Wax Production in Adults of Planthoppers (Homoptera: Fulgoroidea) with Particular Reference to *Metcalfa pruinosa* (Flatidae)

ANDREA LUCCHI[1] AND EMANUELE MAZZONI[2]

Ann. Entomol. Soc. Am. 97(6): 1294–1298 (2004)

ABSTRACT Although wax characteristics, wax-producing structures, and their probable functions in planthopper juveniles have been summarized in recent articles, very little has been published regarding the morphology of these structures in adults. In the Nearctic flatid *Metcalfa pruinosa* (Say), most wax is secreted on the forewings of both sexes and on the anal tube of females. There is also a sparse powdery layer of wax that lightly covers most of the body. Along most of the body surface and forewings many small glandular ring-shaped areas occur, delimiting a pore, from which single thin filaments of wax emerge. Moreover, numerous moniliform glandular pore-plates are randomly scattered on the surface of the forewings. On each plate, 8–50 subcircular pores are symmetrically arranged in one or two lines around a long central sensory hair. An internally hollow cylindrical wax ribbon emerges from each pore. In addition, many prominent glandular plates occupy the ventral surface of the female anal tube. Each plate is nearly circular and is marginally perforated by seven to eight pores from which long, hollow, cylindrical wax tubules emerge. These plates are not present on the anal tube of the male. Although the function of the anal tube wax is unknown, the wax layer that covers the body and forewings may play an important role in protection against abiotic factors and prevent smearing the cuticle with honeydew.

KEY WORDS wax, wax glands, cuticular pores, tegmina, anal tube

WAX SECRETIONS AND WAX-producing structures have been described in the primary insect orders (Waku and Foldi 1984). In the Homoptera, numerous studies have been published on wax production by aphidoid and coccoid Sternorrhyncha (Foldi and Cassier 1985, Foldi and Pearce 1985, Foldi 1991, Foldi and Lambdin 1995, Smith 1999). Few studies of wax secretion in Auchenorrhyncha have been conducted, although recently some studies have focused on wax-producing structures in Fulgoroidea, the most remarkable wax producers among insects (Yang and Yeh 1994, Bourgoin 1997, Sforza et al. 1999, Liang and Wilson 1999). More than 80 species of planthoppers were examined by Liang and Wilson (1999) to evaluate the taxonomic importance of the ultrastructure of the wax pores. Two older articles deal with wax pores in Flatidae (Bugnion and Popoff 1907, Sulc 1929), whereas only one recent study illustrated the features of wax secretions and cuticular pores in juveniles of *Metcalfa pruinosa* (Say) (Lucchi and Mazzoni 1999). However, analogous investigations have not been carried out with adults of this species.

This nearctic flatid (Dean and Bailey 1961) was introduced into northern Italy from the United States in the 1970s (Zangheri and Donadini 1980, Dlabola 1981). It has since spread through the Italian peninsula and into Sicily and Sardinia, as well as to some regions of France, Switzerland, Austria, Slovenia, Croatia, The Czech Republic, Spain, and Greece (Lucchi and Wilson 2003). Contrary to what has been documented for populations in the United States, population densities of *M. pruinosa* are extremely high in Italy, where it feeds on a wide range of host plants, including grapes, olives, citrus, apples, pears, peaches, and many ornamental plants (Wilson and Lucchi 2001). As such, it is of particular concern to applied entomologists (Bagnoli and Lucchi 2000). In this planthopper, the juveniles produce a considerable amount of wax that covers the whole body and is present on the plants as a whitish layer that protects against adverse abiotic and biotic factors, such as entomopathogenic fungi, parasitoid insects, and predators (Lucchi and Santini 2001). The highest concentration of wax glands occurs on abdominal segments VI, VII, and VIII of *M. pruinosa* nymphs. These wax glands present numerous cuticular pores grouped together to form diverse multiporous pads on the segments mentioned above; moreover, a great number of glands are generally distributed across the body surface (Lucchi and Mazzoni 1999). *M. pruinosa* adults also produce a powdery wax, but the amount is much smaller then that of juveniles.

