigated plots, Kermanshah, Iran, 1990.



| Date irrigated | 4 April | 9 April | 14 April | 19 April | 24 April | Overall Mean |
|---|---|---|---|---|---|---|
| Date sampled | 4 April | 14 April | 19 April | 24 April | 29 April | |
| Irrigated | 15.0 | 19.5 | 23.5 | 18.0 | 18.5 | 17.0 |
| Non-Irrigated | 14.0 | 17.0 | 24.0 | 19.0 | 17.5 | 17.5 |

ANOVA tests on these data for the two treatments showed that there were no significant effects from irrigation (P>0.05). However, as *P. tritici* is at the cyst stage in April, this is perhaps not surprising. Indeed, it might even be that the increased growth of the host-plants caused by irrigation could improve the quality of the sap for the scale. Populations in warm wet seasons have been reported to be greater than in warm dry seasons (Sevumian & Sarkisov, 1981).

### HARVESTING

The efficiency of harvesting can have a marked effect on subsequent populations, because inefficient harvesting implies more volunteer plants the next spring. Two methods of harvesting are commonly used in Iran - traditional hand harvesting and mechanical harvesting using old combine harvesters. The latter methodology is much less clean and is followed by numerous volunteer plants. These methodologies were compared in 1993 to see what effect they had on subsequent populations of *P. tritici.* The results, in terms of the number of subsequent volunteer plants in field trials in 1994, are shown in Table 3. It is clear that combine harvesting was inefficient and was followed by substantially more volunteer plants than when the grain was harvested by hand (P<0.05).

### ROTATIONS

Rotations have been shown to have a significant effect on *P. tritici* populations (Miller *et al.*, 1994) in northern Syria. The effect of rotations was studied in Kermanshah in small plots (10m x 2m) with the following rotations: (a) Wheat/Peas/Wheat; (b) Wheat/Spring-wheat/Wheat, and (c) Wheat/Sunflower/Wheat. The populations in the initial wheat crops were similar (Table 4) and so the purpose of the experiment was to see what effect the intervening crops (peas and sunflowers = non-host crops; spring wheat = host crop) would have on the populations in the final wheat crops. Whilst the differences between the three treatments were not significantly different (P>0.05), there was a trend towards more *P. tritici* in the rotation with continuous wheat. The reasons why there is no apparent reduction in the plots with non-hosts is unclear.

Table 3. Mean number of volunteer plants per m$^2$ in wheat plots in 4 fields in Kermanshah, Iran, 1994, which had been either combine or hand harvested. Five 1m$^2$ plots were sampled per treatment per field.

| Harvesting method | Field 1 | Field 2 | Field 3 | Field 4 | Mean |
|---|---|---|---|---|---|
| Combine | 174 | 203 | 192 | 211 | 195 |
| Hand | 16 | 10 | 26 | - | 17.3 |

(where - = no data available)

Table 4. Effect of three rotations on subsequent *P. tritici* populations: all plots had wheat in 1992, followed by either peas or sunflowers (non-hosts of *P. tritici*) or spring wheat (a host of *P. tritici*) in 1993; all plots were sown to wheat in 1994. Data = mean number of *P. tritici* per plot (4 plots per treatment) in 1994. The final populations in 1994 did not differ at P<0.05.

| | Intervening crop | | |
|---|---|---|---|
| | Peas (non-host) | Sunflower (non-host) | Spring wheat (host) |
| Initial population (1992) | 6.1 | 4.7 | 5.2 |
| Subsequent pop. (1994) | 4.9 | 5.0 | 7.3 |

NATURAL ENEMIES

*P. tritici* has some natural enemies, among which is the coccinellid predator *Lithophylus* sp. (Lithophylinae). In Kermanshah, Iran, this coccinellid has substantially reduced *P.tritici* populations at times but, like most predators, it is most effective when prey is abundant.

## DISCUSSION AND CONCLUSIONS

*P. tritici* appears to be spreading through the wheat production areas of Iran where it can cause serious loss (>40%) in some years when there are large populations. This paper describes the biology of *P. tritici* in the Kermanshah region of Iran. As with most other *Porphyrophora* species for which the life cycle is known, it has one generation per year. The damage is caused mainly by the cyst stage, which feeds on the root collar between the leaf-sheaths of the cereal host (mainly wheat and barley).

The effects of various farming practices on *P. tritici* were studied on experimental plots. Factors considered to be particularly important were the timing of ploughing and the number of volunteer seedlings available at the time when crawlers were emerging from their overwintering site in the soil. It was found that the early ploughing in of volunteer plants gave smaller populations in subsequent crops. However, it is also thought that if ploughing was left until late in the spring, the population would also be significantly reduced because the cyst stage would be starved. It was also found that, after combine harvesting, there were many more volunteer plants than after hand harvesting, which tends to be more efficient. Improving the efficiency of the combine harvesters might therefore help, as there would then be fewer volunteer plants in the spring.

Other farming practices considered were rotations and the effect of irrigation. In neither case was there apparently any significant effect. However, in the case of rotations, there was a suggestion that the plots with continuous cereals did have a larger population, although there was not the expected reduction following non-host crops. Rotations had been found to reduce *P. tritici* populations in northern Syria (Miller *et al.*, 1994). With regard to the irrigation experiment, it is possible that, as the irrigation was applied in April when *P. tritici* would have been at the early cyst stage, the lack of an effect was probably because this stage could survive the short periods of irrigation while the plant hosts might have improved qualitatively.

Another cultural factor which could have a significant effect is grazing. When sheep and goats feed on the volunteer plants, it was observed that they tended to tear the young seedlings out of the ground and that this reduced the population of volunteer plants by as much as 90%. Although this was not tested, it is considered that this not only reduced the number of plants available for colonisation by the dispersing crawlers but removed already infested plants as well.

While pesticides have been recommended for the control of *P. tritici* (Duran, 1971), it is here considered that the manipulation of ploughing times could be very effective and much cheaper.

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WAKGARI, W.M.; GILIOMEE, J.H.
*Department of Entomology and Nematology, University of Stellenbosch,*
*Private Bag X1, Matieland, 7602 South Africa*

# FECUNDITY, SIZE AND DISPERSAL OF THE WHITE WAX SCALE, *CEROPLASTES DESTRUCTOR* NEWSTEAD (HEMIPTERA: COCCIDAE), IN THE WESTERN CAPE PROVINCE OF SOUTH AFRICA.

## ABSTRACT

FECUNDITY, SIZE AND DISPERSAL OF THE WHITE WAX SCALE, *CEROPLASTES DESTRUCTOR* NEWSTEAD (HEMIPTERA: COCCIDAE) IN THE WESTERN CAPE PROVINCE OF SOUTH AFRICA.

*Ceroplastes destructor* Newstead has recently attained pest status in areas of South Africa where citrus is grown, particularly on *Citrus reticulata* in the Western Cape Province. The fecundity, fertility and dispersal of *C. destructor* were studied as part of a comprehensive overview of its morphology, biology and population dynamics, with the aim of providing a more informed basis for control programs. Fecundity varied significantly both between orchards ($P<0.01$) and between individual females from the same orchard ($P<0.001$). Female body-size also differed between orchards ($P<0.05$) and was positively correlated with fecundity ($r^2=0.84$). The oviposition period was longer for large individuals. No differences in fertility were found between orchards ($P>0.05$). Dispersal was by 1$^{st}$-instar nymphs, mainly on air-currents, and the numbers caught on a series of sticky traps up to 4m from the source were very similar, suggesting that wind dispersal was very efficient. The numbers caught appeared to be positively correlated to the initial population. The population of 2$^{nd}$-instar nymphs on the seedlings after 6 weeks was smaller after an initially heavy infestation than on those initially more lightly infested.

Key words: hosts, incubation period, *Psidium quajava*, *Ponocirus trifoliata*, *Eugenia malaccensis*, *Gardenia thunbergia.*

## INTRODUCTION

The white wax scale, *Ceroplastes destructor* Newstead (Homoptera: Coccidae), is among the complex of insects for which citrus is a suitable host. It is increasing both in numbers and distribution in citrus growing areas of the western Cape Province, South Africa, and is widely distributed in Sub-Saharan Africa from where it is thought to have originated (De Lotto, 1965; Snowball, 1969). It is a polyphagous species that infests various trees, shrubs, and ornamentals. Ben-Dov (1993) recorded it off 22 plant families, while Snowball (1969) and Qin & Gullan (1994) considered that it was found on almost all citrus cultivars. In South Africa, it has been recorded from *Citrus* spp., *Psidium guajava* and *Ponocirus trifoliata* (De Lotto, 1965). In addition, in the Western Cape Province, we have recorded it from easy-peel citrus, *Citrus reticulata*, on which it is now a significant pest, and off *Eugenia malaccensis* and *Gardenia thunbergia.*

The fecundity of *C. destructor* has been determined on citrus in Australia by Zeck (1934), Smith (1970) and Beattie (1988), and in New Zealand by Lo (1995) but no information is available for South Africa.

Greathead (1997) has recently reviewed the dispersal of scale insects and considered that spread on wind currents was the major means of dispersal both within and between host plants over a considerable distance (see also Washburn & Frankie, 1981; 1985; Washburn & Washburn, 1984; Yardeni, 1987). The effect of crawler density on the number and distance of dispersion has, however, not been much studied. Our observations in the field revealed that crawlers moved considerable distances between trees. On several occasions, we have noticed that citrus trees that had been free of scale during one generation had become heavily infested in the next. These trees were up to 4m away from any infested trees. This colonization is presumed to be due to crawlers being carried on wind currents since the role of humans and animals in dispersing crawlers in established orchards is thought to be minimal. Experiments were therefore designed to assess whether crawlers could be dispersed on air currents up to 4m and how initial crawler density affected the rate of emigration.

In this paper, our observations on the fecundity, fertility and crawler dispersal of the *C. destructor* will be discussed.

## MATERIALS AND METHODS

**Fecundity and size**: the fecundity of *C. destructor* was assessed using the following procedures:

*Daily oviposition by individual females.* Gravid females were collected from twigs with both isolated and overcrowded populations of adult females in approximately equal proportions. Each female was overturned and observed under the microscope for the presence of eggs beneath its ‘brood chamber’. Only females that had not yet started egg laying were used; these are recognisable because the venter of the abdomen contracts on gravid females and a mass of white, powdery wax is secreted around the vulva. Each female was stuck upside-down in the centre of a numbered glass slide using gum arabic (Bedford, 1968). The slides were placed in shallow glass-topped boxes with some wet cotton wool to raise the humidity. Paper trays (5.0x3.8cm) were inserted into the boxes underneath each glass slide. Each female was suspended on the slide with the ‘brood chamber’ facing downwards so that, as the eggs were laid, they fell onto the paper tray. Both the slide and paper tray were given the same number. The boxes were kept in an incubator at 27°C and 60±5% RH, and were checked every day at 16:00h. A total of 88 females of varying body-size off *C. reticulata* and 44 females off *E. malaccensis* oviposited successfully.

Once oviposition had started, the slides were collected and tapped gently to dislodge the eggs from the 'brood chamber'. All the eggs that dropped onto the paper trays beneath were transferred onto moist filter paper and counted. The slides were put back into the boxes and the assessment continued until no further eggs were laid. This provided information on the oviposition periods of each individual female collected from each of the four farms and on any correlation between female body-size and fecundity.

Female body-size (length and width) was measured under a micrometer eyepiece after the body wax had been removed (see Wakgari and Giliomee (1998) for details).

*Fertility*: egg viability and crawler emergence were investigated by placing a specified numbers of eggs of known age in 10x5cm vials with a cotton wool stopper. The vials were laid horizontally in an incubator at 27°C and 60±5% RH, with the stopper facing a light source (emerging crawlers are positively phototropic). The eggs were observed daily to determine whether they had hatched and whether viable crawlers had emerged. Once egg hatch or crawler emergence was noted, the contents of the vials were emptied onto dry filter paper and the number of crawlers counted. This procedure was repeated until no further hatching was observed (thus giving the incubation period). The number of infertile eggs was also recorded.

*Dispersal*: for this experiment, 16 easy-peal citrus seedlings less than 1 year old, about 1.2m tall and each planted in a 20 litre pot, were infested with four densities of *C. destructor* crawlers (i.e. 400, 600, 800, 1000; i.e. 4 replicates of four densities), each crawler being transferred separately with a camel-hair brush. The seedlings were placed 10 metres apart on a level field. Around each seedling was placed 16 sticky-traps (each 10cm wide and 30cm tall), one at 1, 2, 3 and 4m distances along four compass points (N. S, E and W) away from the source plant; there were therefore 16 treatments. Each trap was tied to a stake 1m above the ground. The traps were collected after six weeks (the maximum duration of the first instar) and the number of crawlers caught counted.

*Data analysis*: differences in female fecundity and fertility between orchards and between females of different body sizes were analyzed using one-way ANOVA. The relationship between female body size and fecundity was analyzed using correlation analysis. Factorial ANOVA was used to determine the effect of crawler density at the source on the observed number of crawlers caught. The observed number of crawlers caught at each distance was multiplied by its respective proportional increase in radius to account for the reduction in circumference taken up by the traps as distance increased and to make comparison possible. The effect of compass directions on the number of crawlers captured was computed using both full and reduced models of dummy variables.

## RESULTS AND DISCUSSION

### Fecundity and size

Total egg production per ovipositing female of *C. destructor* varied significantly between orchards ($P<0.01$). Females collected off *Citrus reticulata* produced significantly more eggs than those off *E. malaccensis* (Table 1). Individual females from the same orchard and off different hosts also varied in their fecundity, ranging from 37-6355/female off *C. reticulata* and 13-4514/female off *E. malaccensis*. The variation between citrus orchards and between *C. reticulata* and *E. malaccensis* may be due to differences in the availability of soluble nitrogen as this is known to have great impact on the survival, fecundity and size of sap-sucking insects (McClure, 1980). Although not tested in the present study, the size of *C. destructor* is known to be positively correlated with the nitrogen levels of citrus trees (Beattie *et al.*, 1990). The variation in female fecundity between orchards has implications for the size of the succeeding scale populations and hence in the forecast of possible outbreaks.

The range in fecundity for *C. destructor* reported here is similar to that found by Lo (1995: 12-5214) infesting citrus in New Zealand. However, the maximum number of eggs laid by individual females of *C. destructor* collected off citrus (6355) exceeded previously reported maxima of 3000 (Smith, 1970), 5475 (Beattie, 1988) and 5214 (Lo, 1995). The mean fecundity for the *C. destructor* in the present study (1774) was less than the 3000 reported by Zeck (1934) but slightly greater than the 1750 reported by Olson *et al.* (1993) and 1233 given by Lo (1995).

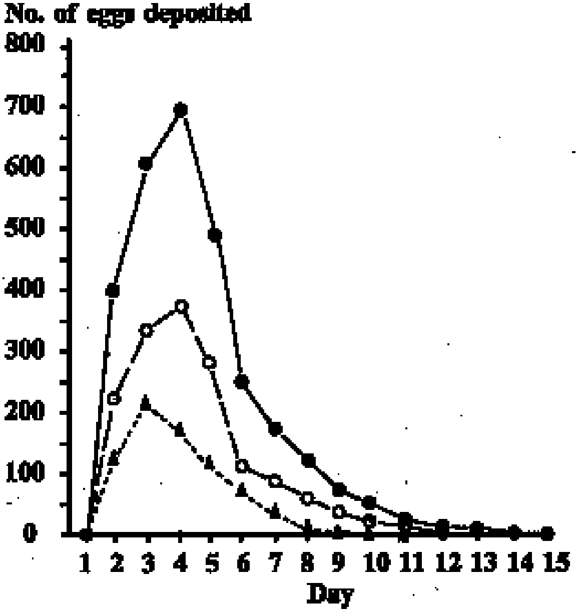
The size of *C. destructor* varied significantly between orchards ($F=7$; $P<0.001$) and between *C. reticulata* and *E. malaccensis* ($F=2.65$; $P<0.05$). Length and width were positively correlated off both hosts (*C. reticulata* ($r^2=0.89$); *E. malaccensis* ($r^2=0.79$)). Size and fecundity were also positively correlated (*C. reticulata* ($r^2=0.84$); *E. malaccensis* ($r^2=0.77$) (Table 2)). These results are similar to those of Yardeni & Rosen (1995, for *Ceroplastes* *floridensis* Comstock), Lo (1995, for *C. destructor*) and Bedford (1968, for *Ceroplastes sinoiae* Hall).

The oviposition period was also affected by body-size (Table 2), with large females off both hosts taking 14 days to complete egg laying; medium-sized females off *C. reticulata* taking 12 days and those off *E. malaccensis* 11 days (Figs 1 & 2), while small *C. destructor* completed oviposition in 10 days. The average number of eggs laid/female/day varied from a maximum of 701 on the 3rd day of oviposition to a minimum of 1 on the last (14th) day for large females off *C. reticulata*; and, off *E. malaccensis*, a maximum of 537 eggs on the 2nd day and 1 on the 14 th day. The maximum number of eggs laid by a large female in one day was 941, on the 3rd day. For *C. sinoiae*, Bedford (1968) recorded a mean of 545 eggs and a minimum of 1 egg/female/day. Egg laying by large females peaked on the 4th day whereas, for medium-sized females, the peak was on the 4th day for females off *C. reticulata* but on the 3rd day off *E. malaccensis*. Small females off both hosts laid their peak number of eggs on the 3rd day. The average duration of oviposition off both hosts for all size categories was 11 days.

Table 1. Mean fecundity, fertility and body-size of adult female *C. destructor* infesting *Citrus reticulata* and *Eugenia malaccensis* at four farms in Western Cape Province, South Africa.

| Farm$^3$ | Fecundity (n*) | Fertility$^2$ (n**) | Days to hatching (range) | Body size$^1$ (mm±SE) | | |
|---|---|---|---|---|---|---|
| | | | | Length | Width | n* |
| WEF | 1935 (74) | 97.8 (1100) | 16-17 | 4.20 (0.38) | 2.52 (0.10) | 133 |
| RFF | 1720 (84) | 97.6 (5055) | 16-19 | 4.33 (0.13) | 2.52 (0.08) | 110 |
| RUS | 1838 (74) | 96.1 (2550) | 16-19 | 4.16 (0.11) | 2.50 (0.08) | 80 |
| STL | 1602 (74) | 98.6 (2660) | 16-17 | 4.50 (0.10) | 2.63 (0.07) | 80 |
| Mean | 1774 (77) | 97.5 (2841) | 17 | 4.30 (0.16) | 2.54 (0.08) | 96 |
| ANOVA | 0.05 | NS | NS | 0.05 | 0.05 | |

1: Dewaxed adult female; 2: % crawler emergence for eggs incubated at 27°C and 60% RH; 3: Farms: WEF = Welgevallen Experimental Farm (host = *C. reticulata*); RFF = Rhodes Fruits Farm (host = *C. reticulata*); RUS = Rustenburg Estate (host = *C. reticulata*) and STL = Stellenbosch (host = *E. malaccensis*); n* = sample size; n** = no. of eggs incubated; SE = Standard Error of Mean; ANOVA = P<0.05 significant differences between farms; NS = not significant (*P*>0.05).



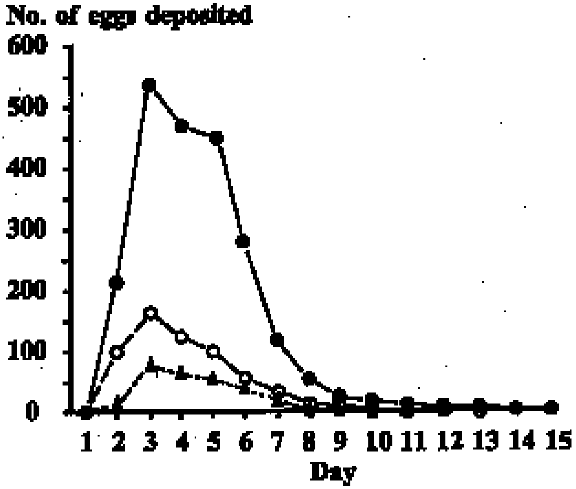
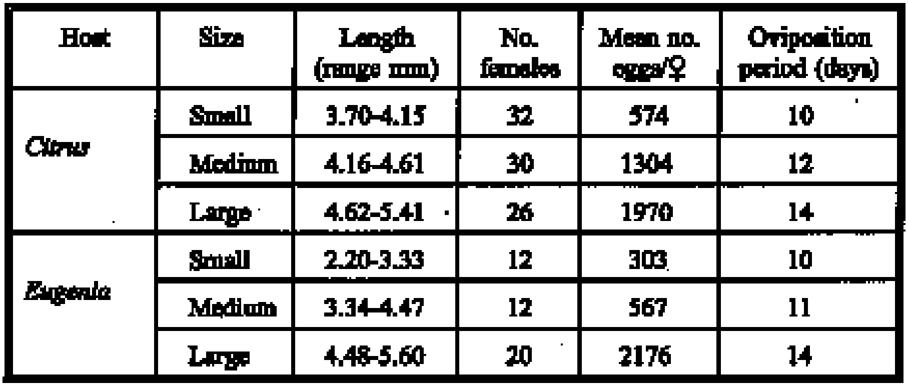


Fig. 1. Effect of body size on duration of oviposition by females of *Ceroplastes destructor* infesting *Citrus reticulata*. Where —•— = large, -o- = medium and --▲-- = small body size.

Fig. 2. Effect of body size on duration of oviposition by females of *Ceroplastes destructor* infesting *Eugenia malaccensis*. Where —•— = large, -o- = medium and --▲-- = small body size.

