

ULTRASTRUCTURE OF THE GLAND RESPONSIBLE FOR THE SYNTHESIS
OF AN AGGREGATION PHEROMONE IN *RHYNCHOPHORUS PALMARUM*
(L.) (Coleoptera: Curculionidae)

PEDRO A. SÁNCHEZ
FONAIAP-Estación Experimental Miranda
calle el Placer
Caucagua, Venezuela

FREDI SÁNCHEZ
Instituto de Estudios Avanzados (IDEA)
Apdo. 17606
Caracas 1015A, Venezuela

KLAUS JAFFÉ
USB, Dpo. Biología de Organismos
Apdo. 89000
Caracas, Venezuela

AND

FLAVIO H. CAETANO
Instituto de Biociencias-UNESP
Río Claro, Brasil

Universidad Central de Venezuela
FACULTAD DE AGRONOMIA
Instituto de Zoología Agrícola
MARACAY

Abstract

The ultrastructure of the glands responsible for synthesizing the aggregation pheromone rhynchophorol in the beetle *Rhynchophorus palmarum* (L.) was studied. Glands from live beetles were removed and examined under a light microscope using semithin sections ($\sim 1\mu\text{m}$) and under a transmission electron microscope (TEM) using ultrathin sections (60 nm). The glands show an alveolar structure without a reservoir and the cells making up the gland are arranged in a typical acinus pattern. The existence of two types of cells with different electron densities, secretion canaliculi, numerous mitochondria and smooth endoplasmic reticulum in abundance were observed. These latter organelles are characteristic of cells which synthesize non-proteinaceous substances and are thus, likely candidates for the production of rhynchophorol.

The beetle *Rhynchophorus palmarum* (L.) is a common species in the Neotropics and is one of the main pests of the Coconut palm, *Cocos nucifera* L. and the African oil palm, *Elaeis guineensis* Jacq. (Bedford 1980; Barreto 1986; Hernández *et al.* 1992; Sánchez and Cerda 1993). A population of 30 beetles is sufficient to cause the death of one palm tree (Fenwick 1967; Griffith 1968). More important than the direct damage caused by larval feeding is that *R. palmarum* is a vector of the phytoparasitic nematode *Bursaphelenchus cocoophilus* (Cobb). This is an obligate parasite, found in all the tissues of the host palm and the causal agent of the Red Ring disease, named after the presence of a red ring, 3-5 cm wide, which circles the inner perimeter of the stem (Griffith 1987; Giblin 1990).

Rhynchophorus palmarum depends on a complex process of chemical com-

munication to locate new hostplants, for the finding of mates and for mating (Jaffé *et al.* 1993). Moura *et al.* (1989) and Rochat *et al.* (1991a) demonstrated in field experiments that it is the adult males that liberate the aggregation pheromone. Rochat *et al.* (1991b) identified this pheromone as the volatile 2(E)-6-methyl-2-hepten-4-ol, giving it the name rhynchophorol. These findings were confirmed by field experiments (Oehlschlager *et al.* 1992, 1993), that also identified the molecular structure of the compound. Sánchez *et al.* (1996) determined through chemical, behavioral and morphological data, that a pair of symmetrically arranged glands in the parietal region of the thorax of the males is responsible for the synthesis of rhynchophorol (Fig. 1.1)

The study of the ultrastructure of exocrine glands in insects has only been developed in recent years with most investigation being undertaken in the social insects (Billen 1987). This author indicates that the cytoplasm generally contains smooth endoplasmatic reticulum, numerous mitochondria and a well developed Golgi complex, typical of cells which produce non-proteinaceous substances. Although in Coleoptera exocrine gland cells have not been well studied, the investigations undertaken indicate that the synthesis of the pheromones occurs principally in the abdominal region and the legs (Borden and Slater 1969; Hammack *et al.* 1973; Levinson *et al.* 1978; Lew and Ball 1978; Faustini *et al.* 1982; Imai *et al.* 1990; Dowd and Bartelt 1993). Many of the details of the cellular structure and their functional relation to the production, liberation and behavioral effects of the different substances secreted, however, remain to be studied.

Here we describe the morphology and ultrastructure of the glandular system responsible for the synthesis and secretion of rhynchophorol in *R. palmarum* and relate this to the function of the pheromone in the behavior of the insect.

Materials and Methods

This study was undertaken with adult beetles collected using the methods described in Hernández *et al.* (1992), from Distrito Acevedo, Estado Miranda, Venezuela.