Secretion of wax by adult fulgoroids is not as common as it is in immatures, but it is known for a number

[1] Sezione di Entomologia agraria, Dipartimento C.D.S.L. "G. Scaramuzzi," Università di Pisa, Via S. Michele degli Scalzi, 2, 56124 Pisa, Italy.

[2] Istituto di Entomologia e Patologia vegetale, Università Cattolica del Sacro Cuore, via Emilia Parmense, 84 29100, Piacenza, Italy.

0013-8746/04/1294–1298$04.00/0

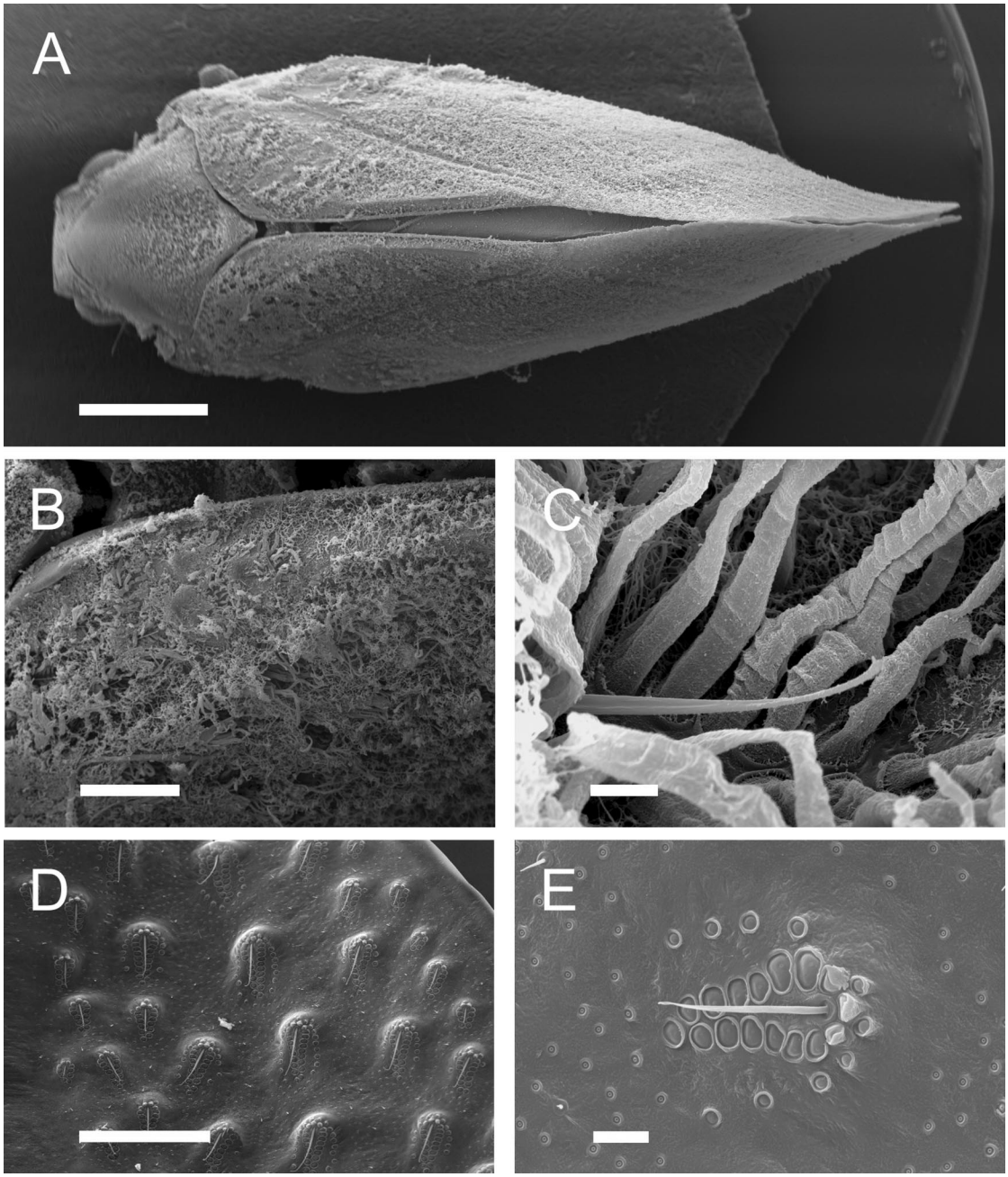

Fig. 1. (A) SEM micrograph of an adult *M. pruinosa* (dorsal view) (bar, 1 mm). (B) Detail of the anterior wing with wax in evidence (bar, 200 μm). (C) Wax ribbons emerging from a moniliform pore-plate, and thin wax threads protruding from the single pores of the ring-shaped areas (bar, 10 μm). (D) SEM detail of some moniliform plates in a chloroform dewaxed specimen (bar, 200 μm). (E) Moniliform plate at SEM and single pores with ring-shaped areas (bar, 20 μm).

of species, including the lophopids *Megacarne albosparsa* Melichar and *Pyrilla sinica* Liang; the fulgorids *Cerogenes auricoma* Burmeister and *Pterodictya reticularis* Olivièr; the eurybrachids *Purusha rubromaculata* Distant, *Purusha pulverosa* Distant and *Messena crudelis* Westwood; and several species of meenoplids and kinnarids (Bourgoin 1997, Liang 1997, 2001).

Within the family Flatidae, wax filaments on the body and forewings are present in the genera *Phromnia*, *Bythopsyrna*, *Adelidoria*, *Flatida*, *Poeciloflata*, and *Ulundia.* In the genus *Metcalfa*, a powdery wax is present on the cuticle of *Metcalfa frigida* (Metcalf & Bruner) and *Metcalfa regularis* (Fowler) adults.