Table 2. Effect of host-plant species and body-size on the fecundity for *C. destructor.*



| Host | Size | Length (range mm) | No. females | Mean no. eggs/♀ | Oviposition period (days) |
|---|---|---|---|---|---|
| *Citrus* | Small | 3.70-4.15 | 32 | 574 | 10 |
| | Medium | 4.16-4.61 | 30 | 1304 | 12 |
| | Large | 4.62-5.41 | 26 | 1970 | 14 |
| *Eugenia* | Small | 2.20-3.33 | 12 | 303 | 10 |
| | Medium | 3.34-4.47 | 12 | 567 | 11 |
| | Large | 4.48-5.60 | 20 | 2176 | 14 |

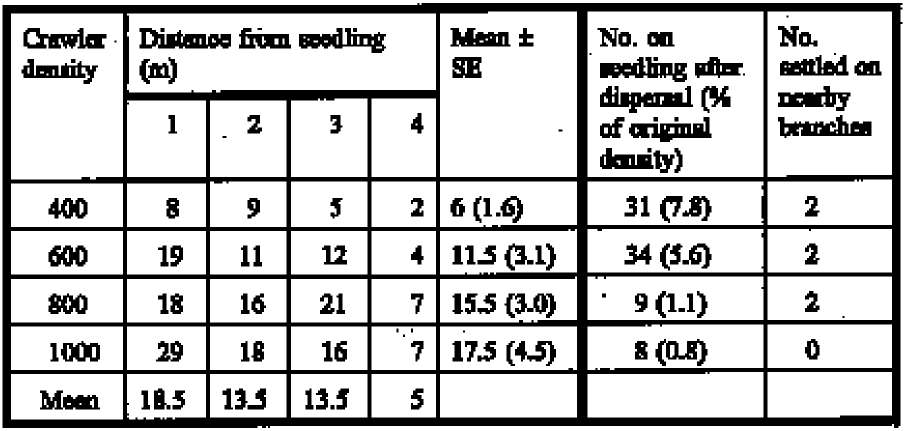
The incubation period ranged from 16 to 19 days (mean 17 days), which was shorter than the 25-31 days reported by Cilliers (1967) for *Ceroplastes mimosae* Sign. in South Africa. In field populations with *C. destructor* in the present experiments, eggs laid by the same generation of females hatched over a period of up to two months. After hatching, the crawlers remained within the 'brood chamber' for about two days before moving onto the leaves or young twigs.

### DISPERSAL

Wind has been shown to be the principal dispersal agent for the crawlers of scale insects (Jenkins *et al.*, 1953; Hulley, 1962; Washburn & Frankie, 1985; Yardeni, 1987; Greathead, 1997). Previous work on the wind dispersal of *C. destructor* (Hely, 1960) showed they could be carried at least 6m. Distances recorded for other scale insects are: 135m for the black scale (*Saissetia oleae* (Bernard) (Quayle, 1916); 54m for the soft brown scale, *Coccus hesperidum* L. (Hoelscher, 1967) and 3.5km for *Icerya seychellarum* (Westwood) trapped at 6m above surrounding vegetation (Hill, 1980). Dispersion distance has also been shown to be affected by the height of take-off and wind speed (Greathead, 1972; Wainhouse, 1980; Moran *et al.*, 1982) and by the temperature and humidity of the environment (Greathead, 1972).

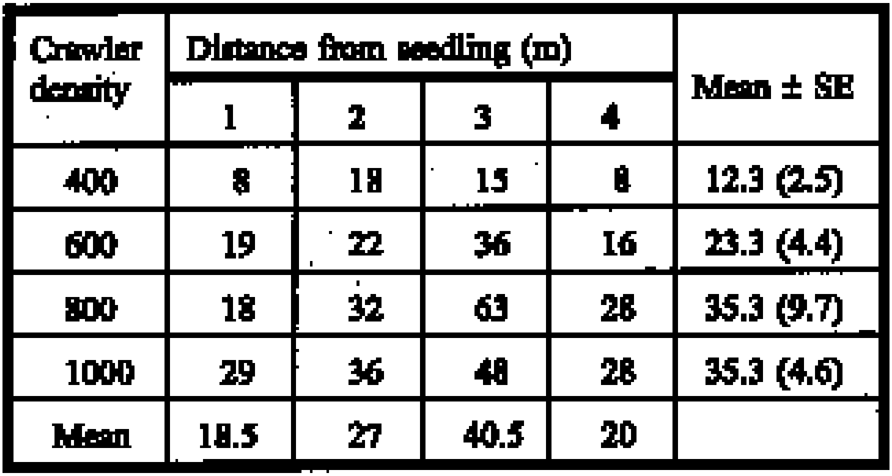
Table 3 shows the mean number of crawlers caught per trap at each distance and there appears to be a significant reduction in the number caught on the traps further from the source. However, because the four traps at each distance were all the same size, the proportion of the circumference of the circle that each trap covered got smaller the further the traps were from the

Table 3. Mean number of crawlers captured per trap after 6 weeks at four distances from citrus seedlings infested with four densities of *C. destructor* crawlers; trap size = 30x10cm; trap distance from the ground = 1m. Also the mean number of 2nd-instar nymphs remaining on each seedling at the original site of release and the number elsewhere on the plant, six weeks after release.



| Crawler density | Distance from seedling (m) | | | | Mean ± SE | No. on seedling after dispersal (% of original density) | No. settled on nearby branches |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | | | |
| 400 | 8 | 9 | 5 | 2 | 6 (1.6) | 31 (7.8) | 2 |
| 600 | 19 | 11 | 12 | 4 | 11.5 (3.1) | 34 (5.6) | 2 |
| 800 | 18 | 16 | 21 | 7 | 15.5 (3.0) | 9 (1.1) | 2 |
| 1000 | 29 | 18 | 16 | 7 | 17.5 (4.5) | 8 (0.8) | 0 |
| Mean | 18.5 | 13.5 | 13.5 | 5 | | | |

Table 4. As for table 3 but with the actual number of crawlers caught multiplied by a factor to make the size of the traps proportional to the circumference at each distance: i.e. x1 at 1 m, x2 at 2 m, x3 at 3 m and x4 at 4 m.



| Crawler density | Distance from seedling (m) | | | | Mean ± SE |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | |
| 400 | 8 | 18 | 15 | 8 | 12.3 (2.5) |
| 600 | 19 | 22 | 36 | 16 | 23.3 (4.4) |
| 800 | 18 | 32 | 63 | 28 | 35.3 (9.7) |
| 1000 | 29 | 36 | 48 | 28 | 35.3 (4.6) |
| Mean | 18.5 | 27 | 40.5 | 20 | |

seedling. This is taken into account in Table 4, which shows the mean number of crawlers caught on each trap multiplied by a factor which equalises the proportion of each circumference covered by the four traps. The resultant figures represents traps about 1/16th of each circumference. It is clear that, when compared on this basis, the number of crawlers being caught does not appear to fall off significantly with distance (up to 4m) as there are approximately the same number being caught at 4m as at 1m (although the numbers at the intermediate distance do seem to be greater). It is also clear that the number caught was greater on those traps associated with seedlings with initially higher crawler densities (F=7.7, *P*=0.001). At what distance a clear reduction in the number caught would be recorded is unclear but, since take-off height in the field would usually be greater than the 1m in this study, the distance that *C. destructor* crawlers could be dispersed on wind currents in the field could be much greater than found here.

Table 3 also shows the number of 2$^{nd}$-instar nymphs which were still present on the seedlings six weeks after release and it clearly shows that more remained on the seedlings with an original crawler density of 400 and 600 than on those with 800 and 1000, suggesting that there may have been some crowding effect on dispersal.

The effects of direction were tested using dummy variables. The reduced model differed from the full model for the observed density (F9, 253 = 2.09; *P*=0.03). However, none of the coefficients for the dummy variables were significant (*P*>0.05) for both observed and expected density. Therefore, a common intercept and common slopes for both distance and density were assigned to the four compass directions. The reduced model did not differ from the full model for the expected density (F9, 253 = 1.26, *P*=0.26) indicating that common regression coefficients could be assumed for all four compass directions. Therefore, it can be said that direction on its own had no significant effect on the number of crawlers caught and that the wind was blowing from all four directions at sometime during crawler dispersal.

## ACKNOWLEDGMENTS

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XIE YINGPING[1]; ZHAO JINLONG[2]; GUO YONGPING[2]; LI YUNFENG[2];
ZHANG HAIJUN[2]; GUO YUQING[2]
[1]*Department of Biology, Nankai University, Tianjin 300071, China*
[2]*Department of Forestry, Shaixi Agricultural University, Taigu 030801, China.*

# THE BIOLOGY OF *PHENACOCCUS AZALEAE* KUWANA, A PEST OF BUNGE PRICKLY ASH (*ZANTHOXYLUM BUNGEANUM* MAXIM) FOREST IN NORTHERN CHINA.

## ABSTRACT

THE BIOLOGY OF *PHENACOCCUS AZALEAE* KUWANA, A PEST OF BUNGE PRICKLY ASH (*ZANTHOXYLUM BUNGEANUM* MAXIM) FOREST IN NORTHERN CHINA.

*Phenacoccus azaleae* Kuwana (Hemiptera: Coccoidea: Pseudococcidae) is a major new pest of bunge prickly ash forest in northern China, where it causes high tree mortality when present for two consecutive years. This paper reports on the biology of this pest in northern China, where it has been studied since 1995. The life cycle can be divided into eight phases, two of which cause severe injury to the host plant, through the feeding of: (a) the 3rd-instar nymphs and adult females between late March and mid-May, and (b) the young nymphs which are present on the leaves between late June and October. The adult sex ratio was 6-7♀:1♂. The various development stages are described. Of the natural enemies, ladybirds (Coccinellidae) and lacewings (Neuroptera) were the major predators, but they were not abundant in the newly-infested areas. In addition, a few parasitic Hymenoptera were recorded but appeared to be ineffective.

Key words: *Aphis gossypii*, *Papilio xuthus*, *Podagri comeiashirahatai, Calloides magnificus*, *Agrilus zanthoxylumi*, plum, elm, *Azalea*, Japan, Korea, voltinism, development, population dynamics, damage, *Lasius fuliginosus*, *L. niger*, sex ratio, growth rate, *Harmonia axyridis*, *Coccinella septempunctata*, *Chrysopa.*

## INTRODUCTION

Bunge prickly ash, *Zanthoxylum bungeanum* Maxim, is one of the most important economic plants in northern China, where it is planted on a large scale as its fruit is used as a condiment and because natural oils can be extracted from its seeds. It has several pests, of which the most important are *Aphis gossypii* Glover, the butterfly *Papilio xuthus* L. and the leaf-eating beetle *Podagri comeiashirahatai* (Chujo), all of which attack the leaves, and also the two bark-boring beetles *Calloides magnificus* (Pic.) and *Agrilus zanthoxylumi* Hou. Until 1994, few scale insects had been recorded on bunge prickly ash but in that year outbreaks of *Phenacoccus azaleae* Kuwana (Coccoidea: Pseudococcidae) occurred in several areas in northern China.

When the trees were attacked for two consecutive years, most plants died and, prior to 1996, there had been a major reduction in yield, with about a third of the trees being killed by the mealybug.

Previously, *P. azaleae* had been restricted to *Azalea* species in Japan and Korea but, in 1988, it was collected on plum and elm in Inner Mongolia, although it was not considered to be an important pest there (Tang Fangde & Li Jie, 1988; Tang Fangde, 1992). Since it was originally discovered on *Z. bungeanum* in 1994 in Shanxi Province and in Yu xian, Li cheng and Rui cheng counties, it has also been recorded on bunge prickly ash in Shandong and Gansu Provinces. The biology of this pest on *Z. bungeanum* has been studied since 1995 (see Xie Yingping *et al.*, 1997) and this paper presents further data on this pest.

## MATERIALS AND METHODS

*Study site*: the ash forests on the mountains and along the Hutuo River in Yu xian county, where it was originally discovered and where the populations of *P. azaleae* are dense.

*Study methods*:

1. *The sex ratio*: during March in 1996 and 1997, 25 twigs with mealybug populations were selected from the forest and the numbers of males and females counted under a microscope in the laboratory.
2. *Female development*: in the Spring, the number and size of the 3rd-instar nymphs and adult females was monitored as they spread from their overwintering sites and settled on the twigs.
3. *Male development*: from the end of March until late April, 1996, the male cocoons were collected and dissected to determine development.
4. *Oviposition*: once oviposition had commenced, the proportion of adult females with an egg sac was recorded, while the number of eggs was estimated in June by collecting the egg sacs off the leaves and counting the eggs.
5. *Natural enemies*: samples were taken from 20 trees between March and May, 1997, when four twigs, each from a different sector of the tree, were removed. Predators: these were mostly Coccinellidae and Chrysopidae, which were mainly recorded in May, when they were in their immature stages; adults predators were counted *in situ* prior to twig removal. Parasitoids were much scarcer and were mainly present in March and April. These were counted in the laboratory by removing the woolly cocoons from the mealybugs. Generally, the parasitised mealybugs had a different body colour and the larva or pupa of the parasitoid could be easily located in the host.

## RESULTS

### DEVELOPMENT, POPULATION DYNAMICS AND HOST PLANT DAMAGE:

*P. azaleae* has one generation a year, the females typically passing through four instars and the males through five. The life history of this pest can be divided into eight stages, depending on behaviour and feeding habits.

1. Egg stage: the adult females secrete their ovisac beneath the leaves in late April or early May. The egg stage lasts about a month and has a very low mortality, with about 93% hatching.

2. Crawler stage: this stage disperses to the leaves, were they settle on the leaf veins. This stage is easily attacked by ladybirds (Coccinellidae) and lacewings (Neuroptera) as it has very little protective wax. In addition, there may be some mortality due to natural factors such as wind, rain and low humidity. Mortality may be around 15-20%.

3. Young nymphal instars: between the middle of June and the end of October, the nymphs feed on the leaves and develop through to the 2nd instar. This stage is covered in wax which protects them from natural factors, so that mortality appears to be quite low. Due to their high population density, they cause serious damage at this stage.

4. Migration to twigs: in October, when the weather gets colder and the plants start to senesce, the 2nd-instar nymphs disperse back to the twigs. There is some mortality at this time due to such environmental factors as wind and rain.

5. Overwintering stage: the nymphs settle at the base of the twigs and buds, and in the seams and cracks in the bark, where they secrete a wax cocoon which resembles a rice grain and go into diapause. The nymphs spend the entire winter in the cocoon, from October through to March, during which time the female nymphs moult to the 3rd instar, while the male nymphs moult first to the prepupa and then the pupal stage. Mortality is very low during the winter, less than 15%. Few parasitoids were found.

6. Dispersal phase: in late March, the 3rd-instar female nymphs emerge from the cocoons and disperse to the young shoots of the ash trees. At this time, the weather in northern China is usually dry and windy and there is little mortality due to environmental factors, although a few are eaten by ladybirds that have also just emerged from dormancy.

7. Feeding stage: as the young shoots elongate, the female nymphs congregate on the twigs and grow fast, feeding in the phloem of the young tissues (Table 1). About the middle of April, they finally moult to become adult and swell to resemble a large bean grain. During this time, their mean

length increases from 0.9 to 3.4mm and their width from 0.6 to 2.1mm. Many eggs are present in their abdomens.

8. Mating and oviposition: as the 3rd-instar female nymphs moult to become adult, the adult males emerge. The adult males only live for a few days, during which time they can fly and locate the females, which they fertilize. The females continue feeding on the leaves until May when, with the expansion of the leaves, they commence ovisac production and egg laying.

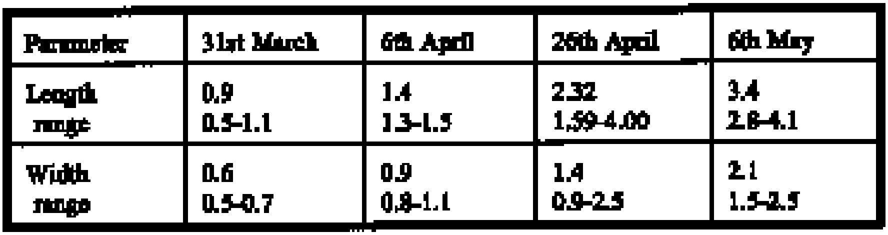
There are two main injurious stages. The first is in the late spring and early summer, when the 3rd-instar nymphs and adult females are growing fast on the young leaves. This feeding causes a serious weakening of the trees, slows leaf growth and can prevent flower and fruit formation. The second important phase is in late summer and early autumn, when the crawlers and 2nd-instar nymphs are feeding in preparation for overwintering and this also weakens the trees. In addition to this direct damage due to sap-sucking, much honeydew is produced on which sooty moulds develop, covering the trees in a black mat and further reducing photosynthesis. Honeydew is particularly abundant during the 3rd instar and early adult stages between March and May. At this time a few ants (*Lasius fuliginosus* Latr. and *Lasius niger* (L.)) are present. Along with the feeding damage, the presence of sooty moulds causes early senescence and leaf fall. This usually occurs in late August, when the temperature is still high. However, the trees may still produce further leaves which leads to a major loss of nutrition for the following year. In addition, the weakened twigs die from the dry air and cold. In our sample of 2000 trees, 300 died after being infected for two consecutive years.

*Sex ratio*: this was 7.3♀:1♂ in 1996 (488 ♀♀: 67 ♂♂ on 25 twigs) and 6.1♀:1♂ in 1997 (429♀♀: 70 ♂♂ on 20 twigs).

*Female growth rate after overwintering*: the growth rate of *P. azaleae* during the period late March to early May is summarised in Table 1 and it is clear that growth is very rapid during this period.

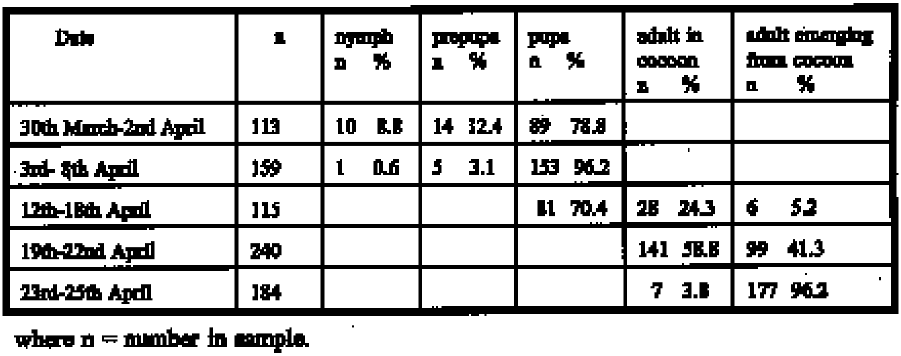
*Male development and emergence*: this is summarised in Table 2. Most males were in the pupal stage in late March although a few were still 2nd-instar nymphs, suggesting that the winter was spent as the 2nd-instar nymph and that pupation mainly occurred in early Spring. The first adult males inside the cocoons were found on the 12th April and all were adult by the 19th April. The first emerging males were seen on the 13th April and all had emerged by the 25th April.

Table 1. Mean body size (mm) of *P. azaleae* on four dates between late March and early May on bunge prickly ash in northern China in 1996 (n = 11).



| Parameter | 31st March | 6th April | 26th April | 6th May |
|---|---|---|---|---|
| Length<br>range | 0.9<br>0.5-1.1 | 1.4<br>1.3-1.5 | 2.32<br>1.59-4.00 | 3.4<br>2.8-4.1 |
| Width<br>range | 0.6<br>0.5-0.7 | 0.9<br>0.8-1.1 | 1.4<br>0.9-2.5 | 2.1<br>1.5-2.5 |

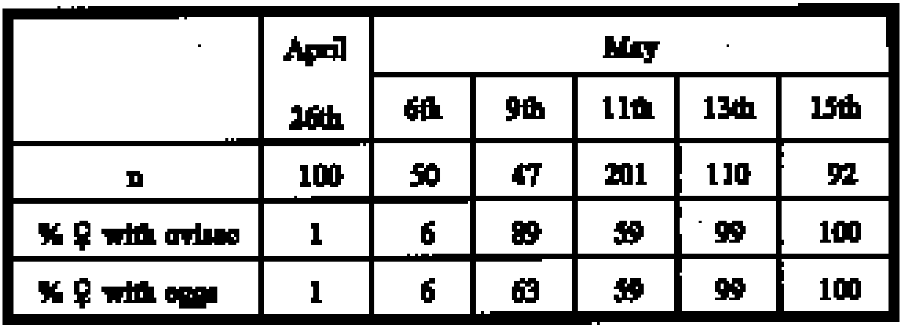
Table 2. Stage of development of male *P. azaleae* on bunge prickly ash in northern China between late March and April, 1996.



| Date | n | nymph | | prepupa | | pupa | | adult in cocoon | | adult emerging from cocoon | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | n | % | n | % | n | % | n | % | n | % |
| 30th March-2nd April | 113 | 10 | 8.8 | 14 | 12.4 | 89 | 78.8 | | | | |
| 3rd- 8th April | 159 | 1 | 0.6 | 5 | 3.1 | 153 | 96.2 | | | | |
| 12th-18th April | 115 | | | | | 81 | 70.4 | 28 | 24.3 | 6 | 5.2 |
| 19th-22nd April | 240 | | | | | | | 141 | 58.8 | 99 | 41.3 |
| 23rd-25th April | 184 | | | | | | | 7 | 3.8 | 177 | 96.2 |

where n = number in sample.

Table 3. The timing of ovisac and egg production of *P. azaleae* on bunge prickly ash leaves in northern China in 1996.



| | April | May | | | | |
|---|---|---|---|---|---|---|
| | 26th | 6th | 9th | 11th | 13th | 15th |
| n | 100 | 50 | 47 | 201 | 110 | 92 |
| % ♀ with ovisac | 1 | 6 | 89 | 59 | 99 | 100 |
| % ♀ with eggs | 1 | 6 | 63 | 59 | 99 | 100 |

*Ovisac development and oviposition*: on maturity, adult female *P. azaleae* move onto the lower leaf surface and commence ovisac production. This occurred over a short period at the end of April and in early May (Table 3).