The beetles were transported to the Behavior Laboratory at the Universidad Simón Bolívar where they were maintained individually in plastic pots at a temperature of 23–27°C, and relative humidity of 70–90% and fed on sugar cane.

The beetles were prepared for structural and ultrastructural studies by cooling them for 15 min at –5°C. They were then dissected using a stereoscopic microscope at 80× in a phosphate solution (PBS), pH 7.2, 360 mOsm/liter. The dissection was accomplished by first removing the rostrum and then cutting the exposed tissue dorsolaterally to facilitate observation of the glands. These were immediately fixed *in situ* at room temperature, in a solution of glutaraldehyde at 2.5% and paraformaldehyde at 1% in PBS. The dissected tissues were submerged in this solution at 4°C for 1 h and immediately washed in PBS for 5 min and post fixed in osmium tetroxide (OsO₄) at 1% in PBS at 4°C for 1h (Coulfield 1957). They were subsequently washed in PBS for two periods of 5 min each at 0°C. The tissues were gradually dehydrated in a series of ethanol at 50, 70, 80 and 100% for 5 minutes at each percentage, ending with a mixture of ethanol:propylene oxide at a ratio of 1:1 at room temperature for 10 minutes and afterwards with pure propylene oxide for the same amount of time. They were then embedded with a mixture of propylene oxide and Polybed resin (1:1) at room temperature for 1 hour and afterwards a Polybed

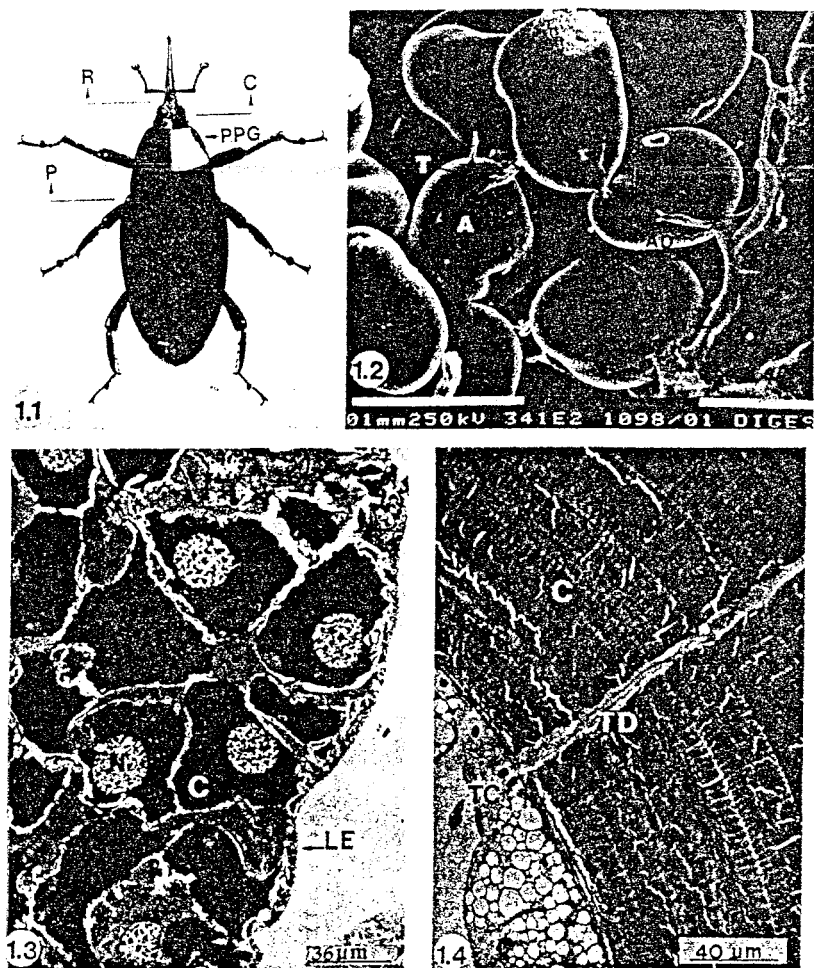


Fig. 1. 1.1) Drawing of *Rhynchophorus palmarum* showing the position of the pheromone gland (PPG) and rostrum (R), head (H) and prothorax (P); 1.2) Scanning microscope view of the gland showing the efferent duct (ED), alveolar duct (AD) and alveolus (A); 1.3) light microscopic view of the cellular structure in the acinum showing the dark cells (type II) and clear cells (type III), nucleus (N), cytoplasm (C) and lacunar space (LS); 1.4) Transverse section of the rostrum showing longitudinal ducts (TD), cuticle (Cu) and trichogen cells (TC).

