

Mealybugs (Hemiptera: Pseudococcidae) on ornamental plants in West Java, Indonesia with a new country species record, and their natural enemies

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Abstract. *Viorenta*, *Sartiamei D*, *Maryana N*, *Watson GW*, *Zarkani A*. 2025. Mealybugs (Hemiptera: Pseudococcidae) on ornamental plants in West Java, Indonesia with a new country species record, and their natural enemies. *Biodiversitas* 26: 1018-1029. Part of Indonesia's biodiversity in ornamental plants has been developed for the global market. However, one of the constraints in meeting market demand is the presence of mealybug pests, which can reduce plant beauty, vigor, and economic value of plants. This study identifies mealybug species associated with ornamental plants in Indonesia and their natural enemies based on morphological characteristics. The research found 15 mealybug species, 14 of which had been previously recorded in West Java, Indonesia, namely *Dysmicoccus brevipes*, *D. neobrevipes*, *Exallomochlus hispidus*, *Ferrisia virgata*, *Maconellicoccus hirsutus*, *Nipaecoccus nipae*, *Paracoccus marginatus*, *Phenacoccus solenopsis*, *Planococcus lilacinus*, *Pl. minor*, *Pseudococcus jackbeardsleyi*, *Ps. longispinus*, *Rastrococcus iceryoides* and *R. spinosus*. The fifteenth species, *Spilococcus mamillariae*, found on cacti, is a new record for Indonesia and Southeast Asia. This study also documented various natural enemies, including both predators and parasitoids. Seven predator species were identified, six of which belonged to Coleoptera: Coccinellidae, namely *Cryptolaemus montrouzieri*, *Curinus coeruleus*, *Illeis* sp., *Nephus* sp., *Cheilomenes sexmaculata*, and *Scymnus* sp.; and one species of Neuroptera: Chrysopidae: *Plesiochrysa ramburi*. Hymenopteran parasitoids were found belonging to two families: Encyrtidae (*Anagyrus pseudococci*, *A. mirzai*, *Blepypus insularis* and *Gyranusoidea tebygi*); and Eulophidae (*Aprostocetus* sp.). Furthermore, Hymenopteran hyperparasitoids belonging to the families Aphelinidae (*Promuscidea unfaiciatventris*) and Encyrtidae (*Prochiloneurus* sp. and *Prochiloneurus nagasakiensis*) were also recorded.

Keywords: *Anagyrus*, cacti, *Cryptolaemus montrouzieri*, morphology, *Spilococcus mamillariae*

INTRODUCTION

Indonesia produces a variety of horticultural commodities, including ornamental plants that are widely used for indoors and garden decorations. The interest in ornamental plants is based on their artistic, architectural, and aesthetic values, particularly the shape and color of their leaves and flowers. They also play an ecological role by absorbing Carbon dioxide (CO₂) and producing Oxygen (O₂), which are essential for many life forms (Francini et al. 2022). In interior spaces, ornamental plants contribute to a refreshing and comfortable human environment (Yerjanovich and Mamadiyoroglu 2021). Consequently, the cultivation of ornamental plants and flowers for cutting is widespread, and they are increasingly used in ceremonies, weddings, religious events and for decoration, congratulations, condolences, and even for medicinal purposes (Van Tuyl et al. 2014; Magsi et al. 2019).

The high economic value and promising business opportunities in ornamental-plant production are supported by changing perceptions, lifestyles, and hobbies like gardening and collecting, resulting in high demand. Indonesia has rich plant biodiversity, including about

27,500 species with ornamental potential, and about 10% of the ornamental plant species are used worldwide (Mubarak et al. 2023); they, therefore, contribute to Indonesia's Gross Domestic Product (GDP), ranking fourth among all the horticultural crops grown. The production of ornamental plants in 2021 was 616 million cut stems and leaves and 39 million trees; in 2022, it increased to 711 million cut stems and leaves and 44 million trees (BPS 2022).