Although ovisac production began on about the 26th April, the ovisacs where quite small and they continued to elongate until at least the last week of May. Thus, the ovisacs had a mean length of about 4.9mm and a width of about 2.3mm on the 7th May but had extended to a mean of 7.9mm and a width of 2.6mm by the 27th (max. length 8.2mm, width 2.8mm). The mean number of eggs per egg sac was 446 (range 206-842).

*Natural enemies*: because *P. azaleae* is a recently established pest, rather few predators or parasitoids were recorded during the first two years and they were ineffective in controlling the mealybug. Thus, in 1995 and 1996, a few ladybirds and lacewings were noted and a few hymenopterous parasitoids were found in the cocoons. However, the populations of two ladybirds (*Harmonia axyridis* (Pallas) and *Coccinella septempunctata* L.) and the lacewing *Chrysopa septempunctata* Wesmael, built up quite fast in both the forest areas studied.

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XUE JIAOLIANG[1]; XIE YINGPING[2]; LIU HONGXIA[1]; LIU JIQUAN[1];
LI YANGFANG[1]

[1]*Department of Forestry, Shanxi Agricultural University, Taigu 030801, China.*
*2Department of Biology, Nankai University, Tianjin 300071, China.*

# THE EFFECT OF AIR POLLUTION ON *SOPHORA JAPONICA* (LEGUMINOSAE) AND *EULECANIUM GIGANTEUM* (SHINJI) (HEMIPTERA: COCCOIDEA: COCCIDAE) IN URBAN AREAS IN CHINA.

## ABSTRACT

THE EFFECT OF AIR POLLUTION ON *SOPHORA JAPONICA* (LEGUMINOSAE) AND *EULECANIUM GIGANTEUM* (SHINJI) (HEMIPTERA: COCCOIDEA: COCCIDAE) IN URBAN AREAS IN CHINA.

A study was made of the effect of two air pollutants (sulphur dioxide and lead) on the pest status of the soft scale *Eulecanium giganteum* (Shinji) and on the accumulation of sulphur and lead in the scale's host tree, *Sophora japonica,* in three cities in China, namely Taiyuan, Yuci and Taigu. *E. giganteum* is a major pest of several tree species in many cities in China where air pollution can be high. This study showed a positive correlation between the level of the pollutants in the trees and the populations of the scale. The leaves absorbed and accumulated a greater amount of sulphur dioxide ($SO_2$ - as sulphur) and lead (Pb) than the twigs, but the trends were the same in each, namely with high levels in these tissues in the Spring and early Autumn. It is concluded that *E. giganteum* can withstand high levels of pollutants, both within the host plant and in the environment, whereas its natural enemies may not.

Key words: urban areas, biology, percentage parasitism, sap quality, pollution levels, *Beijing utila*, *Microterys clauseni*, *Blastothrix sericea*, *Eucomys sasakii*, *Anisetus*, Coccinellidae, Helicodinidae, Encyrtidae, *Coccinella septempunctata*, *Harmonia axyridis*, *Chilocorus rubidus.*

## INTRODUCTION

*Eulecanium giganteum* (Shinji) (Coccoidea: Coccidae) is one of the most important scale insects in urban areas in China. A study of the effects of pollution on the populations of this insect have been undertaken since 1993 and have shown that the population density of *E. giganteum* is positively correlated with traffic pollution (Xie *et al*., 1995), with the pollutants being found in the bodies of both the host plants and the scales (Xie *et al*., 1998). This paper considers the correlation between the levels of two pollutants, sulphur dioxide and lead, in the host plant and the population densities of *E. giganteum.* This is discussed in relation to the biology of the scale.

## MATERIALS AND METHODS

Three sites of relatively high pollution and two sites of low pollution were studied. The former were (a) the city of Taiyuan, capital of Shaixi Province: an area of heavy industry, where the pollution is mainly from vehicular exhaust gases and which is considered to be the most polluted area in China. Some four districts of Taiyuan were studied: Railway Station Street, City Centre Square, Bus Station Street and Xin Jian Road. (b) The city of Yuci, which has light industry and is about 30km south-west of Taiyuan. Two districts were studied: Liang Dian Street and Shun Cheng Street. (c) The county town of Taigu, some 60km south of Taiyuan, where the pollution is from heavy industry such as iron and steel making and from chemical factories which use a lot of coal. The two less polluted sites were Jinsi Park, in the southern suburbs of Taiyuan, and the Botanical Gardens of Shanxi Agricultural University, Taigu.

Samples of *Sophora japonica*, a common tree in suburban areas and a good host for *E. giganteum*, were taken monthly as follows: first, 10-15 sample trees were selected in the particular street and then five twigs were taken from each tree and the number of scales insects on 60cm of the twig tip counted. Most of the sampled trees were 10-20 years old. The plant samples were taken to the laboratory where they were washed to remove the dust.

Sulphur dioxide ($SO_2$ - as sulphur) analysis: the twigs and leaves were separated, dried and ground for chemical analysis. Triplicate samples were digested in a nitric acid/perchloric acid mixture and the diluted digests analysed for sulphur as barium sulphate by turbidimetry using a spectrophotometer.

Lead (Pb) analysis: the samples were dried and 5g were placed in a crucible and reduced to ash in a muffle furnace. The ashes were then dissolved in $HNO_3$ and the amount of lead determined by atomic absorption spectroscopy.

## RESULTS

*LEAD*: the results of the analysis for each district are presented in Table 1 and are compared with the soft scale populations. The level of lead in the twigs and leaves was very similar for each district. The greatest lead concentration was in Taiyuan and the lowest concentration in the Botanical Gardens. The scale population was also greatest in Taiyuan and least in the Botanical Gardens. Indeed, the correlations between the scale population and the level of Pb was highly significant (r = 0.96 for the twigs and 0.99 for the leaves).

Table 1. The population density of *E. giganteum* per 60cm of twig and the amount Pb (ppm) in the twigs and leaves of *Sophora japonica* in 10 districts in northern China (mean of 9 observations).

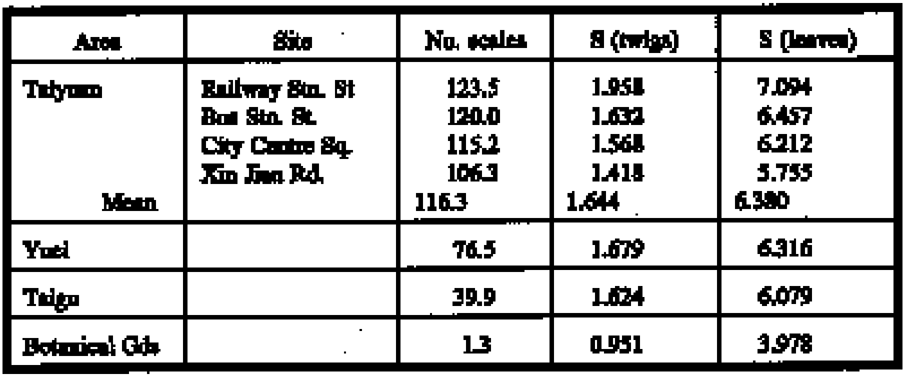
| Area | District | No. scales | Pb (twigs) | Pb (leaves) |
|---|---|---|---|---|
| Taiyuan | Railway Stn St. | 123.5 | 9.00 | 8.49 |
| | Bus Stn St. | 120.0 | 8.25 | 8.25 |
| | City Centre Sq. | 115.2 | 7.49 | 7.74 |
| | Xin Jian Rd | 106.3 | 6.25 | 7.00 |
| Mean | | 116.2 | 7.75 | 7.87 |
| Yuci | Liang Dian St. | 76.5 | 6.90 | 5.25 |
| | Shun Cheng St. | 56.2 | 5.00 | 4.25 |
| Mean | | 66.4 | 5.95 | 4.75 |
| Taigu | Taigu town 1 | 52.8 | 4.00 | 4.50 |
| | Taigu town 2 | 27.0 | 3.00 | 2.25 |
| Mean | | 39.9 | 3.50 | 3.13 |
| Taiyuan | Jinci Park | 4.6 | 1.99 | 1.33 |
| Taigu | Botanical Gdns | 1.3 | - | - |

Where - = level of Pb too low to record. Correlation equations: twigs: $Y_1 = -23.7630 + 17.2698X$ ($r = 0.96$); leaves: $Y_1 = -14.6250 + 16.5861X$ ($r = 0.99$).

*SULPHUR DIOXIDE*: the results of the analysis (as sulphur (g/kg)) for each district are presented in Table 2 and are compared with the soft scale population. The samples from all three polluted cities had similar high levels of $SO_2$, some two times greater than in the less polluted district of the Botanical Gardens, Taigu. Thus, unlike the levels of Pb (Table 1), the levels were equally high in Yuci and Taigu, even though the scale populations were clearly not as large. Nonetheless, the correlations between the scale population and the level of $SO_2$ were still significant ($r = 0.71$ for twigs and 0.81 for leaves).

*Monthly variations*: the variation in Pb and sulphur levels in the twigs and leaves of *S. japonica* at approximately monthly intervals in the four sites of Taiyuan City is shown in Fig. 1. There appear to be two peaks with high levels of the two pollutants, one in the Spring (March to May) and the other in the late Summer/early Autumn (August to October), with a very significant drop in the levels of the two pollutants during the Summer (June/July).

Table 2. The population density of *E. giganteum* per 60cm of twig and the amount of sulphur (g/kg) in the twigs and leaves of *Sophora japonica* at 7 sites in northern China (mean of 9 observations).



| Area | Site | No. scales | S (twigs) | S (leaves) |
|---|---|---|---|---|
| Taiyuan | Railway Stn. St | 123.5 | 1.958 | 7.094 |
| | Bus Stn. St. | 120.0 | 1.632 | 6.457 |
| | City Centre Sq. | 115.2 | 1.568 | 6.212 |
| | Xin Jian Rd. | 106.3 | 1.418 | 5.755 |
| Mean | | 116.3 | 1.644 | 6.380 |
| Yuci | | 76.5 | 1.679 | 6.316 |
| Taigu | | 39.9 | 1.624 | 6.079 |
| Botanical Gdn | | 1.3 | 0.951 | 3.978 |

Correlation equations: twigs: $Y_1$ = -84.4612+108.3969X (r = 0.71); leaves: $Y_1$ = -149.7997 +38.9417X (r = 0.81).

## DISCUSSION

Previous work looking at the effect of vehicle pollutants on aphids (*Aphis pomi*) (Flückiger *et al.*, 1978) found an upsurge in the aphid population on hawthorn (*Crataegus monogyna*) with increasing levels of pollutants, while Beyer & Moore (1980) found that the eastern tent caterpillar (*Malacosoma americanum* (F.) and its host plant (black cherry, *Prunus serotina* (Rosaceae)) absorbed lead from the atmosphere near a motorway near Baltimore, USA. Previous work with *E. giganteum* has shown that its population levels are positively correlated to the level of pollution from traffic (Xie *et al.*, 1995) and that the pollutants can be detected in both the host plants and in the scale (Xie *et al.*, 1998). Environmental records for the level of air pollution in Taiyuan show that the levels fall quite dramatically during the summer, but remain fairly high for the rest of the year, as suggested in Fig. 1. Whilst the correlations between both pollutants and the scale populations were highly significant, the fact that the levels of $SO_2$ was high in all polluted study areas (Table 2) but the scale populations decreased in a manner similar to the Pb levels (Table 1), suggests that it is the latter pollutant which may be most important.

*E. giganteum* has a single generation a year. The scale overwinters as a 2nd-instar nymph on the twigs and so, when the host trees are starting to grow fast in the spring (March/April), the scales also grow fast, finally

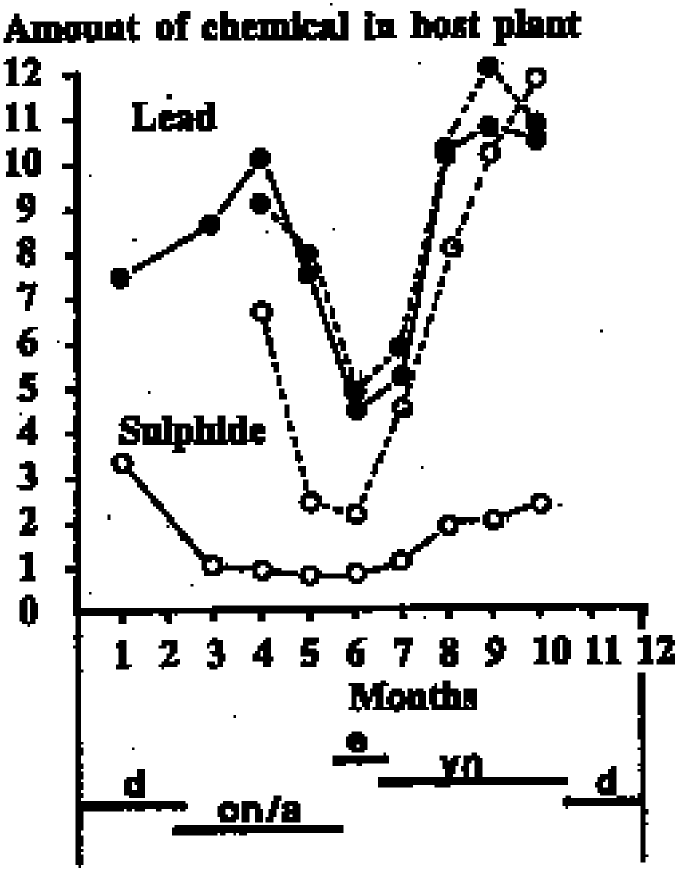


Fig. 1. Fluctuations in sulphur (g/kg) and lead (ppm) in the twigs and leaves of *Sophora japonica* in 1996 in Taiyuan City. Where • = lead; o = sulphide; —— = twigs and -- = leaves; and where **e** = eggs of *E. giganteum*, **yn** = 1st- and 2nd-instar nymphal feeding stage; **d** = dormant period, and **on/a** = 3rd-instar nymphs and adult feeding stage.

becoming adult in late April or early May when the host trees are in their period of maximum growth. The females lay eggs in May and these hatch towards the end of June, with the young nymphs dispersing to the leaves. They remain on the leaves until October but then disperse back to the woody parts of their host to overwinter. Thus, it is mainly the non-feeding egg stage of *E. giganteum* which is present during the early summer when the pollution levels are low; the nymphs and adult females are actively feeding during the two periods of high pollution (March to May and August to October).

Although excessive pollution is very harmful, *E. giganteum* appears to do well under the conditions present in the more polluted cities in China. This could be for a number of reasons: i. an effect of the pollutants might be to improve the nutritional quality of *S. japonica* and other host plants, so that the scales can grow larger and be more fertile (preliminary trials in 1996 suggest that this could be true, with the greatest number of eggs per scale in Taiyuan and least in Taigu); ii. the pollutants have a detrimental effect on the natural enemies of *E. giganteum*, so that the scales are no longer properly controlled (again, preliminary counts of natural enemies suggest that there are more predators (Coccinellidae: *Coccinella septempunctata* L., *Harmonia axyridis* (Pallas) and *Chilocorus rubidus* Hope; Lepidoptera, Helicodinidae: *Beijing utila* Yang) in the less-polluted areas and these are believed to be important biocontrol agents. No ladybirds were noted in the polluted areas of Taiyuan. In addition, percentage parasitisation was 14% in Taiyuan, 26% in Yuci City and 37% in Taigu). The parasitoids found in *E. giganteum* were the encyrtids *Microterys clauseni* Compere, *Blastothrix sericea* (Dalman), *Eucomys sasakii* Ishii and *Anisetus* sp.

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SCALE INSECT BIOLOGY AND BEHAVIOUR: Poster abstract

# OBSERVATIONS ON THE POPULATION DEVELOPMENT OF *PSEUDAULACASPIS PENTAGONA* (HEMIPTERA: COCCOIDEA: DIASPIDIDAE) UNDER SEMI-FIELD CONDITIONS IN THE EAST MEDITERRANEAN REGION OF TURKEY.

ERKILIC, L.B.[1]; UYGUN, N.[2]
*[1]Plant Protection Research Institute, PK 21, 01321 Adana, Turkey; [2]Department of Plant Protection, University of Cukurova, 01330 Adana, Turkey*
*Email: citrusp@pamuk.cu.edu.tr*

Populations of *Pseudaulacaspis pentagona* (Targioni Tozzetti) were observed on naturally infested young peach trees (cv. 'June Gold'), kept in 2x2x2m cages covered in cheese cloth under semi-field conditions. Overwintering adult females were marked (1x2.5cm) on the plants with special glue (Tangle Trap). Both the number of crawlers produced by each female and the duration of each development stage were recorded. In each generation, 35 females were observed. *P. pentagona* had four generations a year and the first crawlers appeared from overwintered females at the beginning of April. The first generation was completed in May, the second in July, the third in August and the fourth in September. The duration of each generation was found to vary significantly in relation to temperature, with the first generation taking the longest (71.6 days) and the second generation the shortest (61.2 days). The number of crawlers produced by each generation was also found to vary significantly. The greatest number of crawlers (99.4 crawlers per female) was produced by the overwintering females and the lowest number of crawlers (17.9 crawlers per female) by the fourth generation.

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DUNKELBLUM, E.[1]; MORI, K.[2]; MENDEL, Z.[1]
[1]*Institute of Plant Protection, Volcani Center, Bet Dagan 50250, Israel.*
[2]*Department of Chemistry, Science University of Tokyo, Kagurazaka 1-3, Shinjuku-ku, Tokyo 162, Japan*

# SEMIOCHEMICAL ACTIVITY OF PHEROMONES AND ANALOGUES OF THREE *MATSUCOCCUS* SPECIES (HEMIPTERA: COCCOIDEA: MATSUCOCCIDAE).

## ABSTRACT

Semiochemical activity of pheromones and analogues of three *Matsucoccus* species
(Hemiptera: Coccoidea: Matsucoccidae).

The sex pheromone of the Israeli pine bast scale, *Matsucoccus josephi* Bodenheimer & Harpaz (Homoptera: Matsucoccidae), was identified as the ketone (*2E,5R,6E,8E*)-5,7-dimethyl-2,6,8-decatrien-4-one. The chiral diene chain is common also to the sex pheromones of *M. matsumurae* Bean & Godwin and *M. feytaudi* Ducasse. The species-specificity of the three pheromones is due to the differences in the second side chain of these ketones. Field and GC-EAD studies indicated that the sex pheromones of each of the three *Matsucoccus* spp. is a potent kairomone of both males and females of the predator *Elatophilus hebraicus* Pericart (Hemiptera: Anthocoridae). The response of *E. hebraicus* to the sex pheromones of *M. matsumurae* and *M. feytaudi* is particularly interesting since it does not occur in the distribution area of these two congeneric spp. These results prompted us to prepare a series of analogues with variations in the two side chains in order to probe the structure-activity relationship of the pheromonal/kairomonal attractancy of *M. josephi* and *E. hebraicus*. Field results indicate that alterations in the common diene moiety affected the kairomonal activity, while structural changes in the second side chain markedly reduced the pheromonal activity.

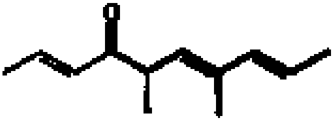
Key words: stereoisomer.

## INTRODUCTION

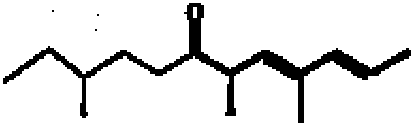
We have recently identified the sex pheromone of the Israeli pine bast scale, *Matsucoccus josephi* Bodenheimer & Harpaz (Homoptera: Matsucoccidae), as the ketone (*2E,5R,6E,8E*)-5,7-dimethyl-2,6,8-decatrien-4-one (Fig. 1 [1]) (Dunkelblum *et al.*, 1993; 1995). Structural analysis of the *M. josephi* sex pheromone has revealed a similarity to the sex pheromones of the allopatric *M. feytaudi* Ducasse (Fig. 1 [2]) (Einhorn *et al.*, 1990) and *M. matsumurae* Bean & Godwin (Fig. 1 [3]) (Lanier *et al.*, 1989). All three pheromones have the same chiral ketodiene moiety (marked in bold in Fig. 1), with the same absolute configuration *R*, while differing in the second side chain. Field tests with the *M. josephi* pheromone and its stereoisomers indicate that only the pheromone [1] is active and that the other stereoisomers are neither synergistic nor inhibitory (Dunkelblum *et al.*, 1995). In addition, it was found that the *M. josephi* pheromone is also a potent kairomone, attracting both males and females of the predatory bug, *Elatophilus hebraicus* Pericart (Mendel *et al.*, 1995; Dunkelblum *et al.*, 1996). Preliminary results indicate that the predatory bug is also attracted by the sex pheromones of *M. feytaudi* [2] and *M. matsumurae* [3] (Dunkelblum *et al.*, 1996), despite the fact that *E. hebraicus* is only associated geographically with *M. josephi* (Mendel *et al.*, 1991). These results prompted us to test a series of analogues with variations in the two side chains in order to probe the structure-activity relationship of the pheromonal response of *M. josephi* males and the kairomonal attractancy to *E. hebraicus*.