resin mixture at 4°C for 24 hours. Finally, they were embedded in Polybed mixture and hardened in an oven at 60°C over a period of 2–3 days. Semifine sections for light microscopy (approx. 1 µm) and ultrafine sections for electron microscopy (60 nm) were obtained using a Reichert ultramicrotome, equipped with a diamond knife. Observations and photographs were taken using a Polyvar light microscope and Philips EM-400T transmission electron microscope.

The tissues selected for scanning electron microscopy were passed from 100% ethanol to 100% acetone and dried using the critical point method in a Balzers CPD-020 apparatus. They were then shaded with gold-palladium and observed in a Philips SEM 505 scanning electron microscope.

Results

The dissection of the thorax of adult male beetles revealed the presence of a pair of symmetrical glands localized internally in the thorax as indicated in figure 1.1. Scanning electron microscopy revealed a structure formed by spherical units, organized in acinous and interconnected by tubules. The tubules converge in a common peripheral duct (Fig. 1.2). Organization of the gland as observed by light microscopy is illustrated in figure 1.3. This gland is made up of acini which are formed by two types of cells, clear and dark, which shall be referred to as types II and III, respectively, following the classification proposed by Noirot and Quennedey (1974, 1991) and Quennedey (1975). Figure 1.4 shows a section of the rostrum of the male in the sensilia zone, without any trace of a gland in this area.

The dark cells (type II cells) are the more numerous of the two types in the gland. The nucleus is circular and located in the centre of the cell. It contains clusters of chromatin of varying sizes uniformly distributed. The cytoplasm is relatively dark, with a granular aspect. These cells are not in contact with the basal lamina.

The clear cells (type III cells) are less numerous than the dark cells, with the nucleus at the periphery of the cell. They are of irregular form and the chromatin is observed as dispersed grains. The cytoplasm is amorphous and less dense than the type II cells. The light cells surround the dark cells starting at the periphery of the acini and reaching the center in the form of trabecule between the dark cells. In the zone of contact with the basal lamina, the basal membrane is very folded (Fig. 1.3, 2.3, 3.1).

Ultrastructural details of the type II and type III cells are shown in figure 2.1. Especially notable is the presence of numerous, dense mitochondria, of variable shape filling the cytoplasm of the type II cells. This large amount of mitochondria accounts for the coloration of the dark cells observed in thick sections. Ribosomes, either free or grouped in rosettes, and glycogen granules are distributed among the mitochondria and small portions of rough endoplasmic reticulum are found closer to the nucleus. In the interior of the mitochondria of these cells are crystalline structures, similar in form to that of the enzymes found in mammalian white blood cells (Fig. 2.2).

The type III cells (Figs. 2.1, 2.3) are clearly seen to be located between the type II cells. They are less electron dense and have fewer mitochondria. The cytoplasm contains generally numerous tubular-vesicular structures corresponding to smooth endoplasmic reticulum. Small portions of rough endoplasmic reticulum can also be observed around the nucleus. In the cytoplasm, free ribosomes or ribosomes in rosettes and glycogen granules can also be seen. A peculiar structure, consisting of small collector ducts larger than the endoplasmic reticulum cisternae and apparently connected to them is also present (Fig. 2.1). These ducts seem to converge towards a wider central tubule containing a dense, amorphous material (Figs. 2.1, 3.3). In longitudinal sections (Fig. 3.4) this same dense material is observed in the interior of the ducts, as well as in narrower intercellular canals connected to them, (Fig. 3.4).