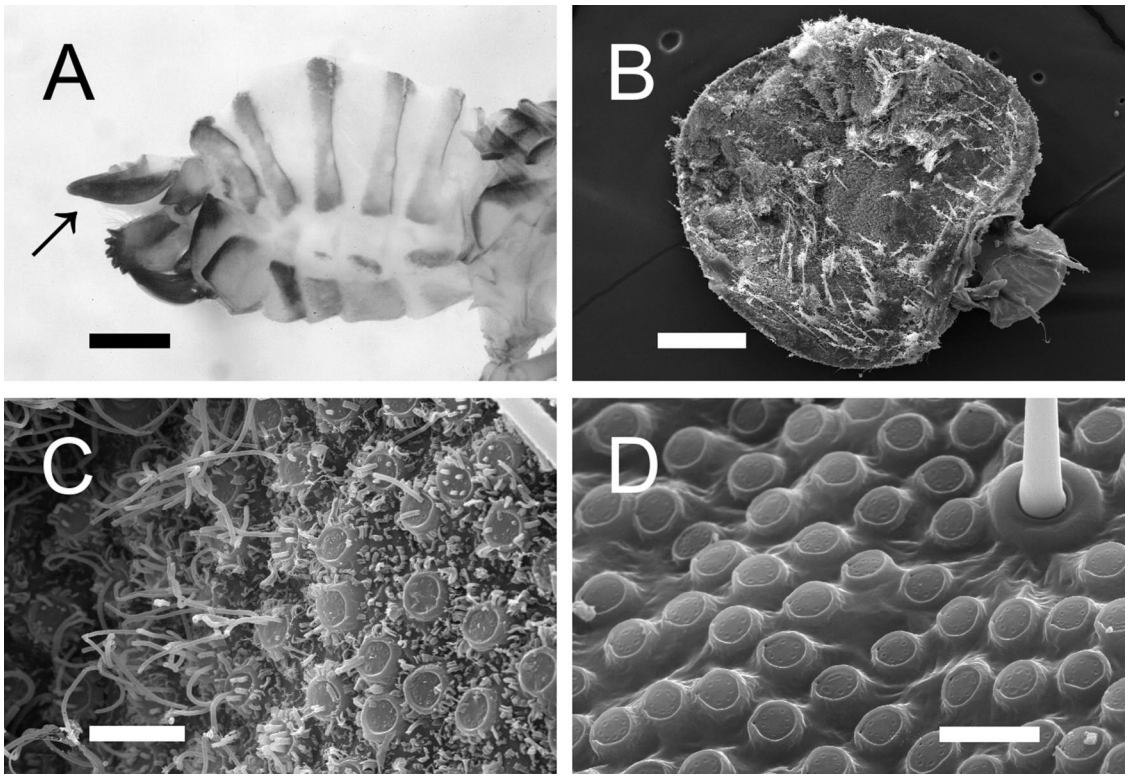

Fig. 2. (A) Female *M. pruinosa* abdominal profile with the anal tube in evidence (arrow) (bar, 0.5 mm). (B) SEM ventral view of a waxed female anal tube (bar, 200 μm). (C) Detail of B with wax tubules emerging from the pores (bar, 10 μm). (D) Wax pore-plates on a dewaxed anal tube (bar, 10 μm).

Here, we present light and scanning electron microscope (SEM) observations on the different types of glandular pores that cover the body cuticle and on the extruded wax in *M. pruinosa.*

Materials and Methods

For preliminary anatomical observations, some males and females collected in Pisa were cleared in a solution of 0.9% KOH and photographed as whole mounts with an interference contrast photomicroscope Zeiss III (Carl Zeiss, Göttingen, Germany).

Specimens for the scanning electron microscopic study were prepared in three ways. Most of them were gradually dehydrated in an ethanol series and dried with the critical point drying method by using a Baltec apparatus CPD 030 (BAL-TEC Inc., Balzers, Liechtenstein). Other specimens were immersed overnight in hot chloroform (≈40°C) and air-dried. Finally, a few of them were mounted on stubs without any cleaning or dehydrating. All specimens were gold-coated with a Pabish Top Autocoater SC-20 (Ted Pella Inc., Redding, CA). Observations and micrographs were carried out with a FEI (Philips) XL30 ESEM microscope (Philips Group, Eindhoven, The Netherlands).

Results and Discussion

In adults of *M. pruinosa*, wax is visible as a whitish layer that partially covers the body cuticle and forewings (Fig. 1A). It is present in a powdery and pruinose consistency that probably inspired Say (1830) in the choice of a specific name.