## RESULTS AND DISCUSSION

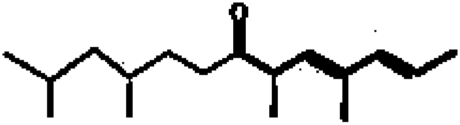
Based on earlier results, it was decided to evaluate the activity of the Z/E-racemic analogues [4A + 4B] and [5A + 5B] (Fig. 2) in relation to the chiral [1] and racemic pheromone [1A + 1B] (Fig. 2), and to include in further field tests the *M. feytaudi* pheromone [2] and chiral analogue [6] (Fig. 2). Since there is only partial overlap of flight activity of *M. josephi* and *E. hebraicus* (Mendel *et al.*, 1997), it was difficult to conduct field tests at a time when populations of both the scale and the predator were high. Several field tests were conducted in 1997 and 1998 until a proper time-window was found and satisfactory results were obtained. The results presented in Table 1 are from a field test which, in part, repeated a similar test that screened the activity of a series of analogues. The results confirmed previous tests indicating that the chiral and racemic E/Z *M. josephi* pheromones have similar pheromonal and kairomonal activity. This observation has important implications underlining the possibility of using the cheaper racemic pheromone for practical work (Mendel *et al.*, 1997). The two analogues [4] and [5] differ from the pheromone [1] in the side chain which is specific to the *M. josephi* pheromone. In earlier tests, analogue [4] revealed only kairomonal activity, attracting *E. hebraicus* and not the males of the scale (Dunkelblum *et al.*, 1996). In the 1997 and 1998 tests, this analogue attracted both insects, although its pheromonal activity was low in comparison with the activity of the true pheromone. Analogue [5], in which the propenyl side chain in the pheromone [1] was replaced by a closely related isopropenyl group, was completely inactive. The analogue [6] belongs to a new group of analogues of the *M. josephi* pheromone [1] which differ in the diene side chain which is common to all known *Matsucoccus* sex pheromones (Dunkelblum *et al.*,



***Matsucoccus josephi*** **[1]**



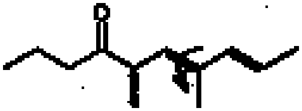
***Matsucoccus feytaudi*** **[2]**



***Matsucoccus matsumurae*** **[3]**

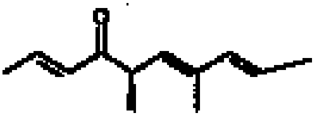
Fig. 1. The structure of the known sex pheromones of *Matsucoccus* spp. The common keto-diene moiety, common to all three pheromones, is marked in bold.

**1A + 1B**

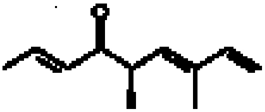


**4A + 4B**

**5A + 5B**



**1**

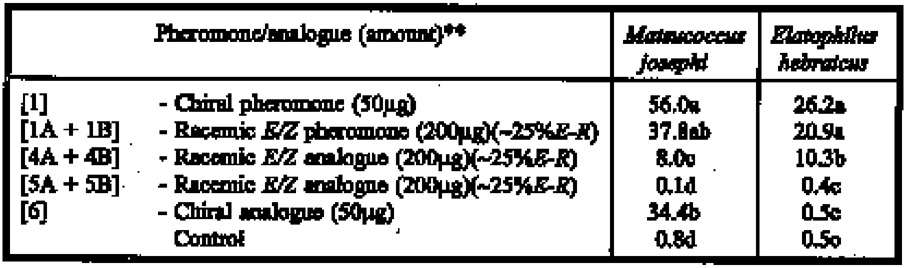


**6**

Fig. 2. The structure of analogues of the *Matsucoccus josephi* sex pheromone.

1995). Its activity is surprising as it behaves like a parapheromone, attracting only males of *M. josephi* and not *E. hebraicus*. The activity of the pheromone, the new analogue [6] and the *M. feytaudi* pheromone [2] were assessed in another test (which included an evaluation of some other parameters not presented here). It was considered important to reaffirm the activity of analogue [6], due to its specific pheromonal attractancy. The results (Table 2) did indeed confirm the previous findings. The *M. feytaudi* pheromone [2] displayed kairomonal activity and attracted the predatory bug only. The activity of [2], as a kairomone in comparison with [1], was lower than that observed before (Dunkelblum *et al.*, 1996), although its specificity remained the same.

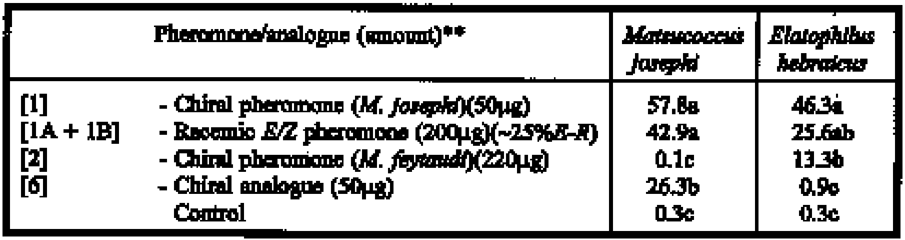
Table 1. Trap catch of male *Matsucoccus josephi* and males and females of *Elatophilus hebraicus* (mean/trap/day) with *Matsucoccus josephi* pheromone and analogues. Yatir forest, 14-22nd July 1998 (8 days), each treatment with five replicates*.



| Pheromone/analogue (amount)** | | *Matsucoccus josephi* | *Elatophilus hebraicus* |
|---|---|---|---|
| [1] | - Chiral pheromone (50µg) | 56.0a | 26.2a |
| [1A + 1B] | - Racemic *E/Z* pheromone (200µg)(~25%*E-R*) | 37.8ab | 20.9a |
| [4A + 4B] | - Racemic *E/Z* analogue (200µg)(~25%*E-R*) | 8.0c | 10.3b |
| [5A + 5B] | - Racemic *E/Z* analogue (200µg)(~25%*E-R*) | 0.1d | 0.4c |
| [6] | - Chiral analogue (50µg) | 34.4b | 0.5c |
| | Control | 0.8d | 0.5c |

*Means followed by the same letter for columns are not significantly different at P>0.05 **The racemic *E/Z* pheromone and analogues contained approximately 25% of the *E-R* stereoisomer in each case.

Table 2. Trap catch of male *Matsucoccus josephi* and males and females of *Elatophilus hebraicus* (mean/trap/day) with *Matsucoccus josephi* pheromone and analogues. Yatir forest, 14-20th May - 1st June 1998 (12 days), each treatment with five replicates*.



| Pheromone/analogue (amount)** | | *Matsucoccus josephi* | *Elatophilus hebraicus* |
|---|---|---|---|
| [1] | - Chiral pheromone (*M. josephi*)(50µg) | 57.8a | 46.3a |
| [1A + 1B] | - Racemic *E/Z* pheromone (200µg)(~25%*E-R*) | 42.9a | 25.6ab |
| [2] | - Chiral pheromone (*M. feytaudi*)(220µg) | 0.1c | 13.3b |
| [6] | - Chiral analogue (50µg) | 26.3b | 0.9c |
| | Control | 0.3c | 0.3c |

*Means followed by the same letter for columns are not significantly different at P>0.05

**The racemic *E/Z* pheromone contained approximately 25% of the *E-R* stereoisomer in each case. The amount of chiral *M. feytaudi* pheromone [2] was adjusted to compensate for its lower volatility as compared with that of *M. josephi* [1].

The activity of analogues is always lower than that of the natural pheromone or kairomone. In the case of the *M. josephi/E. hebraicus* complex, the pheromone of the female *M. josephi* [1] is both a male attractant and a potent kairomone for both males and females of the predatory bug, *E. hebraicus.* The *M. feytaudi* pheromone [2] can be considered as an analogue of [1] and, in this case, the tested analogues may be classified into two groups. The first group consists of analogues [2], [4] and [5] and the second group of analogue [6]. The first group is characterized by changes in the specific propenyl side chain of the *M. josephi* pheromone [1], while the second group is characterized by a change in the structure of the diene side chain common to the three *Matsucoccus* pheromones. The results indicate that alterations in the propenyl side chain, characteristic of the *M. josephi* pheromone, adversely affect the pheromonal activity, whereas changes in the diene side chain adversely affect the kairomonal activity. Analogue [5] is unique among all the analogues, being devoid of any activity, probably due to the introduction of a methyl group α to the ketone. Preparation and testing of more analogues is necessary in order to generalize on this very interesting observation.

## ACKNOWLEDGEMENTS

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HEIDARI, M.
*Environment Department, Wye College, University of London, Wye, Ashford, Kent TN25 5AH, U.K.*

# INFLUENCE OF HOST-PLANT PHYSICAL DEFENCES ON THE SEARCHING BEHAVIOUR AND EFFICACY OF TWO COCCINELLID PREDATORS OF THE OBSCURE MEALYBUG, *PSEUDOCOCCUS VIBURNI* (SIGNORET).

## ABSTRACT

Influence of host-plant physical defences on the searching behaviour and efficacy of two coccinellid predators of the obscure mealybug, *Pseudococcus viburni* (Signoret).

Laboratory and glasshouse trials were conducted to investigate the influence of host-plant physical structure on the predation of the obscure mealybug, *Pseudococcus viburni* (Signoret) (Coccoidea: Pseudococcidae) by two coccinellid predators: *Cryptolaemus montrouzieri* (Mulsant) and *Nephus reunioni* Fürsch. Glasshouse trials showed that good control was achieved by *C. montrouzieri* irrespective of the hairiness of the plant species, but that *N. reunioni* was more effective on smooth leaves, such as those of *Citrus*, coffee and *Passiflora,* than on hairy plants, such as *Streptocarpus* and tomato, on which the density of the trichomes and their sticky exudations significantly reduced the walking speed and other searching parameters. It is concluded that the size of the predator and the type of trichomes have a marked influence on the level of mealybug control and that this could influence the choice of predators.

Key words: tomato crop, *Citrus limon*, *Coffea arabica*, *Lycopersicon esculentum*, *Passiflora caerulea*, *Solanum tuberosum*, *Streptocarpus* sp., damage, searching behaviour.

## INTRODUCTION

The obscure mealybug, *Pseudococcus viburni* (Signoret), is widespread in tropical and subtropical regions and is a serious pest of protected cultivation. It is an occasional pest of tea, citrus, fruit trees, grapevines and many other ornamentals, including glasshouse crops. It causes severe damage to the leaves, stems, fruits and roots of the attacked plants (Miller & Kosztarab, 1979; Heidari, 1986; Heidari & Copland 1993).

In Europe, *P. viburni* is one of the most important pests under glass where it has recently been recorded on tomato crops (Copland *et al.*, 1992). According to Williams (1985), Australia is the probable native home of *P. viburni* and the search for the natural enemies in Australia may prove useful, as biological control is now important under glass, provided that ants are absent (Heidari, 1986; Kosztarab, 1996). At present, only the encyrtids *Anagyrus agraensis* Saraswat and *Pseudaphycus maculipennis* Mercet are considered possible parasitoids against *P. viburni*, although there have been contradictory reports as to their effectiveness.

However, the two coccinellid predators: *Cryptolaemus montrouzieri* (Mulsant) and *Nephus reunioni* Fürsch have shown some promise (Panis, 1979; Heidari, 1986; Clausen, 1987; Heidari & Copland, 1993).

Among several factors affecting the efficiency of biocontrol agents of insect pests, host-plant physical defences have been found to play an important role in the degree of control achieved. This study examined the effect of leaf hairiness on the effectiveness and searching behaviour of the two coccinellid predators, *C. montrouzieri* and *N. reunioni*. It also evaluated the ability of these predators to locate and destroy mealybug colonies on mixed plantings, as might exist in the field or under glass.

## MATERIALS AND METHODS

### SEARCHING BEHAVIOUR:

Six host plants (*Citrus limon*, *Coffea arabica*, *Lycopersicon esculentum*, *Passiflora caerulea*, *Solanum tuberosum* and *Streptocarpus* sp.) were chosen with a range of different physical morphology and secondary chemical attributes. To study the effect of different host plants, the computer programme Micromeasure (Varley *et al.,* 1994) was used, and this provided direct measurements for the distances walked, speed of walking, number of turns and other searching parameters from a video source.

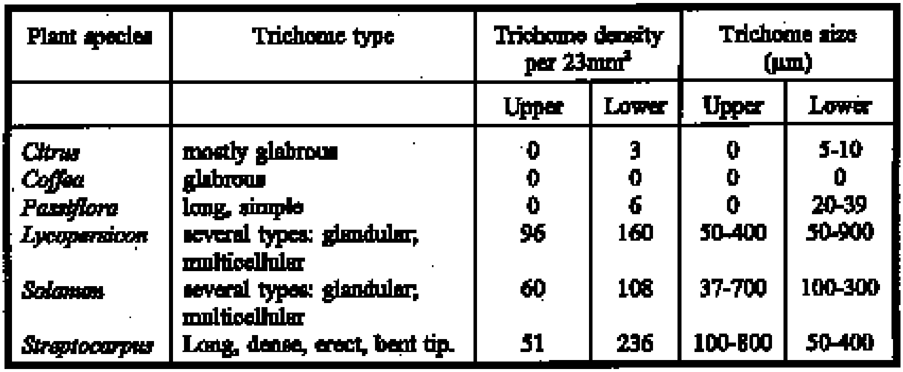
### POPULATION REGULATION:

Seven large cages, each containing one plant each of *C. limon*, *C. arabica*, *P. caerulea*, *S. tuberosum* and *Streptocarpus* sp., were set up in the glasshouse (temp. range 20-25°C; photoperiod 16L:8D). The plants in six of these cages were heavily infested with *P. viburni* while the seventh cage contained uninfested plants as a control. The mealybug population on each infested plant was carefully counted and aged (T1) and then the six infested cages were divided into three treatments, each having added either (i) no predator, (ii) adult *C. montrouzieri* or (iii) adult *N. reunioni*, the latter two species in proportion to the number and age of the mealybugs (this proportion was based on previous observations on the consumption of the two ladybirds, so that the ratios of beetles to mealybugs was approximately 1:5.2mg (*Cryptolaemus*) and 1:0.6mg (*Nephus*) (Heidari, 1989)). After six weeks, the mealybug populations were again counted (T2) on each plant. The change in the mealybug populations after six weeks was calculated as follows:

(1 - (T2P x T1C / T1P x T2C) x 100

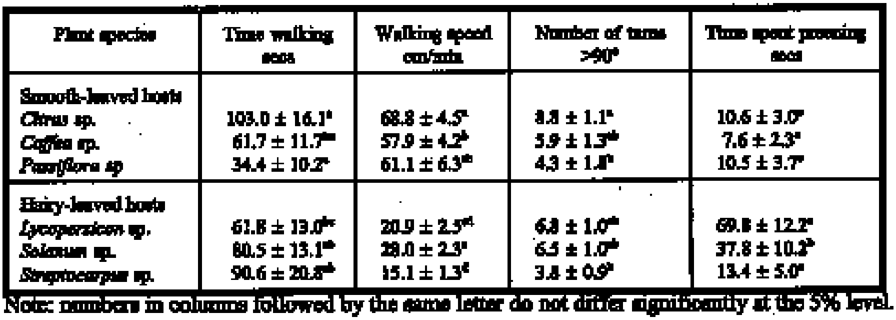
where T2P was the mealybug population after 6 weeks on the plants onto which one or other of the predator species had been released; T1C was the mealybug population on the untreated control prior to the release of predators at the start of the experiment; T1P was the mealybug population on the non-control plants prior to the release of the predators at the start of the experiment, and T2C was the mealybug population on untreated control at the end of six weeks.

Table 1. The density and size of trichomes on the six species of host plant used in these experiments.



| Plant species | Trichome type | Trichome density per 23mm$^2$ | | Trichome size (µm) | |
|---|---|---|---|---|---|
| | | Upper | Lower | Upper | Lower |
| *Citrus* | mostly glabrous | 0 | 3 | 0 | 5-10 |
| *Coffea* | glabrous | 0 | 0 | 0 | 0 |
| *Passiflora* | long, simple | 0 | 6 | 0 | 20-39 |
| *Lycopersicon* | several types: glandular, multicellular | 96 | 160 | 50-400 | 50-900 |
| *Solanum* | several types: glandular, multicellular | 60 | 108 | 37-700 | 100-300 |
| *Streptocarpus* | Long, dense, erect, bent tip. | 51 | 236 | 100-800 | 50-400 |

Table 2. Comparison of four searching behaviour parameters (means ± s.d.) of adult *Nephus reunioni* on six plant species during an observation period of 300 secs.



| Plant species | Time walking secs | Walking speed cm/min | Number of turns >90° | Time spent probing secs |
|---|---|---|---|---|
| **Smooth-leaved hosts** | | | | |
| *Citrus* sp. | $103.0 \pm 16.1^{a}$ | $68.8 \pm 4.5^{a}$ | $8.8 \pm 1.1^{a}$ | $10.6 \pm 3.0^{c}$ |
| *Coffea* sp. | $61.7 \pm 11.7^{bc}$ | $57.9 \pm 4.2^{b}$ | $5.9 \pm 1.3^{ab}$ | $7.6 \pm 2.3^{c}$ |
| *Passiflora* sp | $34.4 \pm 10.2^{c}$ | $61.1 \pm 6.3^{ab}$ | $4.3 \pm 1.8^{c}$ | $10.5 \pm 3.7^{c}$ |
| **Hairy-leaved hosts** | | | | |
| *Lycopersicon* sp. | $61.8 \pm 13.0^{bc}$ | $20.9 \pm 2.5^{cd}$ | $6.8 \pm 1.0^{ab}$ | $69.8 \pm 12.2^{a}$ |
| *Solanum* sp. | $80.5 \pm 13.1^{ab}$ | $28.0 \pm 2.3^{c}$ | $6.5 \pm 1.0^{ab}$ | $37.8 \pm 10.2^{b}$ |
| *Streptocarpus* sp. | $90.6 \pm 20.8^{ab}$ | $15.1 \pm 1.3^{d}$ | $3.8 \pm 0.9^{c}$ | $13.4 \pm 5.0^{c}$ |

Note: numbers in columns followed by the same letter do not differ significantly at the 5% level.

PLANT HEALTH EVALUATION:

The health status of each plant was accessed and scored at the end of the experiment using a scoring system ranging from 0-10, based on the cosmetic appearance of the host plants, where zero referred to completely dead plants and 10 to completely healthy plants, similar to the non-infested treatments.

## RESULTS

The size and density of the trichomes on the leaves of the six species used in the first experiment are shown in Table 1. The time allocated by each coccinellid to each searching activity varied greatly with leaf topography and surface quality. *N. reunioni* showed good searching activity (Table 2) on the smooth and less sticky leaves of *Citrus* and *Passiflora*, whereas its speed was greatly reduced and the amount of time spent preening was much greater on the leaves of tomato and potato which have glandular trichomes.

The proportion of mealybugs destroyed by the two coccinellids is shown in Table 3. It is clear that the searching behaviour of *C. montrouzieri* was unaffected by the leaf surface but that of *N. reunioni*, which, although it had been fairly effective on the smooth-leaved plants was still less effective than the larger *Cryptolaemus*. This is also clearly shown by the plant health assessment data, which are presented in Table 4. The mean score for the mealybug infested with *Nephus* was similar to that in the absence of any predators, whereas there was very little damage to the plants protected by *Cryptolaemus*

## DISCUSSION AND CONCLUSION

The results strongly suggest that the hairiness of the leaves of the host-plants played an important role in the ability of the two coccinellid species to control *P. viburni*. The density and type of trichomes clearly affected the searching ability of *N. reunioni*, which is much smaller than *Cryptolaemus*. It appears, therefore, that *Cryptolaemus* is able to search and control this mealybug on most hosts plants whereas *Nephus* was relatively ineffective even on the smooth-leaved hosts if introduced when there was a heavy mealybug population already present. It is concluded that, of these two coccinellids, *C. montrouzieri* would be the more reliable biocontrol agent against mealybug species, particularly in mixed plantings. However, for classical biocontrol, *C. montrouzieri* may be less suitable because, with the disappearance of the prey, it could die out and resurgence of the pest might then require several seasonal releases; for inundative releases, though, it could be an ideal predator. On the other hand, *N. reunioni* might be efficient at lower population levels and could be introduced as a secondary and complementary predator for many mealybug species.

Table 3. Percentage of mealybug population destroyed by *C. montrouzieri* and *N. reunioni* compared with unpredated control populations (all five plants in same cage replicated twice).

| Host plant species | *C. montrouzieri* | *Nephus reunioni* |
|---|---|---|
| **Smooth-leaved hosts** | | |
| *Citrus limon* | $100.0^{a}$ | $97.9^{a}$ |
| *Coffea arabica* | $100.0^{a}$ | $78.1^{ab}$ |
| *Passiflora caerulea* | $100.0^{a}$ | $63.4^{b}$ |
| **Hairy-leaved hosts** | | |
| *Solanum tuberosum* | $100.0^{a}$ | $41.1^{bc}$ |
| *Streptocarpus sp.* | $99.9^{a}$ | $25.8^{c}$ |

Note: means in columns followed by the same letter do not differ significantly at the 5% level after arcsin transformation.

Table 4. Plant health (scored from 0 for dead plants to 10 for totally undamaged plants) after introduction of *C. montrouzieri* or *N. reunioni.*

| Plant host species | Infested control | *C. montrouzieri* | *Nephus reunioni* |
|---|---|---|---|
| **Smooth-leaved hosts** | | | |
| *Citrus limon* | 6.5 | 8.8 | 5.5 |
| *Coffea arabica* | 6.3 | 9.8 | 5.3 |
| *Passiflora caerulea* | 5.3 | 8.8 | 4.5 |
| **Hairy-leaved hosts** | | | |
| *Solanum tuberosum* | 2.8 | 8.5 | 1.8 |
| *Streptocarpus sp.* | 3.0 | 9.3 | 3.5 |
| Mean (lsd 0.1% = 2.26) | $4.3^{B}$ | $9.0^{A}$ | $4.1^{B}$ |

Note: means followed by the same letter do not differ significantly at the 5% level after arcsin transformation.

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JAPOSHVILI, G.O.
*Institute of Zoology, Chavchavadze av. 31, Vake - 380030, Tbilisi, Georgia*

# THE PARASITOID COMPLEX AND POPULATION DYNAMICS OF THE PLUM SCALE, *SPHAEROLECANIUM PRUNASTRI* FONSCOLOMBE, IN GEORGIA.

## ABSTRACT

THE PARASITOID COMPLEX AND POPULATION DYNAMICS OF THE PLUM SCALE, *SPHAEROLECANIUM PRUNASTRI* FONSCOLOMBE, IN GEORGIA.