The lacunar zones observed around the periphery of the acinus in light

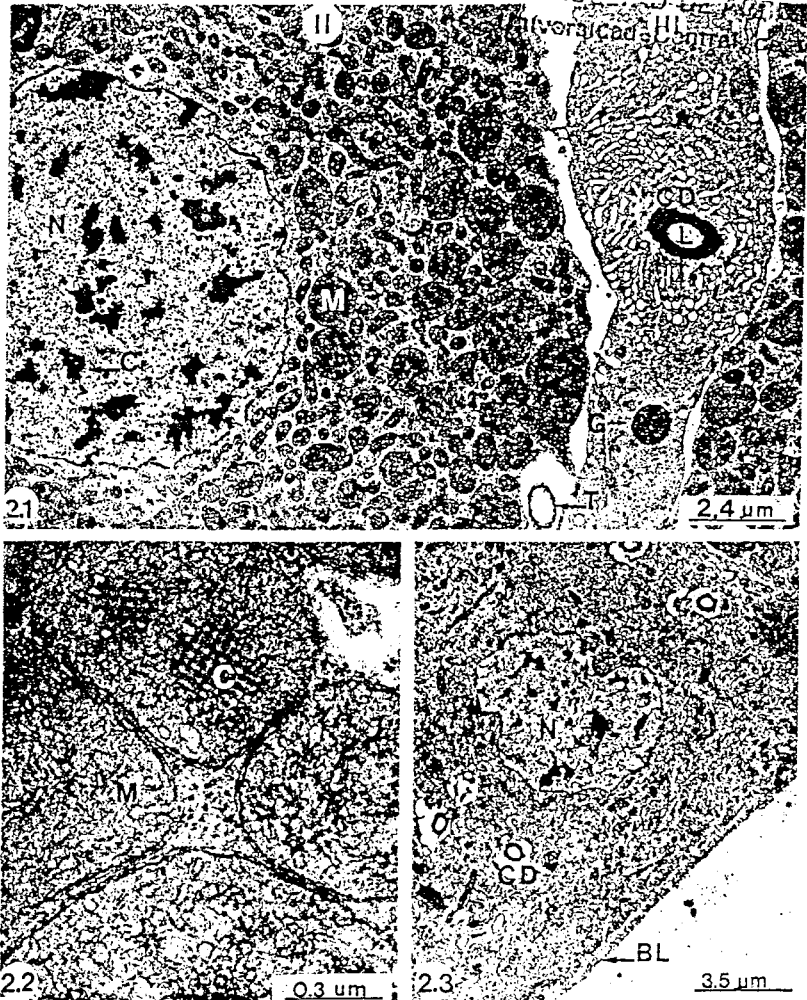


Fig. 2. 2.1) *Rhynchophorus palmarum*, section through associated pair of cells: Dark cells (type II) showing the nucleus (N), numerous mitochondria (M) and Chromatin (Cr); Clear cells (type III) showing transverse section of collector duct (CD), lumen (L), tracheole (T) and granule (G); 2.2) Detail of the mitochondria (M) with crystals (C) in cells type II; 2.3) Clear cells (type III) showing the nucleus (N), ducts (CD) and basal lamina (BL). In 2.1 note the position in the types of cells.

microscopy, appear to be formed by many fingerlike cytoplasmic processes located side by side and separated by many dilated intercellular spaces (Fig. 3.1). A basal lamina of $\sim 0.3 \mu\text{m}$ lines the acinar wall and closes the spaces between the fingerlike processes (Fig. 3.1). Tracheoles are present on the outside of the basal lamina, some of which are branched (Fig. 3.1).