Some ornamental plants that are in great demand in both local and international markets are members of the families Araceae (*Aglaonema* sp., *Alocasia* sp., *Anthurium* sp., *Philodendron* sp. and *Syngonium* sp.); Agavaceae (*Dracaena* sp.); Asteraceae (*Chrysanthemum* sp.); and Apocynaceae (*Adenium* sp.), among many others. Ornamental Araceae are of high economic value because they form unique patterns and shapes and are used to improve indoor aesthetics in interior design; they are easy to maintain and are tolerant of various indoor and outdoor environmental conditions. *Adenium* spp. thrive in low-light environments, require minimal maintenance such as watering and fertilization, and can filter out air pollutants, making them highly desirable internationally (Setiawati et al. 2024). Indonesia has a wide diversity of Araceae; about

410 species in 31 genera grow in Sumatra, Java, Kalimantan, Sulawesi, and Papua (Qodriyah et al. 2021). The most important export markets for ornamental plants are Japan, Netherlands, United States of America, Canada, Australia, Thailand, Taiwan, Singapore, South Korea, Germany, Philippines, Hong Kong, Poland, United Kingdom, France and Sweden (BPS 2022).

One of the main constraints on ornamental plant cultivation worldwide, whether in greenhouses, indoors, or outdoors in open fields, is mealybug infestation. Mealybugs are waxy phytophagous insects belonging to the family Pseudococcidae, superfamily Coccoidea, and order Hemiptera. They can spread rapidly, cause severe damage to the host plant, and are difficult to control with topical insecticide applications (Omkar 2021). Infestations on ornamental plants for export are a significant problem at quarantine inspection because mealybugs can be transported on live plants, survive in cool storage, and are difficult to control. They often live in groups and are frequently associated with unsightly wax deposits and sooty molds (Mani and Shivaraju 2016), which disfigure the plants and can reduce leaf vigor and form, thus reducing their economic value.

Chemical pesticides are the most common method used to control mealybugs, but the waxy coating on the insects sometimes makes applications ineffective. The main active ingredients used to control mealybugs are profenophos, triazophos, carbaryl, imidacloprid, methidathion, organophosphates, and pyrethroids (Rasheed et al. 2014). However, these broad-spectrum insecticides affect non-target insects (e.g. pollinators and natural enemies), and pesticide residues can have long-term environmental impacts (Barbosa et al. 2018). Such adverse effects mean alternative biological controls are needed to reduce mealybug abundance below the economic threshold without using pesticides. Biological controls are more environmentally friendly so that the ecosystem can be sustainable. Insect natural enemies like predators and parasitoids are the primary agents that suppress mealybug populations. Natural enemies in Indonesia are diverse and

abundant, but their information is still limited, especially for mealybug control. The study, therefore, aimed to identify the mealybug species associated with ornamental plants in Indonesia and their natural enemies.

MATERIALS AND METHODS

Study area

The research sampling was conducted from August 2023 to April 2024 on the Indonesian island of Java, in Bogor City, Bogor District, and Cianjur District, West Java (Table 1).

Procedures and data analysis

Sampling and observing morphological characteristics

Members of the family Araceae and various other types of ornamental plants infested with mealybugs were sampled. Sampling was done manually in several locations, such as greenhouses, flower gardens, and other outdoor settings (Table 1). Mealybugs infested on leaves or twigs were cut and put into labeled plastic boxes. In the laboratory, the mealybug specimens were carefully placed under an Olympus SZ51 stereo microscope and photographed or documented to determine the morphological characteristics of the body and wax; then all mealybug specimens were placed into 1.5 mL microtubes containing 95% ethanol using a fine brush and stored at 20°C before slide mounting.

Preparation of mealybugs for identification

Identification of mealybugs and their natural enemies was carried out in the Insect Biosystematics Laboratory, Department of Plant Protection, Faculty of Agriculture, Institut Pertanian Bogor, Bogor. Adult female mealybugs preserved in 95% ethanol were prepared in microscope slide mounts using a method modified from Watson and Chandler (2000) and Sirisena et al. (2013). Adult females were heated in 95% ethanol in a test tube at 70°C for five minutes before each specimen was pierced dorsoventrally using a microneedle and were then heated in 10% KOH.