The plum scale, *Sphaerolecanium prunastri* Fonscolomb, is found infesting stone fruits all over the Europe and in most of the countries of Asia and North America. Its population dynamics and parasitoid complex in Georgia are described and the latter compared with that in other countries in southern Europe. The present rates of parasitism are compared with those of an earlier survey and it is noted that there have been some changes, both in the composition and in effectiveness of the primary and secondary parasitoids. The main primary parasitoids are still *Microterys hortulanus* Erdös and *Discodes coccophagus* (Ratzburg) but, among the secondary parasitoids, *Cerapterocerus mirabilis* Westwood is now the most important species. It was found that the economic importance of *S. prunastri* had become reduced due to a reduction in the number of secondary parasitoids and an increase in numbers of primary parasitoids.

Key words: *Coccophagus lycimnia, C. proximus, C. differens, Metaphycus silvestri, Pachyneuron muscarum, Marietta picta, Tetrastichus sugonjaevi, Cheiloneurus claviger, Prunus domestica, P. spinosa, P. divaricata, P. cerifera*, Chalcidoidea.

## INTRODUCTION

The plum or globose scale, *Sphaerolecanium prunastri* Fonscolombe, is a common species in Palaearctic region and North America (Borchsenius, 1957; Kosztarab & Kozár, 1988), where it is a serious pest of plum (*Prunus domestica* L., *P. spinosa* L., *P. divaricata* Ldb.) and other predominantly stone fruits. The plum scale is heavily parasitized by a large number of species of Chalcidoidea (Hymenoptera), which play an important role in its regulation.

The aim of the present study was to investigate the parasitoid complex of *S. prunastri* and its' role in controlling this scale in Georgia, and to compare the results with similar data from some adjacent regions in southern Europe. The results are significant both ecologically and for the biocontrol of this pest. Plum scale and its parasitoids are relatively well studied in Georgia but long-term observations on its population dynamics and on its parasite complex are still needed.

## MATERIALS AND METHODS

The investigations were carried out in the period 1993-1997 on plum trees in the Botanic Garden, Tbilisi, and in the village of Ude in the southern mountains of Georgia. The phenology of the scale was studied by recording the average developmental stage of 200 insects on cherry plum (*Prunus cerasifera* Ehrh.) and scale densities were recorded as the mean number of scales per 10cm of branch. At the same time, the percentage parasitism and the species of parasites were counted (Goantsa *et al.*, 1974). The species of parasitoids were determined in consultation with Prof. V.A. Yasnosh.

## RESULTS AND CONCLUSION

The biology of plum scale and its complex of parasitoids are well known in Georgia due the investigations of Borchsenius (1957), Hadzibeyli (1983) and Yasnosh (1967, 1972). In Georgia, as in other countries, the plum scale has one generation per year, with the 2nd-instar nymphs overwintering. These moult to become adult between the middle and end of April; in Hungary, this moult occurs a little later, between the end of April and early May (Kosztarab & Kozár, 1988). After mating, which occurs about mid-May, the females lay up to 800 eggs each from early June onwards. These eggs hatch within a few minutes of oviposition and the young nymphs settle on branches. This process continues for more than a month. The development of the plum scale is similar in the Crimea and in Hungary except that development is slightly faster in Georgia.

Table 1 shows the population dynamics of the plum scale at the two sites during the period of observation. The mean number of *S. prunastri* increased at both sites in the second year (1995) but then decreased quite dramatically

Table 1. Population dynamics of the plum scale and effectiveness of parasitoids, 1994-1997.

| Survey site | Year | Mean no. scales/10cm of branch | Total percentage parasitism | Percentage nymphal parasitism | Percentage adult female parasitism |
|---|---|---|---|---|---|
| Tbilisi | 1994 | 38.8 | 32.4 | 1.0 | 31.4 |
| | 1995 | 60.7 | 55.0 | 6.4 | 48.6 |
| | 1996 | 33.5 | 90.0 | 17.0 | 73.0 |
| | 1997 | 12.7 | 91.4 | 11.7 | 79.7 |
| Ude | 1994 | 31.0 | 37.0 | 2.2 | 34.8 |
| | 1995 | 59.0 | 91.4 | 4.7 | 80.2 |
| | | | | | |

due to parasitoid activity. This increase in activity is clearly shown by the percentage parasitism each month during 1995: May: 36%, June 80% and July-August 55%. The percentage parasitism of the adult scales was more than 4x greater than that of the nymphs.

Table 2 shows the parasitoid species which have been recorded attacking *S. prunastri* in Georgia and three other southern European countries. The greatest number of species (11) has been recorded in Moldova, while 7 are known in Georgia. The main species in all three regions are the primary parasitoids *Microterys hortulanus* Erdös, *Coccophagus lycimnia* Walker and *Discodes coccophagus* (Ratzeburg) and the secondary parasitoid *Ceropterocerus mirabilis* Westwood.

Table 2. Parasitoid complex of the plum scale in some southern European regions.

| Parasitoid species | Type | Russia, Krasnodar[1] | Ukraine, Crimea[2] | Moldova[3] | Georgia 1966[4] | Georgia 1968[5] | Georgia 1995[6] |
|---|---|---|---|---|---|---|---|
| *Microterys hortulanus* Erdös | 1ry | + | + | + | + | + | + |
| *Discodes coccophagus* (Ratzeburg) | 1ry | + | + | + | + | + | + |
| *Coccophagus lycimnia* Walker | 1ry | + | + | + | – | + | + |
| *C. proximus* Jasnosh | 1ry | – | – | + | – | – | – |
| *C. differens* Jasnosh | 1ry | – | – | + | – | – | – |
| *Metaphycus silvestri* Sugonjaev | 1ry? | + | + | + | – | + | – |
| *Cerapterocerus mirabilis* Westwood | 2ndry | + | + | + | + | + | + |
| *Pachyneuron muscarum* L. | 2ndry | + | + | + | + | + | – |
| *Marietta picta* André | 2ndry | – | – | + | – | + | + |
| *Tetrastichus sugonjaevi* Kostjukov | 2ndry | – | – | + | – | – | – |
| *Cheiloneurus claviger* Thomson | 2ndry | + | + | + | – | – | – |

Where 1ry = primary parasitoid, 2ndry = secondary parasitoid. References: [1]Dobrovskaya (1956); [2]Khersonskaya (1962) *in* Sugonyaev (1984); [3]Grant [4]Yasnosh (1968); [5]Japoshvili, (1995).

Table 3. Percentage parasitism of plum scale by specific parasitoids in Georgia in 1968 and 1995.

| Parasitoid species | % parasitism 1968 | 1995 |
|---|---|---|
| *M. hortulanus* | 7.2-8.1 | 36.9 |
| *D. coccophagus* | 47.5-69.1 | 40.0 |
| *C. lycimnia* | 4.0 | 10.5 |
| *M. silvestri* | 37.1 | 0 |
| *C. mirabilis* | 8.3 | 11.6 |
| *P. muscarum* | 36.1-77.5 | 0 |
| *M. picta* | 0.4-1.04 | 1.1 |

Tables 2 & 3 also show how the percentage parasitism by the seven species known from Georgia has changed between 1968 and 1995. It would appear that it is the fourfold increase in *M. hortulanus* that has produced the significant decrease in the size of *S. prunastri* populations in the last few years.

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KARACA, I.[1]; SENAL, D.[1]; COLKESEN, T.[2]; ÖZGÖKÇE, M.S.[3]
[1]*Department of Plant Protection, University of Cukurova, 01330 Adana, Turkey*
[2]*Department of Plant Protection, University of Sutcu Imam, K. Maras, Turkey*
[3]*Department of Plant Protection, University of Yuzuncuyil, Van, Turkey.*

# OBSERVATIONS ON THE OLEANDER SCALE, *ASPIDIOTUS NERII* BOUCHÉ (HEMIPTERA: DIASPIDIDAE) AND ITS NATURAL ENEMIES ON BLUELEAF WATTLE IN ADANA PROVINCE, TURKEY.

## ABSTRACT

OBSERVATIONS ON THE OLEANDER SCALE, *ASPIDIOTUS NERII* BOUCHÉ (HEMIPTERA: DIASPIDIDAE) AND ITS NATURAL ENEMIES ON BLUELEAF WATTLE IN ADANA PROVINCE, TURKEY.

The biology of *Aspidiotus nerii* Bouché and the overall efficiency of its natural enemies (the aphelinid parasitoid *Aphytus melinus* DeBach and the coccinellid predators *Chilocorus bipustulatus* (L.) and *Rhyzobius lophantae* (Blaisdell)) were studied. Forty leaves were collected at weekly intervals from 5 blueleaf wattle trees (*Acacia saligna*) from four compass bearings; all live and dead *A. nerii* and the number and stage of all parasitised scales were counted. There were two population peaks of *A. nerii* per year, in May/June and July/August. The number of parasitoids, however, fluctuated considerably, especially during the autumn and winter. The scale stage parasitised was primarily the adult female, followed by the pupae and then a few 2nd-instar nymphs. First-instar nymphs were never attacked by parasitoids but predators fed on all stages.

Key words: *Acacia cyanophylla*, damage, aspect, population density, mortality, shelter, wind breaks.

## INTRODUCTION

Blueleaf wattle (*Acacia saligna* (Labill.) - generally referred to as *A. cyanophylla* Lindley in the Mediterranean region) is used as an ornamental tree in parks and gardens and also for stabilising sand dunes. In addition, it is used as a wind-break around citrus orchards. *A. saliga* is an Australian tree widely grown in the Mediterranean, which can tolerate drought and high temperatures and can be grown on highly calcareous soils.

One of the most important pests of blueleaf wattle is *Aspidiotus nerii* Bouché (Hemiptera: Diaspididae) which can cause leaf-fall and dieback when present in large populations. When used as a wind-break around citrus orchards, the presence of *A. nerii* might be considered to be beneficial because the scale does not attack the citrus but it can act as a source of predators and parasitoids. Thus, the coccinellids *Chilocorus bipustulatus* (L.) and *Rhyzobius lophantae* (Blaisdell) and the aphelinid *Aphytus melinus*

DeBach are important biocontrol agents both on *A. nerii* and on the diaspidid scales in the citrus orchards (*Aonidiella aurantii* (Maskell), *Chrysomphalus dictyospermi* (Morgan) and *Lepidosaphes beckii* Newman, among others (Uygun *et al.*, 1995)).

In this study, the population dynamics of *A. nerii* and its natural enemies was investigated.

## MATERIALS AND METHODS

The populations of *A. nerii* on five randomly selected, unsprayed, heavily infested, blueleaf wattle trees were studied between March 1966 and February 1997, on the campus of Cukurova University, Adana, Turkey. Ten leaves were taken from the north, east, south and west side of each tree, giving 40 leaves per tree and 200 leaves per sampling date. The leaves were then taken back to the laboratory in an ice-chest and all dead and live *A. nerii* were counted along with the number and stage of the parasitised scales; damaged scale covers were considered to be due to the feeding activity of predators. Parasitised scales were identified by the emergence holes in the scale covers. In addition, all the rest of the scales were checked for the eggs, larvae or pupae of *A. melinus*. Percentage parasitisation was then calculated using the following formula:

$$\%\ \text{parasitised} = \frac{\text{No. of parasitised scales}}{\text{(No. live scales + no. parasitised scales + no. scales showing damage by predators) x 100}}$$

The efficiency of predators was indicated by the feeding damage to the scale covers, although it was not possible to separate the damage done to the scale covers by the two main predators (*C. bipustulatus* and *R. lophantae*). The mortality due to the predators was therefore calculated using the following formula:

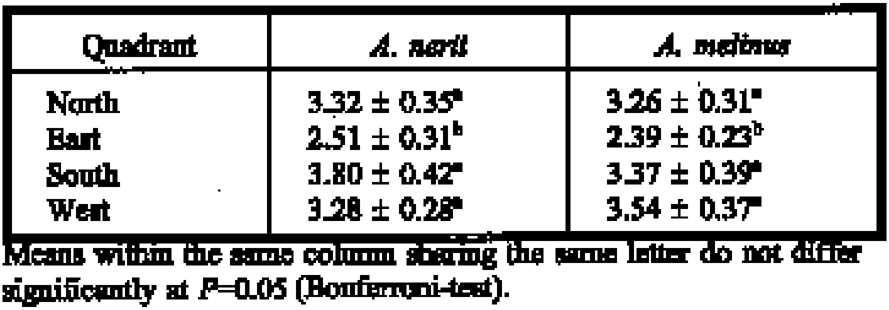
$$\%\ \text{mortality due to predators} = \frac{\text{No. scale covers showing damage by predators}}{\text{(No. live scales + no. parasitised scales + no. scales showing damage by predators) x 100}}$$

## RESULTS AND DISCUSSION

### AFFECTS OF ASPECT ON THE DENSITY OF *A. NERII* AND *A. MELINUS*:

The mean number of *A. nerii* collected per leaf during the year from the four compass points are shown in Table 1 and this indicates that there was no significant difference in the populations on the north, south and west sides of the trees, but that there was a small but significant reduction on the east side. Similarly, the number of parasitised individuals was also lower on the east side (Table 1).

Table 1. Population density of live *Aspidiotus nerii* and *Aphytis melinus* on blueleaf wattle trees (overall mean/leaf/year).



| Quadrant | *A. nerii* | *A. melinus* |
|---|---|---|
| North | 3.32 ± 0.35$^{a}$ | 3.26 ± 0.31$^{a}$ |
| East | 2.51 ± 0.31$^{b}$ | 2.39 ± 0.23$^{b}$ |
| South | 3.80 ± 0.42$^{a}$ | 3.37 ± 0.39$^{a}$ |
| West | 3.28 ± 0.28$^{a}$ | 3.54 ± 0.37$^{a}$ |

Means within the same column sharing the same letter do not differ significantly at $P$=0.05 (Bonferroni-test).

### POPULATION DENSITY OF *A. NERII*:

The changes in population density (as no. per leaf) of *A. nerii* are shown in Figs 1 & 2. The population started to increase in May as the temperature increased to over 20°C. There were two peaks during the year, suggesting that *A. nerii* had two generations, one in May-June and the other in July-August. Papacek & Smith (1981), in a laboratory study, also found that *A. nerii* took two months to complete a generation. During the autumn and winter, the population was very low, never more than two individuals per leaf. The composition of the population throughout the year is shown in Fig. 2 and it is clear that it is the immature stages which are most abundant.

### PARASITISATION BY *A. MELINUS*:

The percentage parasitisation by *Aphytis melinus* per leaf is shown in Fig. 3. The population was rather low during the spring and summer but rose again during the autumn and continued with a varying population throughout the winter. The reason for this low population of *A. melinus*, especially in the

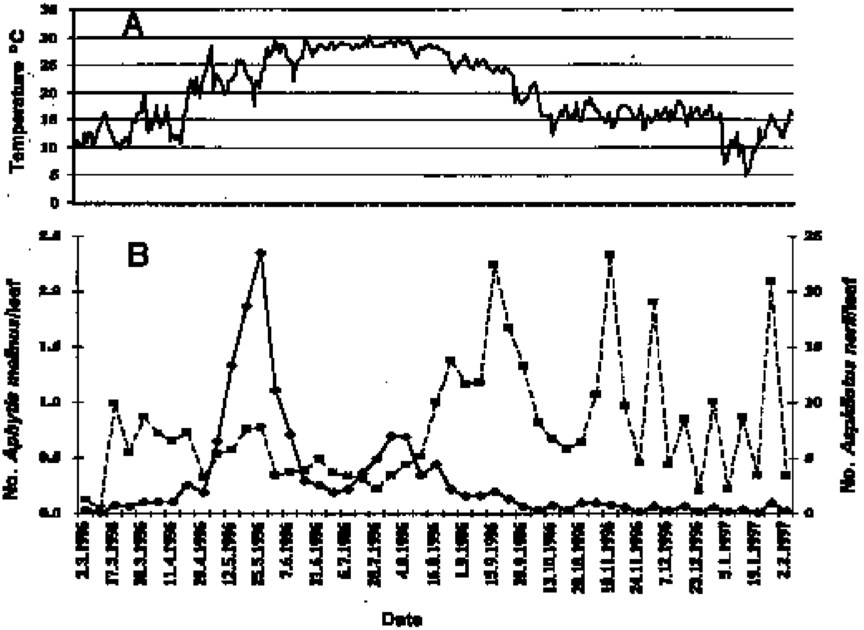


Fig. 1. A. Temperature (°C) and B. Mean number of live *Aspidiotus nerii* (—♦—) and *Aphytus melinus* (- ■ -) per leaf for the period March 1996 to February 1997 at Adana, Turkey.

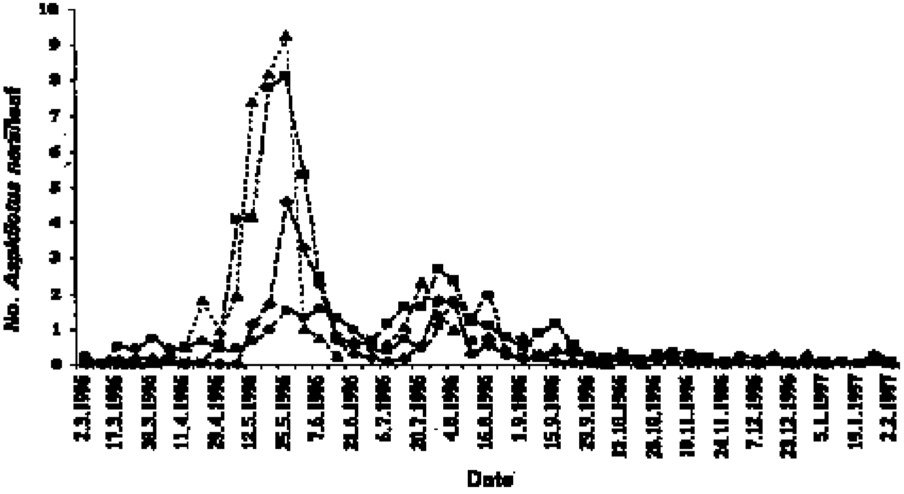


Fig. 2. Mean number of live 1st- (▲) and 2nd-instar (■) nymphs, pupae (♦) and adult females (•) of *Aspidiotus nerii* per leaf on each sampling occasion.

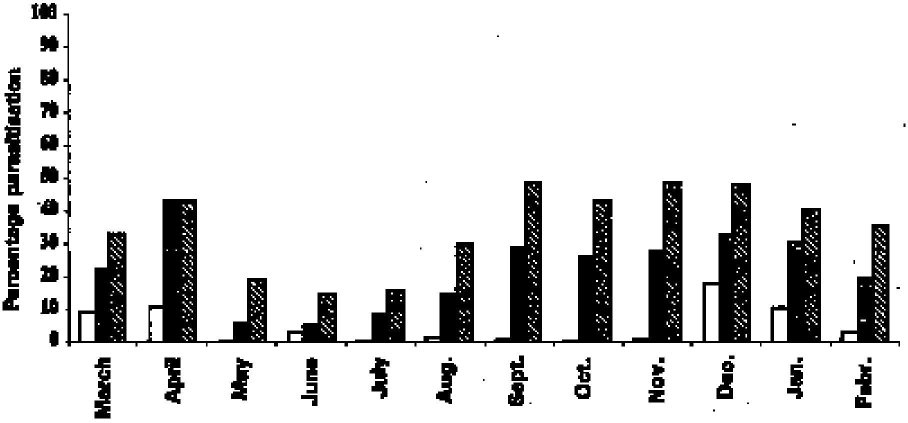


Fig. 3. Percentage parasitisation by *Aphytus melinus* of 2nd-instar nymphs (white bars), pupae (horizontally hatched bars) and adult females (diagonally hatched bars) of *Aspidiotus nerii* per month.

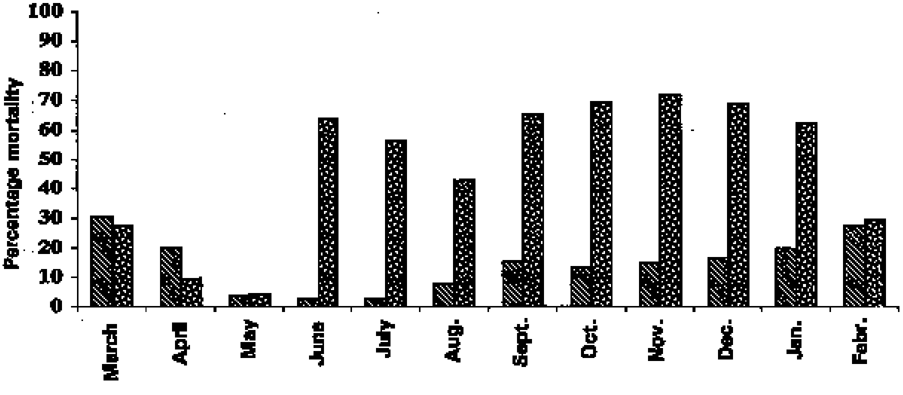


Fig. 4. Percentage mortality of *Aspidiotus nerii* each month caused by the parasitoid *Aphytus melinus* (diagonally hatched bars) and the predators *Chilocorus bipustulatus* and *Rhyzobius lophantae* (dotted bars).

spring, was probably due to the high proportion of 1st- and 2nd-instar nymphs, which is the non-preferred stage for *A. melinus* - only 8% of the 2nd-instar nymphs were parasitised, whereas 35% of the pupae and 57% of the adult females were parasitised. This size preference by *A. melinus* has been noted previously by Luck & Podoler (1985), Opp & Luck (1986) and Karaca (1998).

### PERCENTAGE MORTALITY DUE TO PREDATION:

The population density of predators during the year was reasonably high and the % mortality varied between 5 and 70% (Fig. 4) and appeared to be particularly important from June through to January. Fig. 4 suggests that the mortality due to the combined predation of the two predators was much more important than that caused by the parasitoid, probably because the predators feed on all stages without discrimination.