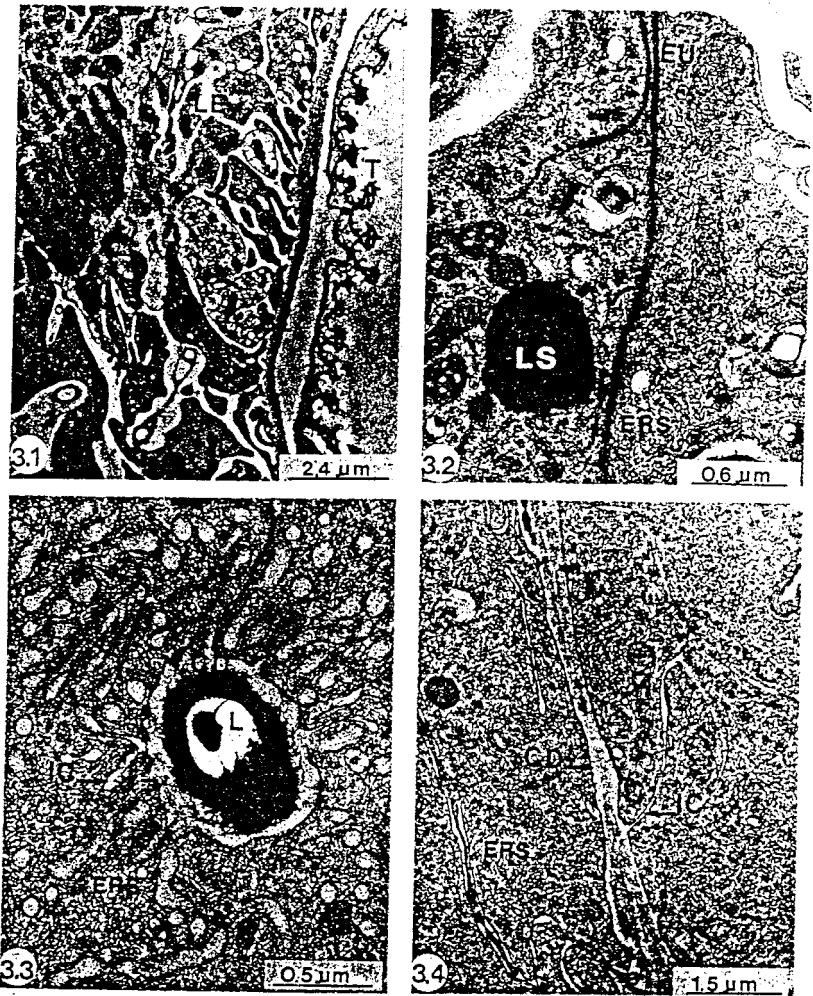


Fig. 3. 3.1) *Rhynchophorus palmarum*, detail of the lamina basal; 3.2) Epithelial union between two cells (EU) and lysosome (LS); 3.3) Detail of the transverse section of the collector duct; 3.4) Longitudinal section of the duct, lacunar space (LE), basal lamina (BL), tracheole (T), mitochondria (M), smooth endoplasmic reticulum (SER), lumen (L), collector duct (CD), canaliculus within one of the cells (IC).

In the lateral walls of the cells of the acini, epithelial junctions can also be observed (Fig. 3.2) where single desmosomes (not shown) are located between the fingerlike processes.

Discussion

The present results verify and complement those obtained by Sánchez *et al.* (1996) who indicated that the pair of symmetrical glands localized in the thorax

of male beetles could be modified salivary glands. These authors also reported that the glands do not have a reservoir and that the organization of the cells corresponded to that of acini. The majority of the papers in the literature report that the pheromones in Coleoptera are produced principally in the abdominal tissues (Borden and Slater 1969; Hammack *et al.* 1973; Levinson *et al.* 1978; Lew and Ball 1978; Imai *et al.* 1990; Dowd and Bartelt 1993). Apparently, however, there is no specific region in the body of the beetle responsible for the synthesis of pheromones. In *Tribolium castaneum* (Herbst), for example, the glands are located in the femur of the prothoracic legs (Faustini *et al.* 1982), whereas in *Carpophilus freemani* Dobson they are associated with the tracheal system (Dowd and Bartelt 1993).

A knowledge of the structure of the gland complements that of behavioral and chemical data. Thus, Sánchez *et al.* (1996) indicated that the exocrine glands continually produce the aggregation pheromone and that this is liberated when the insect is stimulated by odours of vegetable origin. The presence of the numerous ducts, which initially receive and transport the secretion from several cells via intra and extracellular canals (Figs. 2.1, 3.3, 3.4), explain at a structural level, how the secretory function of the cell is maximized.

A general characteristic of all the tissues processed is the existence of cells with different electron densities. This, along with other ultrastructural observations, suggests the existence of two populations of cells which agrees with the classification proposed by Noirot and Quenedey (1974, 1991) and Quenedey (1975) of cell types II and III (Fig. 2.1). The type II cells contain a large number of polymorphic mitochondria, distributed randomly in the cytoplasm and are responsible for the provision of energy for the cellular processes and for the liberation of products to the type III cells, thus functioning as endocrine cells. The type III cells are characterized by a thick network of smooth endoplasmic reticulum and abundant excretion canaliculi which comply with the exocrine function of the acinus. This would suggest a glandular system which synthesizes non-proteic substances such as rhynchophorol. These results corroborate those of Billen (1987), who states that this type of organization in the cytoplasm is typical of insect cells which secrete non-proteinaceous substances and also typical of the parietal cells of the gastric mucosa in mammals engaged in the production of hydrochloric acid (Sedar 1955, 1957; Vial and Orrego 1960).