From SEM observation of the chloroform-dewaxed specimens, both sexes have numerous cuticular openings that are either generally distributed across the body surface or that are restricted to distinct regions of the body. The openings occur singly or are grouped together to give rise to differently shaped and sized pore-plates. The secreted wax is extruded as thin threads or cylindrical, internally hollow ribbons or tubules with different diameters, depending on the pores from which they emerge (Fig. 1B and C).

Thin threads are extruded from single pores surrounded by glandular ring-shaped areas (3–4 μm in diameter) randomly scattered on most of the body surface and forewings (Fig. 1D and E). Each thread has a diameter of ≈0.4 μm and is similar to the "microspaghetti" mentioned by Pope (1985).

Approximately 70 moniliform glandular pore-plates randomly cover the surface of each forewing. The pore-plates are 50–100 μm in length and depending on their size, have from 8 to 50 subunits. These pores have a diameter of 10–15 μm and are symmetrically ar-

ranged in one or two lines around a sensory hair, which probably has a mechanoreceptive function (Fig. 1D and E). An internally hollow cylindrical wax ribbon emerges from each pore (Fig. 1C).

Prominent glandular plates that almost fill the ventral side of the anal tube (Fig. 2A) are found only in *M. pruinosa* females. Each plate is nearly circular in shape (4 μm in diameter) and is marginally perforated by seven to eight pores (0.5 μm in diameter) (Fig. 2D), from which long, cylindrical, hollow wax tubules emerge (Fig. 2B and C). These plates are absent in male anal tubes, whereas, in the female, they have a density of $\approx$2 U/100 μm^2.