The results suggest that the natural enemies of *A. nerii* should be able to maintain the scale at a relatively low level. Thus, the use of blueleaf wattle as a wind-break could provide both shelter for the orchard and a useful supply of natural enemies for the diaspidid scales on the citrus.

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MOHAMMAD, Z.K.; GHABBOUR, M.W.; TAWFIK, M.H.
*Plant Protection Research Institute, Agricultural Research Center, Dokki-Giza, Egypt.*

# POPULATION DYNAMICS OF *AONIDIELLA ORIENTALIS* (NEWSTEAD) (COCCOIDEA: DIASPIDIDAE) AND ITS PARASITOID *HABROLEPIS ASPIDIOTI* COMPERE & ANNECKE (HYMENOPTERA: ENCYRTIDAE).

## ABSTRACT

Population dynamics of *Aonidiella orientalis* (Newstead) (Coccoidea: Diaspididae) and its parasitoid *Habrolepis aspidioti* Compere & Annecke (Hymenoptera: Encyrtidae).

An experiment was carried out at Giza governorate, Egypt, between Aug. 1995 and Aug. 1997 to study the fluctuation and seasonal abundance of *Aonidiella orientalis* and its parasitoid *Habrolepis aspidioti* on *Ficus nitida* trees. A brief description of the parasitoid is given. The populations of *A. orientalis* in both years showed three distinct peaks during the summer, whilst the parasitoid probably had four. The effect of such climatic factors as temperature, relative humidity, photoperiod, dew point and wind velocity were also studied and the size of the populations of both the scale and the parasitoid appeared to be correlated with many of them.

Key words: biocontrol, citrus, meteorological conditions, ecology, oriental scale, host range, *Chrysomphalus aonidum*, *Aonidiella aurantii*, *Habrolepis rouxi.*

## INTRODUCTION

The Diaspididae are an important component of the homopterous fauna on many plants. The oriental scale, *Aonidiella orientalis* (Newstead) was first recorded in Israel in 1980 (Ofek *et al.*, 1997) and its ecology and biology has been studied by several researchers: Badawi & Al-Ahmed (1990 - in Saudi Arabia), Dutta & Baghel (1991 - in India), Khalaf & Sokhansanj (1993 - in Iran) and Elder & Smith (1995 - in Australia). *A. orientalis* was first recorded in Egypt by Ghabbour (1988) and, as it is potentially an important pest, a study was undertaken.

*A. orientalis* has a wide host range and has been found on olive, guava, feijoa, litchi, acacia and avocado in Israel (Ofek *et al.*, 1997), sporadically on mangoes in South Africa (Daneal *et al.*, 1994) and on sapota in India (Mani & Krishnamoorthy, 1996). The parasitoid identified as attacking *A. orientalis* in Israel was the encyrtid *Habrolepis aspidioti* Annecke (Ofek *et al.*, 1997) and this species was also found in Egypt.

The present work was designed to: i. identify the diagnostic characters for *H. aspidioti* for rapid identification; ii. study the occurrence of *A. orientalis* in relation to this parasitoid and iii. study the relationship between the population densities of *A. orientalis* and *H. aspidioti* and the following meteorological factors: temperature, relative humidity, photoperiod, dew point and wind velocity.

## MATERIALS AND METHODS

Ecological studies on *A. orientalis* and its parasitoid *H. aspidioti* were carried out at Dokki, Giza governorate, on *Ficus nitida* in the absence of chemical control. Four trees of *F. nitida* of similar size, height and leaf density were selected. The trees were about 10 years old and 7m high. Studies were carried out during two successive seasons, from the second half of August 1995 to the beginning of August 1997. Samples of 15 leaves were picked at random from the four sides of each tree (total 60 leaves from each of the four trees) at 15 day intervals. Each sample was kept separately in a polythene bag and examined in the laboratory. The total number of live scales in each sample was taken as the population index. The parasitoid was recorded as the number of parasite pupae present.

Records of the following meteorological factors were obtained from the nearest meteorological station about 1km distant: temperature, relative humidity, photoperiod, dew point and wind velocity. The daily records of these factors were then grouped into half-monthly averages to correspond with those for the insect samples. To investigate the effect of these climatic factors, simple correlation tests were applied.

## RESULTS AND DISCUSSION

*Habrolepis aspidioti* Compere & Annecke is an African species originally described from Ethiopia and North Africa under the name *Habrolepis famari*, but today known to be widely distributed (Annecke & Mynhardt, 1970).

**Adult female:** about 1mm long, body somewhat flattened. Retaining its natural shape in dry specimens; largely black. Dorsum of thorax with a strong metallic blue-green lustre. Antennae largely blackish, except for distal two funicle segments. Legs blackish, except for distal half of tibia and tarsus, base of femur of foreleg, tibia and tarsus of middle leg and tarsus of hind leg, which are yellowish. Wing distinctly marked as illustrated (Compere, 1961).

**Biology:** an internal, solitary, primary parasitoid of a number of armoured scale insects, including circular purple scale (*Chrysomphalus aonidum* (L.)) and red scale (*Aonidiella aurantii*).

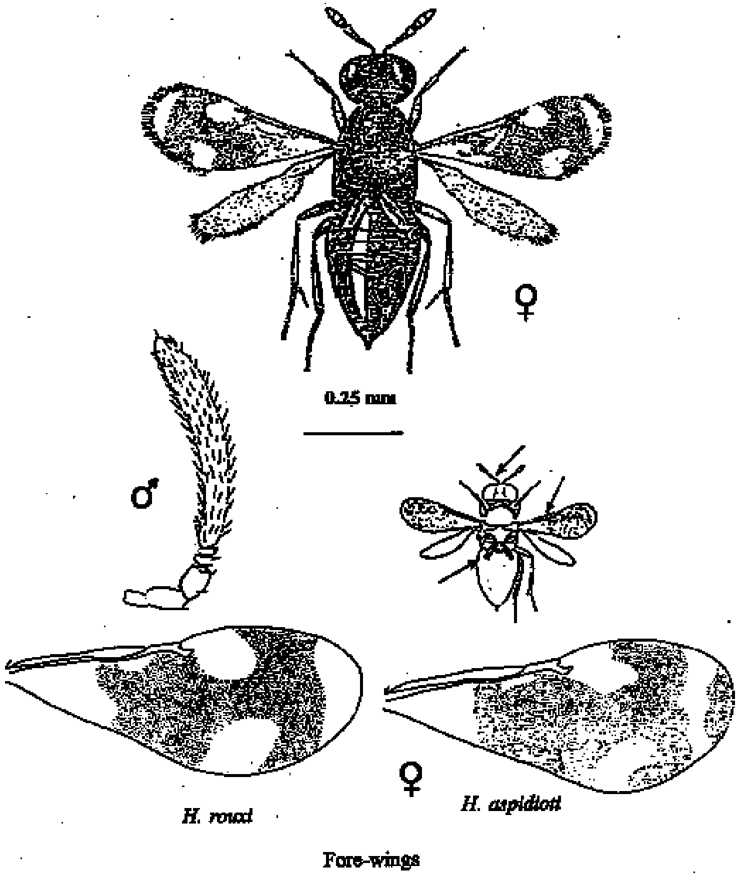


Fig. 1. Characters of adult males and females of *Habrolepis rouxi* and *H. aspidioti.*

**Distribution:** widespread in Africa and Israel; introduced into North America.

*Habrolepis rouxi* Compere is a closely related species which coexists with *H. aspidioti* on circular purple scale in South Africa. The adult females of these two species can be separated by the pattern of the fore-wings as indicated in Fig. 1 and the key (Compere, 1961).

Key for identification of adult female *Habrolepis aspidioti* and *H. rouxi*:

-Apex of fore-wing distinctly marked with a black area *Habrolepis aspidioti*
-Apex of fore-wing without a black area and hyaline..........*Habrolepis rouxi*

### OCCURRENCE OF *A. ORIENTALIS* AND *H. ASPIDIOTI* IN EGYPT:

The abundance of *A. orientalis* between the 2nd half of Aug. 1995 to the beginning of Aug. 1997 is shown in Fig. 2. In both years, there was a distinct trough during the winter, with the populations dropping to around 5000/240 leaves between Oct. and March, followed by three distinct peaks of 30,000 or more during the summer, one in April/May, another in July/Aug. and the last in Sept. These data suggest that *A. orientalis* has three distinct generations during the summer in Egypt, going into some sort of diapause during the winter. This does not agree with the observations of Badawi & Al-Ahmed (1990), who recorded four distinct peaks for *A. orientalis* on *Ficus nitida* in Saudi Arabia.

With regard to the frequency of *H. aspidioti*, the population fluctuations are less clear, although the patterns are more or less similar in the two years. In both years, the greatest populations (of more than 500/240 leaves) were in April/May, July/Aug. and in Sept., coinciding with the three *A. orientalis* peaks. However, there is also a strong suggestion in both years of a smaller, fourth peak in November, rising to about 400-500/240 leaves from a low of about 150/240 leaves; this peak was rather less distinct in 1995 than in 1996. In 1996, there is also a suggestion of a further peak in late March, but this was not evident in the following year.

### SCALE AND PARASITOID FREQUENCY IN RELATION TO METEOROLOGICAL CONDITIONS:

The correlations found between the populations of *A. orientalis* and *H. aspidioti* and certain meteorological conditions are shown in Table 1. Both insects had positive correlations with all the measured weather parameters except relative humidity, where they were negative. The degree of significance of the correlations was also relatively similar for both the scale and the parasitoids. In addition, there were highly significant positive correlation between size of *A. orientalis* populations and those of *H. aspidioti* ($r = 0.740^{**}$ in the first year; $r = 0.767^{**}$ in the second year).

The slightly lower “r” values for the parasitoid compared with the scale insects suggests that these correlations may be affected by its endoparasitic behaviour and that it is less affected by weather whilst a larva within the scale.

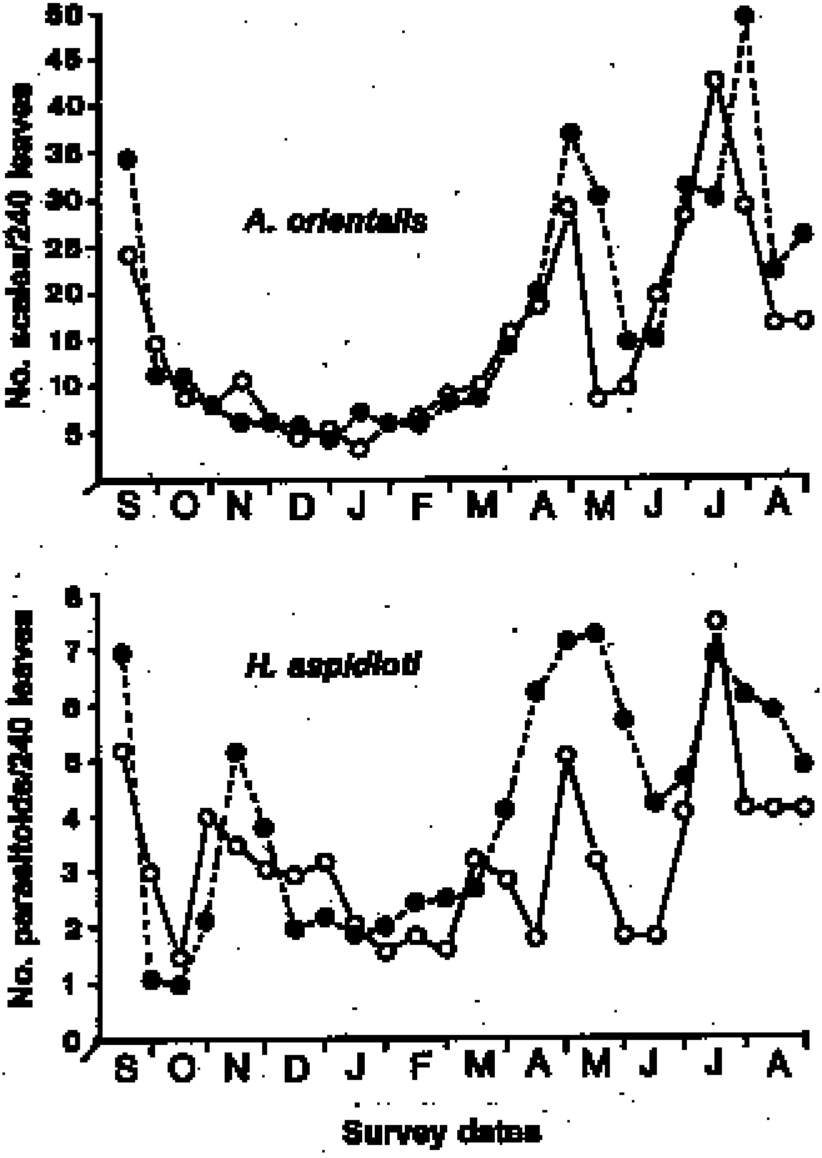
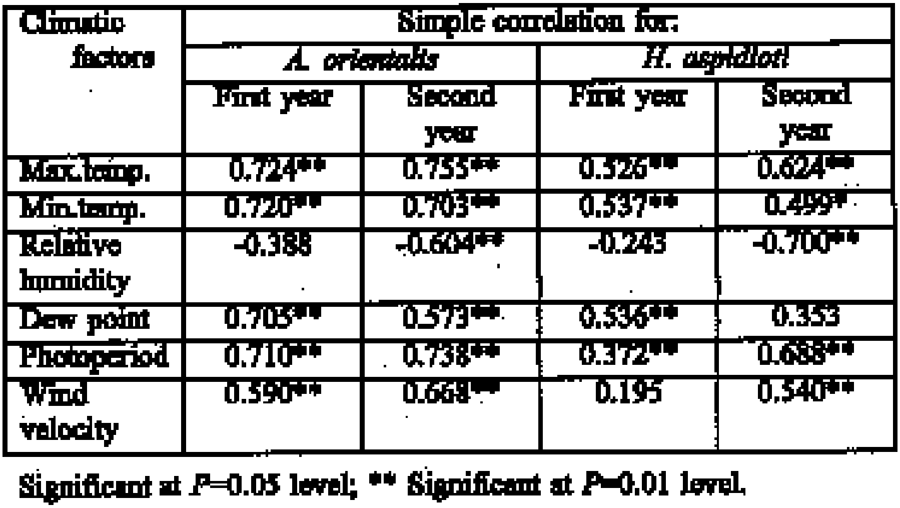


Fig. 2. Population densities of *A. orientalis* (in '000) and *H. aspidioti* (in '00) at fortnightly intervals between Aug. 1965 and Aug. 1997. Where -O- = data points for first 12 months and -•- = data points for second 12 months.

Table 1: simple correlations between the total number of *A. orientalis* and *H. aspidioti* on 240 leaves per tree collected at 15 day intervals between Aug. 1995 and Aug. 1997 and certain meteorological conditions during the same period.
* Significant at *P*=0.05 level; ** Significant at *P*=0.01 level.



| Climatic factors | Simple correlation for: | | | |
|---|---|---|---|---|
| | *A. orientalis* | | *H. aspidioti* | |
| | First year | Second year | First year | Second year |
| Max.temp. | 0.724** | 0.755** | 0.326** | 0.624** |
| Min.temp. | 0.720** | 0.703** | 0.537** | 0.499* |
| Relative humidity | -0.388 | -0.604** | -0.243 | -0.700** |
| Dew point | 0.705** | 0.573** | 0.536** | 0.353 |
| Photoperiod | 0.710** | 0.738** | 0.372** | 0.688** |
| Wind velocity | 0.590** | 0.668** | 0.195 | 0.540** |

Significant at *P*=0.05 level; ** Significant at *P*=0.01 level.

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PANIS, A.[1]; PINET, C.
*INRA, Laboratoire de Biologie des Invertébrés, Antibes, France*
*[1]14 Avenue Schubert, 83440 Montauroux, France*

# A DISCUSSION OF SOME ECOLOGICAL FACTORS AFFECTING *COCCIDENCYRTUS MALLOI* BLANCHARD (HYMENOPTERA: ENCYRTIDAE) AS A PARASITOID OF DIASPIDID SCALES UNDER GLASS IN FRANCE.

## ABSTRACT

A discussion of some ecological factors affecting *Coccidencyrtus malloi* Blanchard (Hymenoptera, Encyrtidae) as a parasitoid of diaspidid scales under glass in France.

The encyrtid parasitoid *Coccidencyrtus malloi* Blanchard has been recorded in orchid glasshouses of south-eastern France where its diaspidid host, *Diaspis boisduvalii* Signoret (Hemiptera, Diaspididae), is sometimes a pest of ornamentals. In order to study its biology and potential as a biological control agent, it was cultured on a bromeliad and released into several hot temperate commercial houses. It was found to have a very restricted distribution which appeared to be determined by deep shade and very high humidities.

Key words: Argentina, Boisduval scale, parasitoid development, thelytokous parthenogenesis, *Diaspis bromeliae*, *D, coccois*, *Laeliocattleya*, *Vriesea*, *Aechmea*, *Cattleya*, *Citrullus*, *Cymbidium*, *Coccos*, *Dendrobium*, *Neodypsis*, *Hohenbergia.*

## INTRODUCTION

*Coccidencyrtus malloi* Blanchard (Hymenoptera: Encyrtidae) had only been reported as a parasitoid of the Boisduval scale, *Diaspis boisduvalii* Signoret (Coccoidea: Diaspididae), on an undetermined orchid in Argentina (Buenos Aires Province) (De Santis, 1964). In 1970, it was found for the first time in south-eastern France (Alpes-Maritimes department) on orchids in a glasshouse. According to Noyes (1980), the species *malloi* should be correctly placed in *Coccidencyrtus.* In Argentina, both sexes are known but males appear to be completely lacking in France and so the parasitoid reproduces by thelytokous parthenogenesis. This paper considers some ecological factors affecting its distribution in glasshouses in France.

## MATERIALS AND METHODS

Three species of *Diaspis* (*D. boisduvalii*, *D bromeliae* (Kerner) and *D. coccois* (Lichtenstein)) were found to be parasitised by *C. malloi.* Adult female *D. boisduvalii* and *D. bromeliae* were separated using the illustrations in Williams & Watson (1988). *D. coccois* was validated by Miller (1996), who listed it separately from the Boisduval scale as a new record on coconut palms in Mexico.

In 1970, *Coccidencyrtus malloi* was bred from the Boisduval scale on a fairly shaded *x Laeliocattleya* plant which had recently been imported from Brazil within a hot and humid temperate glasshouse whose sides were below ground level (Glasshouse 1). From this initial collection, the parasitoid was maintained in a culture (Culture 1) of the Boisduval scale raised on uncaged and potted *Vriesea splendens* (Brongn.) (Bromeliaceae) at 15-18°C and 60-80% RH, in a small, north-facing, greenhouse against a high wall which provided shade in the afternoons for about 6 months of the year. Under these same conditions, it failed to parasitise the Boisduval scale on another bromeliad, *Aechmea fasciata* (Lindl.) which has upright leaf blades. *C. malloi* from Culture 1 was then released into two commercial orchid houses, one of which was used to grow *Cattleya x* (Glasshouse 2) and the other *Cymbidium x* (Glasshouse 3), where it successfully parasitised *D. boisduvalii.*

The second glasshouse (Glasshouse 2), which was used to grow 10 year old potted-*Cattleya x* plants, was 75m$^2$ and was maintained at 18°C constant temperature and 60-70% RH (except when pots were outdoors in summer) and periodically shaded between November and early April for flowering requirements. Infestations of *D. boisduvalii* on the sheathing leaf bases which enclosed the flower stem and on the pseudobulbs resulted in flower spotting, indicative of economic loss for grower, even though the level of infestation had been scored as low to medium on many plants. After high pressure sprays of petroleum white-oil had failed to control the scale, 200 *C. malloi* were released during April and May 1971, when the RH was obviously less than normal and with little shade.

*C. malloi* was also released in another glasshouse (Glasshouse 3) with 7 year old potted *Cymbidium x* (Orchidaceae) plants. This glasshouse was 200m$^2$ and, between October and late April (during flowering), it was maintained at 15-18°C and 60-65% RH but from spring to early autumn, the temperatures were maintained at 14-15°C nightly and 20-26°C daily, with an RH of 50-65%. The glasshouse was shaded according to the sky conditions from February to April. Many of the plants had a light infestation of Boisduval scale towards the base of their pseudobulbs. In November 1971, about 200 *C. malloi* were released during a rather long cloudy and rainy period (more than 65% RH was measured from time-to-time indoors). The effectiveness of the parasitoid was estimated by roughly counting the number of live scales on the same infested plants before and after release.

In March 1991, a second "wild" population of *C. malloi* was discovered in a small orchid collector's glasshouse (Glasshouse 4) which backed onto a northern wall, fairly humid and hot temperate, and somewhat shaded during the morning and evening between mid-autumn and early spring. The parasitoid was probably introduced in parasitised *D. boisduvalii* on the flower stem of a *Cattleya* plant imported from Brazil; it was also found on the pseudobulb of a *Dendrobium sp.* imported from Thailand. The parasitoid was collected and maintained in culture on caged water-melon fruit, *Citrullus lanatus* (Thunb.), previously contaminated with Boisduval scale, in a rearing chamber at 25°C, 60-70% RH and artificial overhead lighting (L:D 16:8 h) (Culture 2). Parasitoids from this second culture were not subsequently used experimentally under glass.