The large number of mitochondria and tracheoles in the cells suggests that this gland consumes a high level of energy and thus demands high quantities of oxygen, especially during the biosynthetic processes. In the same way, the ultrastructural characteristics of the basal region of the cell, conformed by a network of fingerlike processes separated by lacunar spaces, suggest that the cell captures immense quantities of water, ions and molecules in a similar way to the cells of the renal glomeruli (Fawcett 1989).

Referring to the work reported by Sánchez *et al.* (1996), and to the observations made in the present study, we can assume that the gland continually synthesizes rhynchophorol at minimal levels during periods of low activity and that this synthesis is greatly increased when the insect reaches a highly motivated state, to achieve an efficient aggregation of individuals at a specific site.

It is probable that the structural and functional model of the glands that synthesize rhynchophorol in *R. palmarum* will also be found in the glands of other species of the Curculionidae and with this in mind a general scheme of

glands specialized in the rapid synthesis and release of pheromones when required, could be the following:

1. Stimulation of and synthesis in the type II cells.
2. Release of hormones from type II cells to type III cells.
3. Reception of the hormonal signal by the type III cells.
4. Stimulation and synthesis of the rhynchophorol by the type III cells.
5. Release and secretion of the rhynchophorol.

Acknowledgments

The authors would like to express their gratitude to Gerónimo Guerra for technical assistance, to Juan Carlos Urbina and Paulo Frías (Fundación Instituto de Ingeniería) for photographic support, to Dra. Gloria M. Villegas for her continuous advice and the logistic support offered by the laboratory she directs at IDEA. To Frances Osborn for the translation. This study was financed by the project QF-36 of BID-CONICIT.

Literature Cited

- Barreto, J. M. 1986. Principales plagas y enfermedades del cocotero en Venezuela. *Coco y Palma* 38:14-20.
- Bedford, G. O. 1980. Biology, ecology and control of palm rhinoceros beetles. *Annual Review of Entomology* 25:309-339.
- Billen, J. P. 1987. Morphology and ultrastructure of the exocrine gland in social Hymenoptera. [pp. 81-84]. In: Eder, J., and H. Rembold (editors), *Chemistry and biology of social insects*. Verlag J. Peperny, München.
- Borden, J., and C. Slater. 1969. Sex pheromone of *Thrypodendron lineatum*: Production in the female hindgut-malpighian tubule region. *Annals of the Entomological Society of America* 62(2):454-455.
- Coulfied, J. B. 1957. Effects of varying the vehicle for OsO₄ in tissue fixation. *Journal of Biophysical Biochemistry and Cytology* 3:827.
- Dowd, P., and R. Bartelt. 1993. Aggregation pheromone glands of *Carpophilus free-mani* (Coleoptera: Nitidulidae) and gland distribution among other sap beetles. *Annals of the Entomological Society of America* 86(4):464-469.
- Faustini, D., D. Post, and E. Burkholder. 1982. Histology of aggregation pheromone gland in the red flour beetle. *Annals of the Entomological Society of America* 75(2):187-190.
- Fawcett, D. W. 1989. Tratado de Histología. Interamericana. [pp. 761-801]. In: McGraw-Hill (Eds.). México, D. F., 11ª Edición.
- Fawcett, D. W. 1989. Tratado de Histología. Interamericana, McGraw-Hill, México. 995 pp.
- Fenwick, D. W. 1967. The effect of weevil control on the incidence of red ring disease. *Journal of the Agricultural Society of Trinidad and Tobago* 67:231-244.
- Giblin, R. 1990. The red ring nematode and its vectors. Florida Department of Agriculture Nematology Circular 181.
- Griffith, R. 1987. Red ring disease of coconut palm. *Plant Diseases* 71(2):193-196.
- Griffith, R. 1968. The relationship between the ring nematode and the palm weevil. *Journal of the Agricultural Society of Trinidad and Tobago* 68(3):480-488.
- Hammack, L., W. Burkholder, and M. Ma. 1973. Sex pheromone localization in females of six *Trogoderma* species (Coleoptera: Dermestidae). *Annals of the Entomological Society of America* 66(3):545-550.
- Hernandez, J. V., H. Cerda, K. Jaffe, and P. Sanchez. 1992. Localización hospedera, actividad diaria y optimización de la captura del picudo del cocotero *Rhynchophorus palmarum* L. (Coleoptera: Curculionidae), mediante trampas inocuas. *Agronomía Tropical* 42(3y4):211-226.
- Imai, T., H. Kodama, M. Mori, and M. Kohno. 1990. Morphological and chemical studies of male abdominal exocrine glands of the black larder beetle *Dermestes*