The moniliform glandular pore-plates, described above for *M. pruinosa,* are defined as "pustules" by taxonomists and are a recurrent feature in Flatidae (S. W. Wilson, personal communication). However, they have not previously been associated with the presence of epidermal wax glands. Preliminary light microscopic observations, carried out on anterior wings of other planthoppers, confirmed the existence of similar structures in the Nearctic flatids *Anormenis chloris* (Melichar) and *Ormenoides venusta* (Melichar), in the palearctic flatids *Phanthia subquadrata* (Herrich-Schäffer) and *Cyphopterum difforme* (Spinola), and in the American issid *Acanalonia conica* (Say), but until now, there has been no information available on a possible connection with wax-producing structures.

The function of the wax layer that covers the body and wings of *M. pruinosa* adults is probably connected, as in other homopterans (Smith 1999), with protection against abiotic factors such as UV radiation and rain. Moreover, in this species, the wax is likely to play an important role in preventing individuals from becoming contaminated with honeydew, continuously secreted by juveniles and adults, which would smear the cuticle with sticky droplets.

As far as we know, the existence of wax glands in the female anal tube of flatids has not been recorded. The function of the anal tube wax is still obscure for *M. pruinosa.* In other planthoppers, for example, the delphacid *Saccharosydne saccharivora* Westwood, the wax extruded from the internal surface of the valvifers is collected by the female with the hind legs and used to protect the eggs after they are inserted into an opening cut onto the host plant during oviposition (Metcalfe 1969). In some species of Cixiidae, the female lays eggs in the ground and covers them with the caudal wax tuft to protect them against changes in humidity and from being washed away by rain (Sforza et al. 1999). This is not the case with *M. pruinosa* females, in that they do not cover their eggs with wax or use wax in any other obvious way.

Acknowledgments

We thank Mick Webb for access to the fulgoroid collection of the Museum of Natural History, London (United Kingdom) and Prof. S. W. Wilson (Central Missouri State University, Warrensburg, MO) for providing some of the Nearctic species of planthoppers and for critical reading of the manuscript.

References Cited

Bagnoli, B., and A. Lucchi. 2000. Dannosità e misure di controllo integrato. *In* A. Lucchi [ed.], La Metcalfa negli ecosistemi italiani, ARSIA Regione Toscana 3: 65–88.

Bourgoin, T. 1997. The Meenoplidae (Hemiptera, Fulgoromorpha) of New Caledonia, with a revision of the genus *Eponisia* Matsumura 1914, and new morphological data on forewing venation and wax plate areas. *In* J. Najt and L. Matile [eds.], Zoologia Neocaledonica, vol. 4. Mémoires du Muséum national d'Histoire naturelle 171: 197–249.

Bugnion, E., and N. Popoff. 1907. Les glandes cirières de *Flata* (*Phromnia*) *marginella.* Bull. Soc. Vaudoise Sc. Nat. 43: 549–563.

Dean, H. A., and J. C. Bailey. 1961. A flatid planthopper, *Metcalfa pruinosa.* J. Econ. Entomol. 54: 1104–1106.

Dlabola, J. 1981. *Metcalfa pruinosa* (Say, 1830), eine schädliche nordamerikanische Flatide als Erstfund in der Palaearktis (Insecta, Homoptera, Auchenorrhincha, Faunistiche Abhandlungen 8: 91–94.

Foldi, I. 1991. The wax glands in scale insects: comparative ultrastructure, secretion, function and evolution (Hemiptera: Coccoidea). Ann. Soc. Entomol. France 27: 163–188.

Foldi, I., and P. Cassier. 1985. Ultrastructure comparée des glandes tégumentaires de treize familles de cochellines (Hemiptera: Coccoidea). Int. J. Insect Morphol. Embryol. 14: 33–50.

Foldi, I., and P. Lambdin. 1995. Ultrastructural and phylogenetic assessment of wax glands in pit scales (Hemiptera: Coccoidea). Int. J. Insect Morphol. Embryol. 24: 35–49.

Foldi, I., and M. J. Pearce. 1985. Fine structure of wax glands, wax morphology and function in the female scale insect, *Pulvinaria regalis* Canard. (Hemiptera: Coccidae). Int. J. Insect Morphol. Embryol. 14: 259–271.

Liang, A.-P. 1997. Sugarcane and rice planthoppers of the genus *Pyrilla* in southern China (Insecta: Homoptera: Auchenorrhyncha: Lophopidae). Reichembachia, Museum für Tierkunde, Dresden 32: 33–39.