In 1996-1997, yet more *C. malloi* of undetermined origin were found in a large, 2.3 hectare, wet-tropical house with a special plastic roof (Glasshouse 5). The tallest vegetation was about 6m tall, while the understorey provided a wide variety of conditions, some of which were permanently shaded throughout the day. Gradients of temperature (22-28°C) and RH (60-85%) were present depending on the situation and vegetational strata in the glasshouse. Control of the temperature and RH (misted water from above the top vegetation) was automatic, so that the temperature above the vegetation was 17°C at night and 20-25°C daily from October to late in March and 20°C at night and (at most) 25°C during the day from April to September. The RH above the canopy was controlled at 75-80% between February and October and at 70% between November and January. Three species of *Diaspis* were present: *D. boisduvalii* was widespread on various tropical plant-species, either scattered on both leaf surfaces or on the sheathing leaf bases which enclosed the stem; it also formed mixed infestations with *D. coccois* on two palms (*Coccos nucifera* L. and *Neodypsis decaryi* Baill.). In addition, *D. bromeliae* was present on both leaf surfaces of three bromeliads: *Hohenbergia stellata* Schult., *Vriesea hieroglyphica* (Carr.) and *V. spendens*, but only in very small groups.

## RESULTS AND DISCUSSION

The development of the *C. malloi* under the conditions of Culture 2 lasted 20-25 days, with the eggs being laid in the 2nd-instar nymphs and young adult females only. Parasitoid emergence was from young female scales prior to ovarian maturation. Adult parasitoids were mainly found beneath the water melons and were never found to lay their eggs in scales on the upper surface. Similarly, in the first culture (Culture 1) which had been raised on *V. splendens*, the parasitoid rarely emerged from scales on the upper leaf surface, preferring to remain beneath the leaves. All the populations introduced into glasshouses (Glasshouses 1, 3, 4 and 5) preferred to rest and oviposit in fairly to very shady situations.

In the case of Glasshouse 2, it is considered that the failure of the parasitoid to establish was due to too low a humidity. Glasshouse 3 had a much higher RH and the pseudobulbs were very shaded and it is considered that these conditions were suitable for biological control on *Cymbidium,* which remained undamaged up to October 1972 when observations ceased. Again, in Glasshouse 5, *C. malloi* was restricted to *D. bromeliae* infesting two bromeliad plants: *H. stellata* (0.7m high) and *V. hieroglyphica* (0.5m high) growing on the margin of a small pond in deep shade in a nearly water-saturated atmosphere. About 2m away from these two bromeliads, in fairly shady situations but with sunny areas at times and with 70-80% RH, were three plants of *Vriesea splendens* (0.4m tall) infested with *D. bromeliae* and a plant of *Vriesea imperialis* Carr. (1.25m tall) infested with *D. boisduvalii.* These plants grew under brighter light conditions and lower RH and were not attacked by *C. malloi*; nor was a mixed colony of *D. boisduvalii* and *D. coccois* on the two palm species. It is concluded that *Coccidencyrtus malloi* requires high humidity and deep shade for it to become established in glasshouses in France.

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PANIS, A.[1]; PINET, C.
*INRA, Laboratoire de Biologie des Invertébrés, Antibes, France*
*[1]14 Avenue Schubert, 83440 Montauroux, France*

# A STUDY OF TWO *PLAGIOMERUS* SPECIES (HYMENOPTERA: ENCYRTIDAE) PARASITISING DIASPIDID SCALES (COCCOIDEA) IN GLASSHOUSES IN FRANCE.

## ABSTRACT

A STUDY OF TWO *PLAGIOMERUS* SPECIES (HYMENOPTERA: ENCYRTIDAE) PARASITISING DIASPIDID SCALES (COCCOIDEA) IN GLASSHOUSES IN FRANCE.

*Plagiomerus diaspidis* Crawford was imported from Tenerife (Canary Islands, Spain) and released experimentally as a biological control agent against *Diaspis echinocacti* (Bouché) (Hemiptera, Diaspididae) within a cactus glasshouse in south-eastern France but it failed to provide control, apparently due to very weak powers of dispersal. A second undescribed *Plagiomerus* was found in a wet tropical greenhouse in the same region of France and was thought to be a potential biocontrol agent of Diaspididae. It was found to parasitise the three *Diaspis* species (*D. boisduvalii* Signoret, *D. coccois* (Lichtenstein) and *D. bromeliae* (Kerner)) present in the greenhouse, although it failed to control them. Both parasitoid species reproduced by thelytokous parthenogenesis.

Key words: development, Boisduval scale, preferred environments, USA, Mexico, Azerbaidjan, *Opuntia*, *Strelitzia*, *Calanthe*, palm.

## INTRODUCTION

The biology of an undescribed species of *Plagiomerus* was observed in a tropical glasshouse of south-eastern France (Alpes-Maritimes department) in 1996 and 1997. Within the genus *Plagiomerus* as redefined by Noyes (1980), this species could be separated from the other six described species by the scutellar setae - this undescribed species had four setae which were long and slender, while the described species have either two or four setae which are thickened, with the anterior pair on the posterior third of the scutellum somewhat shorter than the posterior pair on the scutellum apex.

Four species of *Plagiomerus* are known to be internal parasitoids of armoured scale-insects. Of these, *P. diaspidis* Crawford, is known to be a parasitoid of the cactus scale, *Diaspis echinocacti* (Bouché), on cacti in the USA and Mexico (Gordh & Lacey, 1974) and in Azerbaidjan (Trjapitzin, 1968). *P. diaspidis* has also been recorded on an undetermined host in Italy (IOBC Secrétariat, 1960). In November 1997, an old branch of *Opuntia ferox* Salm.-Dyck was brought from Tenerife (Canary Islands, Spain) to Antibes (Alpes-

Maritimes department). It was infested with the *D. echinocacti* from which adult *P. diaspidis* emerged in February 1998. This was the second record of *P. diaspidis* from a hot temperate European country. Both sexes are known in Azerbaidjan and in California, but the frequency of males is very low, with less than 5 males per several hundred females in California and it is likely, therefore, that *P. diaspidis* has thelytokous parthenogenetic reproduction, as in France where no males have been found.

## MATERIALS AND METHODS

The undescribed species of *Plagiomerus* was found in a 2.3 hectare, wet, tropical greenhouse within which the tallest vegetation was about 6m high and which had automated control of temperature and relative humidity (RH), with temperature gradients between 22 and 28°C and RH between 60 and 85% between the lowest layer of the vegetation and the sunny top of the canopy. All diaspidid species living indoors could be regarded as potential hosts. Very limited samples of plants were collected for observations on the behaviour and emergence of the parasitoid and hence quantitative data could not be obtained.

For the study of *P. diaspidis*, a 25cm tall branch of *Opuntia ferox* from Tenerife was firmly fixed in an upright position in soil in a pot and used as a host for rearing *Diaspis echinocacti*, in which the parasitoid could breed. The uncaged branch was in a very sunny position in a heated laboratory. Honeydew droplets were artificially deposited on the branch to provide food for the emerging parasitoid adults. These wasps never appeared to try to escape. Some flew a few centimetres away before landing but would then fly back to the scale-infested branch. Between mid-March and mid-May 1998, 300 cultured *P. diaspidis* were released once a week into a 10m$^2$, hot temperate, cactus collector's glasshouse with about 200 plants in the Alpes-Maritimes department. Approximately two-thirds of the plants had low or medium infestations of *D. echinocacti.* In California, according to Gordh & Lacey (1976), gravid and ovipositing female scales were attractive to searching *P. diaspidis* but 2$^{nd}$-instar male and female scales were not. Larval development required between 13 and 21 days at 25-28°C.

Using these biological data, the efficiency of *P. diaspidis* was estimated in the cactus collector's glasshouse. It was found impossible to count all the scales on a plant and, therefore, the cactus pots were not removed from the bench but were regarded as having low infestations when less than 10 female scales were visible, and as having a medium infestation when more than 10 were visible. The number of living and dead female scales were counted in mid-March 1998 before the first parasitoid release, in mid-May after the last release and on the 30th June 1998 when the experiment was ended. On each occasion, 10 plants with a low scale infestation and 10 with a medium infestation were removed from the bench. Using a needle and a fine, wet brush, the scale covers were removed and the female bodies extracted and examined under a microscope. The bodies of healthy females were yellow and turbinate, those which had died naturally were shrivelled, whilst those which had been attacked by fungi were a dirty grey colour. Females that had been parasitised showed one to three tiny, brownish spots on the dorsum. These spots appeared 1-3 days after parasitisation, each spot indicating where the parasitoid had punctured the skin when ovipositing. In consequence, recently parasitised individuals would be counted as healthy. Once the parasitoid was well developed, the larvae or pupae were visible through the scale cuticle. If all scales were naturally dead or had been attacked by a fungus, additional plants were sampled. After discarding all naturally dead and diseased scales, sampling of each plant was stopped when either all scales on that plant had been studied or when up to 10 healthy and/or parasitised scales had been counted. Because each count was considered to be a biased estimate, additional observations were made on the 15th April, 29th May and 15th June. These observations involved marking plants on the margins of the bench on which recently emerged scales (crawlers and 1st-instar nymphs before the test-cover had been completely built) could be seen using a hand lens. A small, brightly-coloured plastic marker was fixed to each plant. When examined a second time, a second marker was fixed. The markers were intended to show whether the scales had been controlled by *P. diaspidis*.

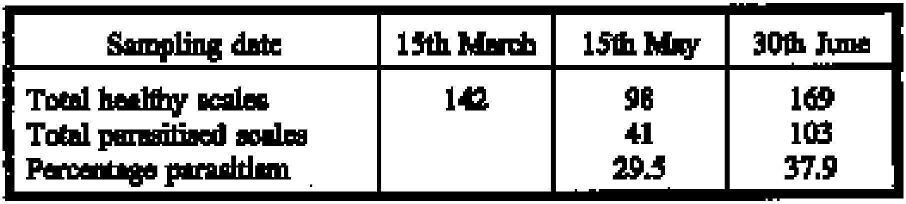
## RESULTS AND DISCUSSION

The hosts of the undescribed species of *Plagiomerus* in the tropical greenhouse were the Boisduval scale, *Diaspis boisduvalii* Signoret, which was widespread on many plant species, *Diaspis coccois* (Lichtenstein) (here regarded as a good species distinct from *D. boisduvalii* (Miller, 1996)) which occurred in mixed colonies with *D. boisduvalii* on coconut palm, and *Diaspis bromeliae* (Kerner) which was present in a small area of the greenhouse on three bromeliad species. *Plagiomerus* sp. was most abundant when (a) *D. boisduvalii* and *D. coccois* were crowded together on the dark base of the leaves of coconut palm, (b) when *D. boisduvalii* was overcrowded on the dark sheathing base of leaves of *Strelitzia alba* Skeels, and (c) in *D.*

*boisduvalii* scattered on the two-leafed orchid, *Calanthe furcata* Lindl. It was also found to parasitise *D. boisduvalii* on about 10 further plant species but did not parasitise all Boisduval scales in all situations. Its distribution appeared to be unrelated to such climatic conditions as light, RH and temperature. *Plagiomerus* sp. laid its eggs in non-ovipositing adult female *Diaspis* species, frequently with 2 or more rarely 3 eggs per host, all of which emerged.

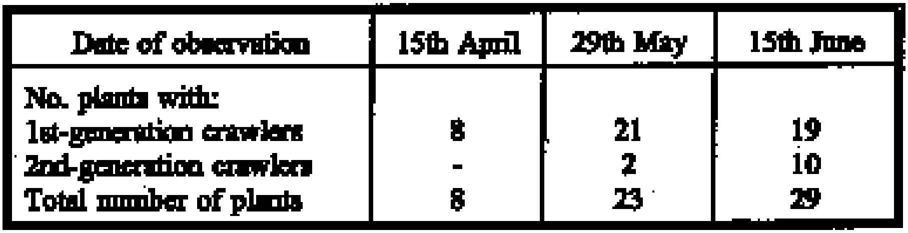
On the other hand, *Plagiomerus diaspidis* cannot be regarded as a useful biocontrol agent of *D. echinocacti* in Mediterranean glasshouses, because the percentage parasitism was too low (Table 1) and because the level of scale infestation remained constant during the experimental period (Table 2), probably due to the very weak dispersal ability, with the parasitoid rarely leaving the source plant, as revealed by observing the scale populations on neighbouring plants.

Table 1. Percentage parasitism of adult female *D. echinocacti* by *P. diaspidis* released in a collector's glasshouse once a week. Data were collected on 15th March (just before first parasitoid release), on 15th May (just after the last release) and on 30th June (6.5 weeks later). On each occasion, up to 10 healthy and/or parasitised scales per plant were examined on 20 plants as described in the text. Naturally dead scales and those attacked by fungi were discarded.



| Sampling date | 15th March | 15th May | 30th June |
|---|---|---|---|
| Total healthy scales | 142 | 98 | 169 |
| Total parasitised scales | | 41 | 103 |
| Percentage parasitism | | 29.5 | 37.9 |

Table 2. Number of plants with recently emerged crawlers of *D. echinocacti* in a cactus collectors glasshouse into which *P. diaspidis* had been released once a week between mid-March and mid-May. Where 1st and 2nd generations refer to generations subsequent to the release of the first parasitoids.



| Date of observation | 15th April | 29th May | 15th June |
|---|---|---|---|
| No. plants with: | | | |
| 1st-generation crawlers | 8 | 21 | 19 |
| 2nd-generation crawlers | - | 2 | 10 |
| Total number of plants | 8 | 23 | 29 |

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TABATADZE, E.S.; YASNOSH, V.A.
*Kanchaveli Plant Protection Research Institute, Tbilisi - 380062, Georgia*

# POPULATION DYNAMICS AND BIOCONTROL OF THE JAPANESE SCALE, *LOPHOLEUCASPIS JAPONICA* (COCKERELL) IN GEORGIA.

## ABSTRACT

POPULATION DYNAMICS AND BIOCONTROL OF THE JAPANESE SCALE,
*LOPHOLEUCASPIS JAPONICA* (COCKERELL) IN GEORGIA.

The Japanese scale, *Lopholeucaspis japonica* (Cockerell) was discovered in Georgia in the Batumi Botanical Garden in 1931, where it was probably introduced from Japan. During the 1950's, it was widespread and became a major pest of citrus, other fruits, tea, tung and ornamental plants. Japanese scale differs greatly from many other diaspidid species because it is pupiparial, the adult female being enclosed in a chitinous "puparium" which makes the use of contact pesticides to control this insect difficult. The scale has 2 generations a year (sometimes 3) and development of some stages is prolonged. Recently, the populations of Japanese scale have been significantly reduced due to effective control by its natural enemies, which include some chalcid parasitoids and coccinellid predators, but which is mainly due to an undescribed species of the fungus genus *Aschersonia*, hitherto not found in the Caucasus.

Key words: Black Sea, insecticides, biology, Aphelinidae, Acarina, *Chilocorus bipustulatus*, *Aspidiotiphagus citrinus*, deuteromycete fungi, entomopathogenic fungi.

## INTRODUCTION

The Japanese scale, *Lopholeucaspis japonica* Cockerell (Coccinea: Diaspididae) was apparently accidentally introduced into Georgia from Japan and was first discovered on a *Magnolia* plant in the Botanical garden near Batumi in 1931. Since 1951, it has become as serious pest of many crops along the Black Sea coast, including citrus, many types of fruit trees, tea, tung and ornamental and wild plants. Heavy infestations were observed prior to the end of the 1980's. During this period, its distribution, biology, and biological and chemical control were studied in detail (for reviews, see Borchsenius (1966), Hadzibeyli (1983) and Konstantinova & Kozárzhevskaya (1990)).

Prior to the present time, pesticides were the only means of controlling *L. japonica*. However, insecticides are effective only against nymphs which are only covered by a thin scale-like test, whereas the adult females are enclosed in a chitinous "puparium" which completely covers them with a thick sclerotised sheath, impenetrable to insecticides. Since the end of the 1980's, the importance of *L. japonica* has been significantly reduced, mainly due to:

(a) the decreasing use of broad-spectrum pesticides against pests in orchards, which has led to an increase in the biodiversity and efficiency of natural enemies, and (b) the appearance of a new and effective biocontrol agent, an entomophathogenic fungus in the genus *Aschersonia*, previously unknown in Georgia and throughout the Caucasus.

This paper gives information on the population fluctuations and natural enemies of *L. japonica* during the period 1983 to 1997.

## MATERIAL AND METHODS

The investigations were conducted at Adjaria (Batumi region) on the Black Sea coast. The population fluctuations of *L. japonica* and the efficiency of its natural enemies were determined by monitoring the populations in two mandarin (*Citrus nobilis*) orchards, namely:

I. Akhalsheni farm plus some of the surrounding area (total about 1000ha) during 1986-88. Here a new integrated management program (IPM) for citrus pests was being used. This programme had been designed by specialists at the Georgian Plant Protection Institute (Recommendation, 1986; Yasnosh, 1995; Yasnosh *et al.*, 1996) and it significantly reduced input of chemicals, especially the organophosphorous insecticides, which are dangerous to the beneficial fauna.

II. Angisa (Makvilauri) farm. Here no insecticides were applied to the experimental plots between 1989 and 1991, the period during which the study was undertaken. In addition, data on the population densities of *L. japonica* were available for the period 1983-88.

In each orchard, three trees infested with *L. japonica* were selected and the number of scales on four areas of the trunk and main branches, each $1cm^2$, were counted on each tree. The efficiency of natural enemies was determined in the same sites by counting the number of scales which had been parasitised or destroyed by predators. The beneficial insects were identified by the second author and the entomophathogenic fungus, *Aschersonia* sp., by Prof. E.S. Koval (Microbiological and Virological Institute of the Ukraine, Kiev).

## RESULTS AND DISCUSSION

*L. japonica* infests nearly all parts of the plant but mainly the trunk and main branches and, in the case of heavy infestations, can cause death of the host. It is a polyphagous species, with an extensive host list and attacks more then 20 plants from different botanical families in Georgia (Hadzibeyli, 1983).

Table 1. List of the natural enemies of the Japanese scale in Georgia.

| **PARASITOIDS** | **PREDATORS** |
|---|---|
| **HYMENOPTERA, Aphelinidae** | **COLEOPTERA, Coccinellidae** |
| ***Aspidiotiphagus citrinus* Craw.**<br>***Aphytis hispanicus* Mercet**<br>***Encarsia fasciata* Malenotti**<br>***E. intermedia* Ferrière** | ***Chilocorus bipustulatus* L.**<br>***Ch. renipustulatus* Scriba**<br>***Exochomus quadripustulatus* L.**<br>***E. flavipes* Thunb.**<br>***Lindorus lophanthae* Blaisd.** |
|  | **ACARI**<br>***Hemisarcoptes dzhashii* Dzhibladze**<br>***Hemisarcoptes sp.*** |

It has two generations per year in Georgia, although sometimes there is a distinct 3rd generation. It overwinters as the 2nd-instar nymph, giving rise to adult males and females at the end of March (Tabatadze, 1994). Each female generally lays between 11 and 28 eggs (range 4-50). The 1st (Spring) generation develops between the end of May and the beginning of June, while the 2nd (Summer) generation develops between the end of July and the beginning of August. However, the development of all stages of the scale in the summer is prolonged and there is no clear separation of the generations, so that during the later periods in the year, all development stages of the scale may be present.

Figs 1 & 2 show the population densities and percentage parasitism of *L. japonica* at Akhalsheni farm since 1983, when the new IPM program against a complex of pests (coccids, aphids, citrus whitefly and mites) was introduced and, since when, the use of broad-spectrum pesticides (mainly organophosphorous) has been rare.

Fig. 3 shows similar data for Angisa farm between 1989 and 1991, where no insecticides were applied during this period. There are no significant differences in the population density of *L. japonica* between the two experimental orchards, where the fluctuations in scale density were always below the economic threshold of 20-25 scales/cm$^2$ on the trunk and main branches (Tabatadze, 1994) and where the peaks of percentage parasitism were at similar times in both orchards. The efficiency of the natural enemies was sometimes high, when about 50% of the scale population were destroyed by the parasitoids, predators and fungi.

The complex of natural enemies (Table 1) also includes such non-specialized (oligophagous) predators as mites and spiders. The main controlling agent of this complex of natural enemies of *L. japonica* is the new pathogenic

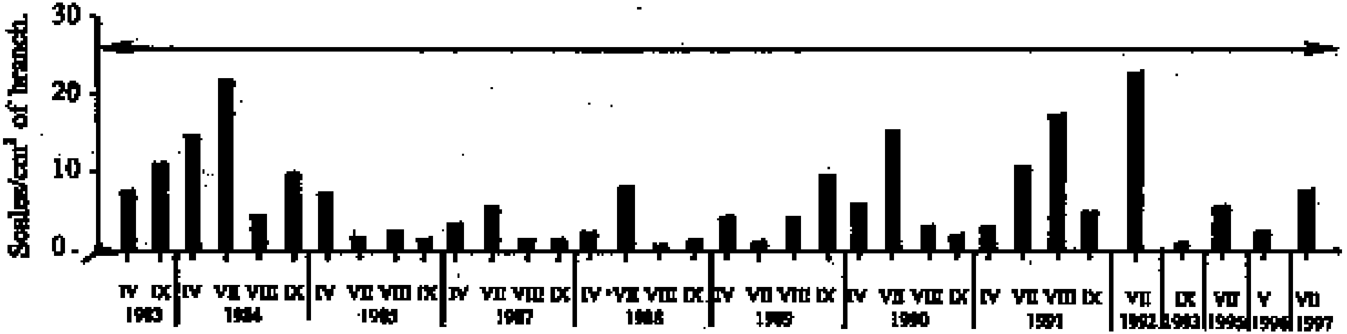

Fig. 1. Population fluctuations of the Japanese scale in citrus orchards, Akhalsheni farm, 1983-1997. Where ■ = coccid populations and <—> = economic threshold (25 scales $10cm^{-1}$).