- ater Degeer (Coleoptera: Dermestidae). *Applied Entomology and Zoology* 25(1): 113-118.
- Jaffe, K., P. Sanchez, N. Urdaneta, J. V. Hernandez, G. Guerra, R. Jaffe, R. Martinez, and B. Miras. 1993. Chemical ecology of the palm weevil *Rhynchophorus palmarum* L. (Coleoptera: Curculionidae): Attraction to host plants and to a male-produced aggregation pheromone. *Journal of Chemical Ecology* 19(8):1703-1720.
- Levinson, H., A. Levinson, T.-C. Jen, J. Williams, G. Kahn, and W. Franke. 1978. Production site, partial composition and olfactory perception of pheromone in the male hide beetle. *Naturwissenschaften* 65:543-544.
- Lew, A., and H. Ball. 1978. The structure of apparent pheromone-secreting cells in female *Diabrotica virgifera* (Coleoptera: Chrysomelidae). *Annals of the Entomological Society of America* 71:685-688.
- Moura, J, E. Vilela, M. Sgrillo, M. Aguilar, and M. Resende. 1989. A behavioral olfactory study of *Rhynchophorus palmarum* L. (Coleoptera: Curculionidae), in the field. *Anais da Sociedade Entomologica do Brasil* 18(2):267-274.
- Noirot, C., and Quennedey, A. 1974. Fine Structure of epidermal glands. *Annual Review of Entomology* 19:61-80.
- Noirot, C., and Quennedey, A. 1991. Gland, Gland cells, Glandular units: Some comments on terminology and classification. *Annales de la Société Entomologique de France* (NS):123-128.
- Oehlschlager, A. C., H. Pierce, B. Morgan, P. Wimalaratne, K. Slessor, G. King, G. Griwes, R. Gries, J. Borden, L. Jiron, C. Chinchilla, and R. Mexon. 1992. Chirality and testing of rhynchophorol, the aggregation pheromone of the american palm weevil. *Naturwissenschaften* 79:134-135.
- Oehlschlager, A. C., C. Chinchilla, L. Gonzalez, L. Jiron, R. Mexon, and B. Morgan. 1993. Development of a pheromone-based trapping system for the american palm weevil. *Journal of Economic Entomology* 86(5):1381-1392.
- Quennedey, A. 1975. Morphology of exocrine gland producing pheromone and defensive substances in subsocial and social insects. *Pheromones and Defensive Secretions of Social Insects*. Proceedings of a Symposium of the International Union for the Study of Social Insects, Dijon, France, Dijon, France. 21 pp.
- Rochat, D., A. Gonzalez, D. Marian, A. Villanueva, and P. Zagatti. 1991a. Evidence for male produced aggregation pheromone in american palm weevil *Rhynchophorus palmarum* L. (Coleoptera: Curculionidae). *Journal of Chemical Ecology* 17(6): 1221-1230.
- Rochat, D., C. Malosse, M. Lettere, P. Ducrot, P. Zagatti, M. Renou, and C. Descoins. 1991b. Male-produced aggregation pheromone of the american palm weevil *Rhynchophorus palmarum* L. (Coleoptera: Curculionidae): Collection, identification, electrophysiological activity and laboratory bioassay. *Journal of Chemical Ecology* 17(11):2127-2141.
- Sanchez, P., and H. Cerda. 1993. El complejo *Rhynchophorus palmarum* L. (Coleoptera: Curculionidae)-*Bursaphelenchus cocophilus* (Cobb), (Tylenchida: Aphelenchoididae), en palmeras. *Bol. Entom. Venezolano*. 8(1):1-18.
- Sanchez, P., H. Cerda, A. Cabrera, F. Caetano, M. Materan, F. Sanchez, and K. Jaffe. 1996. The male produced aggregation pheromone of the palm weevil *Rhynchophorus palmarum* L. (Coleoptera: Curculionidae). *Journal of Insect Physiology* 42(11-12):1113-1119.
- Sedar, A. W. 1955. Fine structure of parietal cells. *Anatomical Record* 121:365.
- Sedar, A. W. 1957. Further studies on the fine structure of parietal cells. *Anatomical Record* 127:482.
- Vial, J. D., and H. Orrego. 1960. Electron microscope observations on the structure of parietal cells. *Journal of Biophysical and Biochemical Cytology* 7:367.