Table 1. Locations in Java, Indonesia, sampled for mealybugs (Hemiptera: Pseudococcidae) on ornamental plants

City / District	District	Location	GPS coordinates	Altitude (m asl)
Bogor City	Tanah Sareal	Outdoor	6.5360S 106.7863E	193
	Jalan Raya Cifor	Outdoor	6.5620S 106.7502E	208
	Bogor Barat	Greenhouse	6.5858S 106.7823E	256
	Bogor Tengah	Greenhouse	6.5954S 106.8033E	271
Bogor District	Kemang (Setapak)	Greenhouse	6.5072S 106.7605E	127
	Kemang (Parakan)	Greenhouse	6.5190S 106.7634E	169
	Dramaga	Greenhouse	6.5646S 106.7352E	199
	Taman Sari	Greenhouse	6.6491S 106.7690E	504
	Cijeruk	Greenhouse	6.7039S 106.7987E	510
	Cigombong	Greenhouse	6.7131S 106.8006E	518
	Tenjolaya	Greenhouse	6.6549S 106.7150E	642
	Cisarua (Sirnarasa)	Flower garden	6.6552S 106.9205E	718
	Cisarua (Gadog)	Greenhouse	6.7010S 106.9932E	1436
	Cianjur District	Sukaresmi	Flower garden	6.7277S 107.0823E
Pacet		Greenhouse	6.7073S 107.0574E	927

The body contents of each mealybug were gently expressed. The clean cuticle was immersed in a stain mixture of acid fuchsin (two drops) and glacial acetic acid (two drops) for two minutes to 24 hours before being rinsed in a series of graduated ethanol at 80%, 95%, and 100%, for 5-10 minutes in each. Each cuticle was then immersed in carbol xylene (50:50 phenol crystals: xylene by volume) for three minutes to remove fats and waxes and rinsed again in 100% ethanol before being immersed in clove oil for 5-10 minutes to clear. The cuticle was then transferred to a glass microscope slide, and one drop of Canada balsam was added before a cover glass was lowered onto the specimen. Slide mounts were dried on a hotplate for 12-24 hours at 40°C before being examined.

Identification of mealybugs

Slide-mounted mealybugs were identified using an Olympus CX 33 compound light microscope connected to a computer monitor. Identification was performed by observing specific morphological characteristics using the keys and species descriptions provided by Williams and Ganara (1992) and Williams (2004).

Natural enemies

Predators were found during field observations. Larvae predators were put into plastic boxes to be reared until they reached the imago stage, whereas adults were preserved immediately in microtubes containing 95% ethanol. Mealybugs showing symptoms of parasitoid infestation were placed individually in 2 ml microtubes for rearing; when the adult parasitoid wasps emerged, they were preserved in a fresh microtube containing 95% ethanol. All the natural enemies were identified. Predators were determined using CSIRO (1996) and a key based on Bienkowski (2018), while parasitoids were identified using Noyes and Hayat (1988), Goulet and Huber (1993) and Gibson et al. (1997).

RESULTS AND DISCUSSION

A morphological study of mealybugs from ornamental plants in greenhouses and open fields identified 15 species (Table 2). *Dysmicoccus brevipes*, *D. neobrevipes*, *Exallomochlus hispidus*, *Ferrisia virgata*, *Maconellicoccus hirsutus*, *Nipaecoccus nipae*, *Paracoccus marginatus*, *Phenacoccus solenopsis*, *Planococcus lilacinus*, *Pl. minor*, *Pseudococcus jackbeardsleyi*, *Ps. longispinus*, *Rastrococcus iceryoides*, and *R. spinosus*. Based on the data of a checklist of Indonesian scale insects (Zarkani et al. 2021), 14 species of mealybugs are already present in Indonesia, but the species, *Spilococcus mamillariae* is a new record for Indonesia and Southeast Asia.

Morphological characteristics

Mealybugs are easily recognized because they secrete a white, powdery wax coating over the soft body that protects the body and eggs from adverse environmental conditions, including pesticide applications, retain moisture, and protect them from their natural enemies. The

shape of the body and wax secretions on the dorsal surface and the lateral filaments and ovisac vary between mealybug species; however, age and environmentally induced variation can make these characters quite variable. Therefore, the authoritative identification of species was based on the morphology of slide-mounted cuticles, which is a much more reliable identification method. An identification key to separate slide-mounted adult females of the 15 species in this study is provided below.

Identification based on cuticular characters confirmed initial tentative identifications based on live appearance, especially when wax character-based identification was difficult or impossible because the wax had been damaged or lost. Descriptions of live appearances are given below.