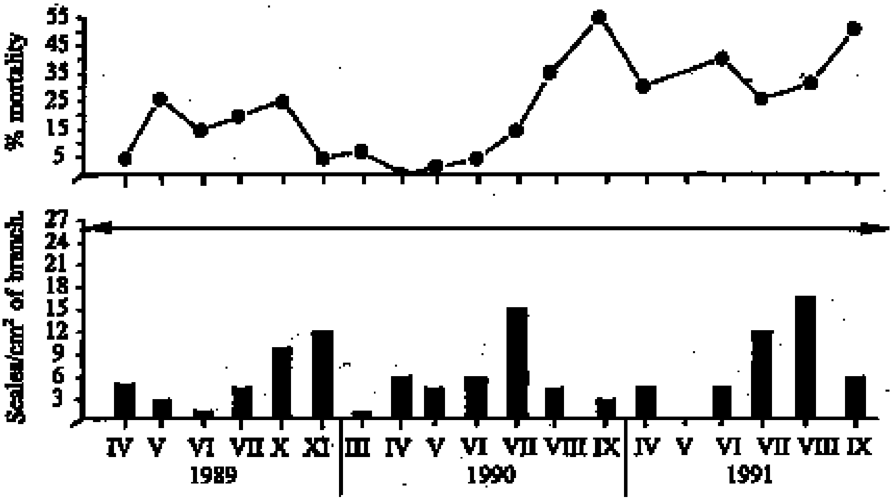

Fig. 2. Population fluctuations of the Japanese scale and percentage mortality due to natural enemies in citrus orchards, Akhalsheni farm, 1989-1991. Where ■ = coccid populations and <—> = economic threshold (25 scales $10cm^{-1}$).

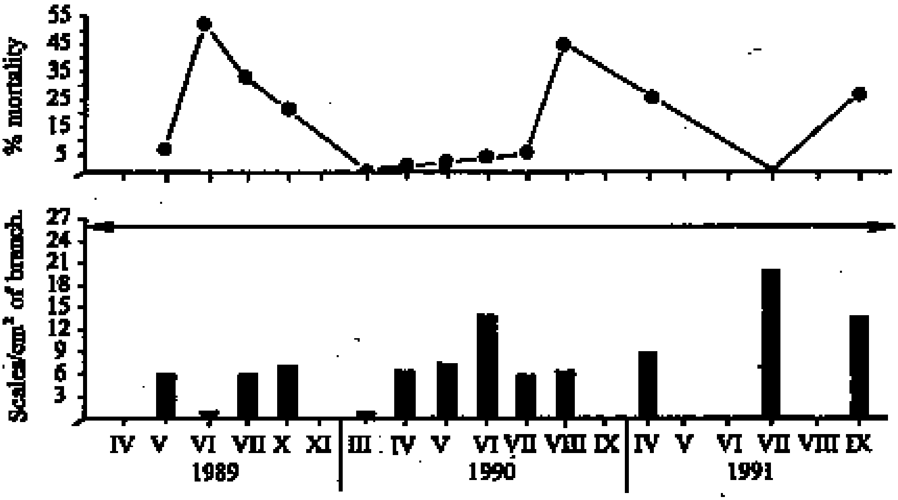

Fig. 3. Population fluctuations of the Japanese scale and percentage mortality due to natural enemies in citrus orchards, Angisa farm, 1989-1991. Where ■ = coccid populations and <—> = economic threshold (25 scales $10cm^{-1}$).

fungus *Aschersonia* sp. (which caused 43% of the mortality due to biocontrol agents in 1990), closely followed by the predators (Table 1) (38% of the mortality). Coccinellids are the most common predators of many coccids, of which *Chilocorus bipustulatus* L. is the most common. The coccinellid *Lindorus lophanthae* does not appear to be effective against Japanese scale populations. Only 19% of scales died due to parasitoids, of which *Aspidiotiphagus citrinus* Graw appears to be the most effective at the present time. The number and effectiveness of the parasitoids is higher in the autumn.

Three species of deuteromycetic fungi have been recorded attacking the Japanese scale: *Aschersonia* sp, *Fusarium larvarum* (Fusk) Bilai and *Fusarium* sp. At present, *Aschersonia* sp. is found in many orchards, particularly those not treated with pesticides. The discovery of this new *Aschersonia* species in our subtropics is of great interest because it is parasitic on scale insects (previously known *Aschersonia* species in Georgia are parasites of Aleurodidae and were especially introduced for the control of citrus whitefly, *Dialeurodes citri* Ashmead, in the sixties from China, Vietnam, USA, Cuba, etc. (Yasnosh & Tabatadze, 1997)).

The results of this investigation show that the population density of *L. japonica* has been significantly reduced by its natural enemies, particularly the new pathogenic fungus *Aschersonia* sp., which is now its most important biocontrol agent.

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YASNOSH, V.A.
*Kanchaveli Plant Protection Research Institute, Tbilisi - 380062 Georgia*

# OBSERVATIONS ON SOME MEALYBUGS (COCCINEA: PSEUDOCOCCIDAE) AND THEIR NATURAL ENEMIES ON ARBORATE PLANTS IN THE REPUBLIC OF GEORGIA.

## ABSTRACT

Observations on some mealybugs (Coccinea: Pseudococcidae) and their natural enemies on arborate plants in the Republic of Georgia.

Twenty-one species of Pseudococcidae are associated with arborate plants in Georgia. About 50% are adventive species which are mostly restricted to the subtropical zone of the Black Sea, although *Pseudococcus comstocki* (Kuwana) and *Planococcus ficus* (Signoret) are widespread, while the main pest is *Planococcus ficus*, which is injurious to grapevine and some other plants. The indigenous species are related to other European or Euro-central asian species. Three species have been described from Georgia, but native mealybugs are of no economic importance and are rarely found in urban areas. The main biocontrol agents for most of these mealybugs are encyrtid wasps (Hymenoptera: Chalcidoidea). The species described from Georgia which may be effective biocontrol agents are: *Aphycus hadzibeyliae* Trjapitzin, a parasitoid of *Phenacoccus aceris* (Signoret) and *Phenacoccus transcaucasicus* Hadzibeyli, and *Pseudaphycus phenacocci* Jasnosh, also a parasitoid of *P. aceris* (as *P. mespili* (Signoret)). A revised check-list of the mealybugs and their parasitoids in Georgia is given.

Key words: distribution, host plants, damage, natural enemies, Aphelinidae, Proctotrupoidea, Platogasteridae, Coccinellidae, Chrysopidae, Chamaemyidae, Encyrtidae, Pteromalidae, Signiphoridae, overwinter, faunistics, *Nephus*, *Chrysopa*, *Leucopis*.

## INTRODUCTION

The sap-sucking scale insects (Hemiptera: Coccinea) and their natural enemies form a large component of the biodiversity of the southern Palaearctic. Many coccoid species are important pests of agriculture and horticulture and studies of these insects and the use of their natural enemies for biological control rather than using pesticides can greatly help sustainable agriculture and also benefit the environment. Faunistic, systematic and biological studies of coccoids in Georgia are mainly known from the broad investigations of Gogiberidze (1938) in the subtropical zone, and the books of Borchsenius (1949, 1963) and Hadzibeyli (1983), which have summarized other information. Other works on scale insect parasitoids and other aspects of scale biology in the Caucasus are those by Nikol'skaya & Yasnosh (1966, 1968) and Trjapitzin (1968, 1989), while similar information for Georgia can be found in Yasnosh (1967, 1972, 1995).

This review presents recent information on the distribution, host plants, damage and natural enemies of the mealybugs associated with arborate plants in Georgia. Georgia lies within the Caucasus and is divided into two regions by mountains, a humid, western, subtropical region occupying the coast of the Black Sea and neighbouring territories, and an eastern part with a drier climate. Twenty-one species of Pseudococcidae have been recorded on arborate plants in Georgia (Table 1), eight of them are adventive species, mainly found in the subtropical Black Sea coastal zone, on plants that were probably introduced when the coastal areas of ancient Kolchida were being brought under cultivation in the 19th century. Three species are found only in greenhouses but the Comstock mealybug, *Pseudococcus comstocki* (Kuwana) is widespread. The thirteen indigenous species have European or Euro-central Asian connections. Three of these species were described by Hadzibeyli and are associated with high-montain forests (e.g., *Phenacoccus montanus* on *Picea orientalis* and *Phenacoccus transcaucasicus* and *Phenacoccus gorgasalicus* on broad-leaved forest trees). The two species of *Trabutina* are restricted to the arid zone of eastern Georgia, while *P. ficus* is widespread.

Table 2 lists the 24 parasitoid species known from these mealybugs in Georgia, with 20 belonging to the superfamily Chalcidoidea and four to the Proctotrupoidea. Of these, five chalcids and two proctotrupoids have been introduced for mealybug biological control, five of which have become established and these are discussed further below. Of the rest, five are secondary parasitoids.

In addition, there are some oligophagous native predators, including *Nephus (Scymnus) bipunctatus* Kugel and *N. saturalis* Thunberg (Coleoptera: Coccinellidae); *Chrysoperla carnea* Stephan, *Chrysopa* spp. (Neuroptera, Chrysopidae), and *Leucopis alticeps* Czerny (Diptera, Chamaemyidae). Also within this complex of species are three encyrtid parasitoides of the larvae and pupae of *Nephus* sp.: *Homolotylus flaminius* (Dalman), *H. qualei* Timberlake and *Aminellus niger* Masi.

With the exception of *Planococcus ficus* (Signoret), which is a major pest in vineyards, native mealybugs are of no economic importance and are rarely, if ever, found in urban areas. The populations of species such the Maple mealybug, *Polystomophora ostiaplurima* (Kiritshenko), the polyphagous tree mealybug, *Phenacoccus aceris* (Signoret) are both primarily under the control of their natural enemies.

In 1955-56, the encyrtid parasitoid *Pseudaphycus phenacocci* Yasnosh was introduced for the control of apple mealybug in Tashkent, Uzbekistan (Central Asia) (Yasnosh, 1961). It has been found to overwinter successfully and is a very effective biocontrol agent (Dr A. Sonina, personal communication). *P. phenacocci* is an internal parasitoid of the nymphs and adult females and has a very high reproductive potential with several generations annually, with 25-30 (occasionally more) parasitoids developing simultaneously in one female host.

Table 1: Species of Pseudococcidae recorded on arborate plants in Georgia.

| Mealybug sp. | Plant genera |
|---|---|
| *Heliococcus bohemicus* Šulc | *Robinia, Rubus* |
| *H. destructor* Borchsenius$^{x}$ | *Morus, Punica, Robinia* |
| *Nipaecoccus nipae* (Maskell)$^{xx}$ | *Chamaerops* |
| *Phenacoccus aceris* (Signoret) | *Acer, Carpinus, Malus* and other plants |
| *P. aceris* (= *P. mespili* (Signoret)†) | *Cydonia, Fraxinus, Malus, Persica, Pyrus* |
| *P. gorgasalicus* Hadzibejli | *Malus, Pyrus, Quercus* |
| *P. montanus* (Hadzibeyli) | *Picea* |
| *P. querculus* (Borchsenius) | *Quercus* |
| *P. transcaucasicus* Hadzibeyli | *Lonicera* |
| *Planococcus citri* (Risso)$^{x}$ | *Citrus* |
| *P. ficus* (Signoret) | *Ficus, Platanus, Punica, Vitis* and other plants |
| *P. vovae* (Nasonov) | *Juniperus* |
| *Polystomophora ostiaplurima* (Kiritshenko) | *Acer* |
| *Pseudococcus calceolariae* (Maskell)$^{x}$ | *Citrus* and many other plants |
| *P. comstocki* (Kuwana)$^{x}$ | *Albizia, Catalpa, Ficus, Morus, Punica,* many fruits and plants |
| *P. longispinus* Targioni-Tozzetti$^{xx}$ | *Trachicarpus, Citrus* and other subtropical plants |
| *P. viburni* (Signoret)$^{x}$ (= *obscurus* Essig) | *Albizia, Citrus, Laurus, Vitis* and other plants |
| *Ritsemia pupifera* Lichtenstein | *Ulmus* |
| *Spinococcus morrisoni* (Kiritshenko) | *Carpinus, Corylus* |
| *Trabutina crassispinosa* Borchsenius | *Tamarix* |
| *T. mannipara* (Hemprich & Ehrenberg) | *Tamarix* |

Where: x = adventive species and xx = restricted to greenhouses. † *Phenacoccus mespili* (Signoret) was synonymised with *Phenacoccus aceris* (Signoret) by Ben-Dov & Matile-Ferrero (1995, p. 251).

Table 2: List of hymenopterous parasitoids of mealybugs on arborate plants in Georgia.

| Parasitoid species | Host species |
|---|---|
| **PROCTOTRUPOIDEA** | |
| **Family Platygasteridae** | |
| _Allotropa burrelli_ Muesebeck* | _Pseudococcus comstocki_ |
| _A. convexifrons_ Muesebeck* | _P. comstocki_ |
| _A. mecrida_ (Walker) | _Planococcus ficus_ |
| _Allotropa_ sp. | _Polystomophora ostiaplurima_ |
| **CHALCIDOIDEA** | |
| **Family Aphelinidae** | |
| _Coccophagus gurneyi_ Compere* | _Pseudococcus calceolariae_ |
| C. _lycimnia_ (Walker) | _Planococcus ficus_ |
| _Marietta picta_ (André)** | _Planococcus citri, P. ficus, Trabutina crassispinosa_ |
| **Family Encyrtidae** | |
| _Anagyrus pseudococci_ (Girault) | _P. ficus, P. comstocki_ |
| _A. tamaricicola_ Trjapitzin | _T. crassispinosa_ |
| _Aphycus apicalis_ (Dalman) | _Phenacoccus aceris_ |
| _A. hadzibeyliae_ Trjapitzin | _Phenacoccus aceris_ (as _Ph. mespili_),<br>_Phenacoccus transcaucasicus_ |
| _A. sumavicus_ Hoffer | _Phenacoccus montanus_ |
| _Hadzhibeylia physococci_ Myartseva & Trjapitzin | _Ritsemia pupifera_ |
| _Leptomastidea abnormis_ (Girault)* | _P. ficus_ |
| _Leptomastix dactylopii_ Howard* | _P. ficus_ |
| _Prochiloneurus bolivari_ Mercet** | _P. comstocki, P. ficus, P. citri_ |
| _P. pulchellus_ Silvestri** | _T. crassispinosa_ |
| _Pseudaphycus hungaricus_ Erdos | _P. ostiaplurima_ |
| _P. maculipennis_ Mercet* | _P. viburni_ (= _obscurus_) |
| _P. malinus_ Gahan* | _P. comstocki_ |
| _P. phenacocci_ Yasnosh | _Ph. aceris_ (as _Ph. mespili_) |
| **Family Pteromalidae** | |
| _Eunotus_ sp. | _Ph. aceris_ |
| _Pachyneuron muscarum_ (Linnaeus)** | _P. ficus_ |
| **Family Signiphoridae** | |
| _Chartocerus subaeneus_ (Förster)** | _P. comstocki, P. ficus_ |

where: * =introduced for biological control and ** = secondary parasitoids.

Some years ago, the adventive mealybugs _Planococcus citri_ Risso, _Pseudococcus comstocki_ and _P. viburni_ (Signoret) were pest species but, at the present time, they are of no economic importance due to the introduction of parasitoids to control them: i.e. for the citrus mealybug: _Coccophagus gurneyi_ Compere; for the Comstock mealybug: _Pseudaphycus malinus_ Gahan and _Allotropa_ spp., and for the obscure mealybug: _Pseudaphycus_ *maculipennis* Mercet. All are now well established. Currently, the dominant noxious species is *P. ficus* and the coccinellid predator *Cryptolaemus montrouzieri* Mulsant has been introduced to control it (Yasnosh, 1995).

In the 1960s and 1980s, two parasitoids (*Leptomastidea abnormis* (Girault) and *Leptomastix dactylopii* Howard) were introduced to control *P. ficus* but neither was able to overwinter. However, they were found to be effective when introduced seasonally in the humid region of sea coast (Loyk & Sanaja, 1986; Yasnosh, 1995). Similarly, the coccinellid *Nephus reunioni* Fürsch, which was introduced from France, was unable to overwinter but is also recommended for control of this pest by annual introduction (Orlinsky & Izhevsky, 1987).

In conclusion, from a faunistic point of view, Georgia is of interest because it lies within the Caucasus, a transition area between Europe and Central Asia and this is reflected by the 7 species (30%) which are distributed in both these regions. Within Georgia, there are nine genera of Pseudococcidae associated with arborate plants at the present time. Two of them, namely *Phenacoccus* and *Pseudococcus*, are dominant, together comprising 50% of all known species, and their natural enemies are therefore of great importance in population control and so further parasitoid species may be recommended in the future as biocontrol agents for their control.

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# BIOLOGY AND HOST-INTERACTIONS OF NATURAL ENEMIES: Posters and Abstracts:

## FACTORS RESPONSIBLE FOR THE EXTINCTION OF *CHRYSOMPHALUS AONIDUM* (L.) FROM CITRUS ORCHARDS IN EGYPT.

AMIN, A.H.; RISK MADIHA, A.; SAKR, H.E.A.
*Plant Protection Department, Faculty of Agriculture, Ain Shams University, Cairo, Egypt.*
*Email: asuagr@asunet.shams.eun.eg*

Ecological studies have shown that the black armoured scale, *Chrysomphalus aonidum* (L.), has four overlapping annual generations on navel orange trees under the conditions in Qalyubyia Governorate, Egypt. Five species of natural enemies were recorded on *C. aonidum* during the present work. The ectoparasitoid, *Aphytis holoxanthus* DeBach, was recorded for the first time from Egypt, and the other bioagents were three endoparasitoids: *Aspidiotiphagus citrinus* Craw., *A. lounsburyi* Berl. & Paoli and *Habrolepis pascuorum* Mercet and an entomogenous fungus, *Cladosporium cladosporides* (Fresen).

Recently, *C. aonidum* appears to have become extinct in citrus orchards in many localities in Egypt. It is considered that this is due to a combination of spray timing and the effects of these five bioagents. Since 1967, the Ministry of Agriculture in Egypt has recommended the use of summer sprays against this pest, instead of autumn and winter applications. Summer sprays are less harmful to these natural enemies, which are mainly effective against the winter and spring populations of *C. aonidum*.

## ANTIMICROBIAL ACTIVITY OF SECRETORY MATERIALS OF SOME SCALE INSECTS.

MAHMOUD, F.A.; HAMDY, M.K.; HEGAZI, A.G.
*National Research Center, Dokki, Giza, Egypt.*
*Email: ahmedgaffer@frcu.eun.eg*

The antimicrobial activity of the secretory materials associated with the test or wax covers of five scale insects was tested for Gram-positive and Gram-negative bacteria. The scale insects studied were the margarodid *Icerya aegyptiaca* (Douglas), the soft wax scale *Ceroplastes rusci* (Linnaeus) and three hard scales: *Aonidiella aurantii* (Maskell), *Lepidosaphes beckii* Nerwman and *Parlatoria zyziphi* (Lucas).

The Gram-positive bacteria found included *Staphylococcus aureus* and *Streptococcus agalactia*, while the Gram-negative bacteria included *Escherichia coli*, *Pseudomonas aeruginosa* and *Corynebacterium pseudotuberculosis*.

The results of these observations revealed that there was some highly significant antimicrobial activity associated the secretary materials of the diaspidids *A. aurantii*, *L. beckii* and *P. zyziphus*. The antimicrobial activity observed varied according to type of the pathogenic bacteria it was used against. Thus, the activity from all three species was effective against *Staphylococcus aureus*, but that of *A. aurantii* and *P. zyziphus* was less effective against *Corynebacterium pseudotuberculosis*.

# A MORPHOLOGICAL BASIS OF PARASITIZATION STRATEGIES OF CHALCID WASPS (HYMENOPTERA: CHALCIDOIDEA) INFESTING SOFT SCALE INSECTS (HEMIPTERA: COCCOIDEA: COCCIDAE).

SUGONYAEV, E.S.
*Zoological Institute, Academy of Sciences, St. Petersburg, 164, Russia.*
*Email: ses@zisp.spb.su*

A study was undertaken of the morphological and biological adaptations of chalcid wasps for the synchronisation of their life-cycles with that of the host, so as to provide optimal conditions for parasitization under temperate conditions. This revealed two strategies by the adult wasp for overcoming the period when a suitable host stage is absent. These are referred to here as the "surviving" strategy and the "evasion" strategy. These two strategies are shown by two structural features of the adult wasp:

I. *Body size*. Adult wasps with a "surviving" strategy are robust, with a long adult life, thus reflecting a trend towards body enlargement and increased longevity (e.g., *Microterys* spp). The alternative "evasion" strategy is to be very small; here, the adult life cycle is very short and the wasp survives in the pre-imaginal stages of its host (e.g., *Pseudorhopus testaceus* (Ratzeburg)).

II. *Structure of ovipositor and abdomen.* For the group with the "surviving" strategy and a large body size, there are three types of ovipositor associated with particular abdominal structures:

A. An unexerted ovipositor of moderate length, with an oval abdomen, rounded at the apex. The ovipositor of these parasitoids is only used to pierce the thin integument of their hosts (e.g., *Microterys hortulanus* Erdös and *Coccophagus lycimnia* (Walker)).

B. A long ovipositor, with long basal parts (i.e. gonopophysis and gonocoxites) but with short exerted parts (gonostyles) associated with a long abdomen, conical at apex. This is common in species with ectoparasitic predatory larvae, where the female parasitoid pierces the host body causing paralysis and then lays its egg on the ventral surface of the host (e.g., *Microterys sylvius* (Dalman) and *M. lunatus* (Dalman)).

C. The ovipositor is long due to the presence of long external parts, i.e. long gonopophysis and gonostyles. The parasites attack hosts defended by thick layers of wax or a layer of fine wax threads (e.g., *Microterys indicus* Subba Rao, *Sauleria dlabolai* Hoffer and *Mesaphycus taigae* Sugonjaev).

In the group with the "evasion" strategy and small body size, the ovipositor is very small and short, situated at the apex of the abdomen. Here, the females lay their eggs into 1st-instar nymphs of their hosts and the resulting larvae do not disturb the growth and metamorphosis of the host, the adult wasps emerging from the adult scale (e.g., *Pseudorhopus testaceus* and *Encyrtus infidus* (Rossi)).

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