Liang, A.-P. 2001. First record of the genus *Adolenda* Distant (Hemiptera: Fulgoroidea: Kinnaridae) from China, with description of one new species. Zool. Studies 40: 365–370.

Liang, A.-P., and M. R. Wilson. 1999. Wax and wax glands in Fulgoroidea (Hemiptera: Fulgoromorpha): morphological diversity and phylogenetic implications, p. 90. *In* Abstracts volume of the 10th International Auchenorrhyncha Congress, 6–10 September, 1999, Cardiff, United Kingdom. National Museums and Galleries of Wales, Cardiff, United Kingdom.

Lucchi, A., and E. Mazzoni. 1999. Wax glands and cuticular pores in nymphs of *Metcalfa pruinosa* (*Say*) (Homoptera Flatidae): a light and scanning electron microscopy study, p. 94. *In* Abstracts volume of the 10th International Auchennorhyncha. Congress, 6–10 September 1999, Cardiff, United Kingdom. National Museums and Galleries of Wales, Cardiff, United Kingdom.

Lucchi, A., and L. Santini. 2001. Aspetti fisiologici e morfofunzionali in *Metcalfa pruinosa* (Homoptera: Fulgoroidea) con riferimento agli effetti prodotti sulle produzioni agricole e sulle alberature ornamentali. Atti dell'Accad. Nazionale Ital. Entomol., Rendiconti, Anno XLIX 2001: 131–147.

Lucchi, A., and S. W. Wilson. 2003. Notes on the dryinid parasitoids of planthoppers (Hymenoptera: Dryinidae; Hemiptera: Flatidae, Issidae). J. Kans. Entomol. Soc. 76: 34–37.

Metcalfe, J. R. 1969. Studies on the biology of the sugar-cane pest *Saccharosydne saccharivora* (Westwood) (Hom., Delphacidae). Bull. Entomol. Res. 59: 393–408.

Pope, R. D. 1985. Visibile insect waxes: form, function and classification. Antenna 9: 4–8.

Say, T. 1830. *Flata pruinosa* Say. J. Acad. Nat. Sci. Philadelphia 6: 237.

Sforza, R., Bourgoin, T., Wilson, S. W., and E. Boudon-Padieu. 1999. Field observations, laboratory rearing and descriptions of immatures of the planthopper *Hyalesthes obsoletus* (Hemiptera: Cixiidae). Eur. J. Entomol. 96: 409–418.

Smith, R. G. 1999. Wax glands, wax production and the functional significance of wax use in three aphid species (Homoptera: Aphididae). J. Nat. Hist. 33: 513–530.

Sulc, K. 1929. Voskové zlazy a jejich vyrobky u larev *Flata* (*Phromnia*) *marginella* d'Olivier. (Die wachsdrüsen und ihre produkte bei den larven von *Flata* (*Phromnia*) *marginella* d'Olivier). Biologicke Spisi Vysoke Skoly Zverolekarske, Brno, VIII: 1–23.

Waku, Y., and I. Foldi. 1984. The fine structure of insect glands secreting waxy substances, 2: 303–364. *In* R. C. King and H. Akai [eds.], Insect ultrastructure. Plenum, New York.

Wilson, S. W., and A. Lucchi. 2001. Distribution and ecology of *Metcalfa pruinosa* and associated planthoppers in North America (Homoptera: Fulgoroidea). Atti dell'Accad. Nazionale Ital. Entomol., Rendiconti Anno XLIX: 121–130.

Yang, C.-T., and W.-B. Yeh. 1994. Nymphs of Fulgoroidea (Homoptera: Auchenorrhyncha) with descriptions of two new species and notes on adults of Dictyopharidae. Chinese J. Entomol., special publication 8: IV + 189 pp.

Zangheri, S., and P. Donadini. 1980. Comparsa nel Veneto di un omottero neartico: *Metcalfa pruinosa* Say (Homoptera, Flatidae). Redia 63: 301–306.

Received 19 December 2003; accepted 24 May 2004.