Dysmicoccus brevipes

This mealybug has a broad host-plant range of 68 families and 167 genera (Morales et al. 2024). The body of the adult female is oval, about 2.0-3.3 mm long (Figure 1.A); the body contents are pink, and the cuticle is covered by a thin layer of powdery white wax. The dorsum lacks bare areas or dorsal ovisac material; the lateral wax filaments number 17 pairs, each filament slightly curved; the anterior filaments are shorter than the posterior ones; the posterior-most pair of filaments is longer than 1/3 or 1/2 of the body length (Mani and Shivaraju 2016). The legs are yellowish brown.

Dysmicoccus neobrevipes

This mealybug has a relatively wide host-plant range, including 41 families and 69 genera (Morales et al. 2024). The body of the adult female is oval, about 2.0-3.8 mm long (Figure 1.B), grayish and covered with flocculent wax, and the dorsum lacks bare areas or dorsal ovisac material; the lateral wax filaments' number is 17 pairs, each filament slightly elongated and curved; the anterior filaments are shorter than the posterior ones; the posteriormost filaments are longer than 1/3 or 1/2 of the body length (Mani and Shivaraju 2016). The legs are yellow-brown.

Maconellicoccus hirsutus

This mealybug has an extensive host-plant range, including 84 families and 258 genera (Morales et al. 2024). The body of the adult female is oval, about 2.0-4.2 mm long; body contents pink to dark red (Figure 2.E); the cuticle is covered with powdery white wax so thin that the body color is visible through it; the dorsum lacks bare areas, and dorsal ovisac material is present; the lateral wax filaments are not visible, and the posterior-most filaments are short and thick. The legs and antennae are yellow. Unless exposed to heat after death, the body contents gradually turn black when preserved in ethanol.

Nipaecoccus nipae

This neotropical species has a host-plant range of 51 families and 118 genera (Morales et al. 2024). The body of the adult female is subcircular, slightly flattened, and about 1.5-2.2 mm long (Figure 1.F), and the body contents are orange-brown. The cuticle is covered with a thick layer of

pale-yellow powdery wax; the center of the dorsum has intermittent flocculent wax cushions but lacks bare areas of cuticle or dorsal ovisac material. The lateral wax filaments are conical, each being thick at the base and tapering towards the tip, and number 10-12 pairs; the posterior-most filaments are slimmer and slightly longer than the anterior ones. Unless exposed to heat after death, body contents gradually turn black when preserved in ethanol.

Exallomochlus hispidus

This mealybug is native to Southeast Asia, and its host-plant range includes 27 families and 40 genera (Morales et al. 2024); in the Asian region, its host range consists of 30 families and 41 host-plant species, including fruit crops, ornamental plants, and plantation crops (Indarwatmi et al. 2021). The body of the adult female is oval and pinkish-brown, about 2.0-2.5 mm long (Figure 1.C), and is covered

with reasonably thick flocculent wax, this thinner on the dorsum but without bare areas or dorsal ovisac material; the lateral wax filaments number 18 pairs, each filament thick; the posteriormost three pairs of filaments are longer than the anterior filaments. The legs are yellowish-brown.

Ferrisia virgata

This neotropical species has a wide host-plant range, including 82 families and 228 genera (Morales et al. 2024). The body of the adult female body is elongated and oval, about 2.0-4.7 mm long (Figure 1.D); it is yellow-brown in young adults but subsequently turns grayish; the dorsum has two dark gray submedian longitudinal stripes. The body has numerous slender, glassy, fine white protruding filaments. The adult female is without lateral wax filaments but except for a pair of long, thick white caudal filaments posteriorly, like long tails. The legs are yellowish-brown.