(Received 29 August 1998; accepted 21 April 1998)

THE COLEOPTERISTS BULLETIN
(FOUNDED 1947 BY ROSS H. ARNETT, JR.)
(ISSN 0010-065X)

The Coleopterists Bulletin is a Fully Refereed Journal published quarterly beginning in March by the Coleopterists Society. The Society is an international organization devoted to the study of all aspects of systematics and biology of beetles of the world.

Membership: Membership is open to anyone. Annual dues of \$30.00 include subscription to *The Coleopterists Bulletin*. Prospective members should send payment and a letter of interest to the Treasurer.

Library Subscription: \$50.00.

Missing issues: These will be replaced free upon notification to the Treasurer or ordering Agent within three months.

Back issues: Most numbers of volumes 4 to date are available at \$18.00/volume or \$5.00/number including postage and handling. The following are out of print: volumes 1, 2, 3(1-3), 4(1), 5(1-4), 7(1), 8(1-4), 14(1), 20(4), 23(1&4), 24(3), 28(3), 30(2), 33(3), 34(1-3), and 35(3). Send orders with payment to the Treasurer.

Payments: All payments should be made by check, money order (US dollars, payable to the Coleopterists Society), or credit card (VISA and MasterCard only). Payment by credit card is recommended for all members outside the US without a US bank account. Send all payments to the Treasurer (FEIN 23-7319132).

Change of address: POSTMASTER, Send address changes to Coleopterists Bulletin % the Treasurer (address below).

Known office of publication: Terry N. Seeno, CDFR-Plant Pest Diagnostics Center, 3294 Meadowview Road, Sacramento, CA 95832-1448, U.S.A.

EDITORIAL BOARD

- | | |
|--|--|
| A. Gillogly, College Station, TX (1996-98) | S. A. Konstantinov, Washington, DC (1998-2000) |
| C. D. Johnson, Flagstaff, AZ (1996-98) | |
| R. W. Hamilton, Chicago, IL (1997-99) | D. A. Pollock, Winnipeg, MB (1998-2000) |
| D. K. Young, Madison, WI (1997-99) | |

Book Review Editor: Charles L. Bellamy, Coleoptera Department, Transvaal Museum, P.O. Box 413, Pretoria 0001, South Africa 27-12-322-7632 FAX 27-12-322-7939 e-mail bellamy@tm.up.ac.za

Executive Committee of the Coleopterists Society

President: Donald E. Bright, Agriculture Canada, Research Branch, K. W. Neatby Building, Ottawa, Ontario K1A 0C6, Canada (613) 759-1789 e-mail brightd@em.agr.ca

President-Elect: Paul J. Johnson, Insect Research Collection, South Dakota State University, Box 2207A, Brookings, SD 57007, U.S.A. (605) 688-4438 FAX (605) 688-4602 e-mail elater@brookings.net

Past-President: Margaret Thayer, Field Museum of Natural History, Chicago, IL 60605, U.S.A. (312) 922-9410 FAX (312) 663-5397 e-mail thayer@fmppr.frnh.org

Secretary: Brett C. Ratcliffe, University of Nebraska, W-436 Nebraska Hall, Lincoln NE 68588-0514 U.S.A. (402) 472-2614 FAX (402) 472-8949 e-mail bcr@unlinfo.unl.edu

Treasurer: Terry N. Seeno, CDFR-PPD, 3294 Meadowview Road, Sacramento, CA 95832-1448, U.S.A. (916) 262-1160 FAX (916) 262-1191 e-mail tseeno@ns.net

Editor: Wayne E. Clark, Department of Entomology, Auburn University, Auburn, AL 36849-5413, U.S.A. (334) 844-2565 FAX (334) 844-5005 e-mail wclark@acesag.auburn.edu

Councilors (1997-1998):
Cheryl Barr, Berkeley, CA
Frank Hovore, Santa Clarita, CA
Darren Pollock, Winnipeg, MB

Councilors (1998-1999):
George Ball, Edmonton, AL
Stewart Peck, Ottawa, ON
Art Evans, Los Angeles, CA

Periodicals Postage Paid at Sacramento, CA 95832-1448, and additional mailing office.

PRINTED BY ALLEN PRESS, INC., LAWRENCE, KANSAS 66044, USA

© This paper meets the requirements of ANSI/NISO Z39.48-1992 (Permanence of Paper).

Mailing date for this issue: December 21, 1998