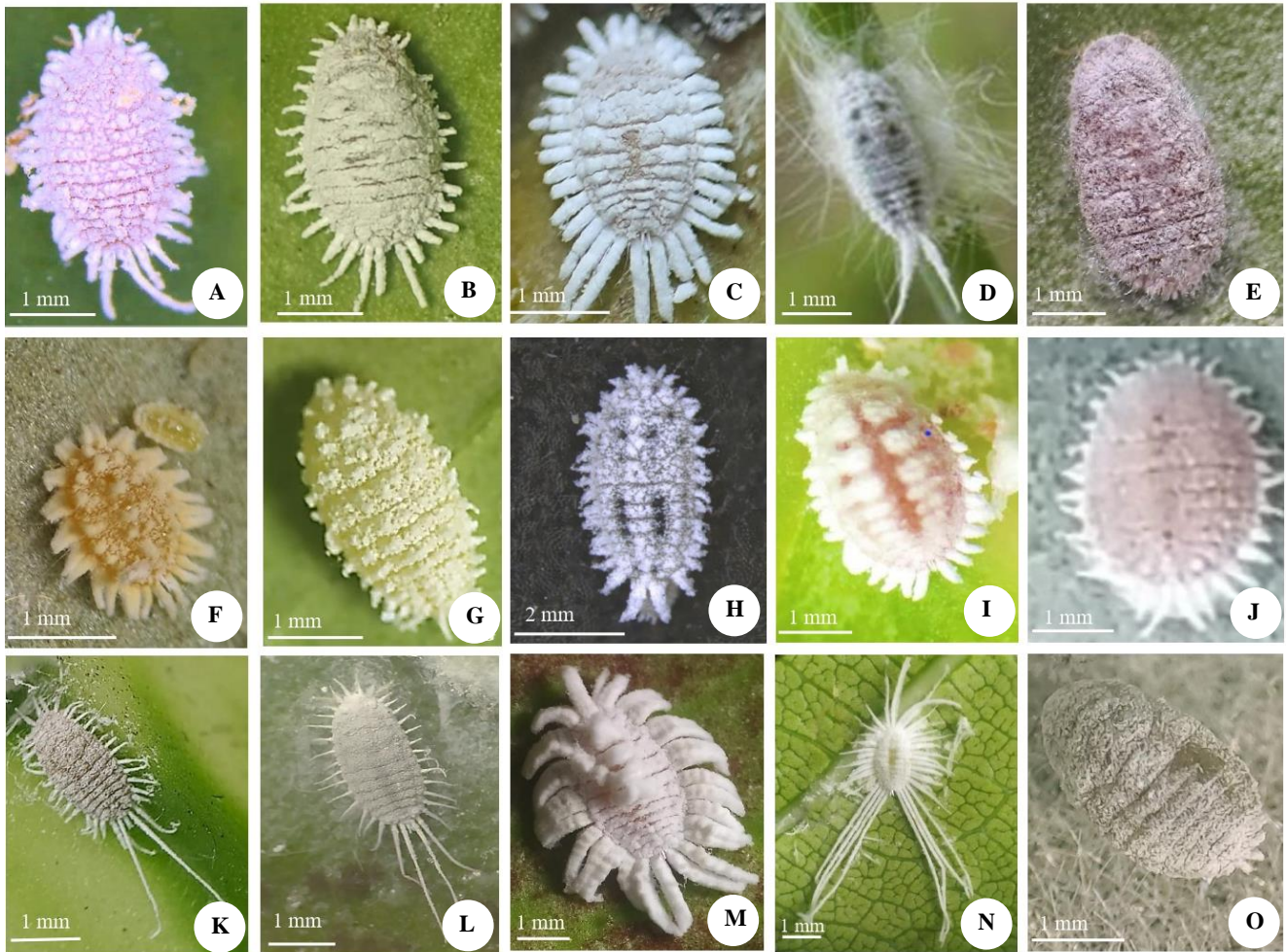


Figure 1. Mealybug adult females of: A. *Dysmicoccus brevipes*; B. *Dysmicoccus brevipes*; C. *Exallomochlus hispidus*; D. *Ferrisia virgata*; E. *Maconellicoccus hirsutus*; F. *Nipaeococcus nipae*; G. *Paracoccus marginatus*; H. *Phenacoccus solenopsis*; I. *Planococcus lilacinus*; J. *Planococcus minor*; K. *Pseudococcus jackbeardsleyi*; L. *Pseudococcus longispinus*; M. *Rastrococcus iceryoides*; N. *Rastrococcus spinosus*; O. *Spilococcus mamillariae*

Table 2. The mealybug species (Hemiptera: Pseudococcidae) identified, and their ornamental host plants

Mealybugs	Ornamental plant families and species																						
	A	B	C	D	E					F			G		H		I	J	K	L	M	N	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
<i>Dysmicoccus brevipes</i>	-	-	-	●	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Dysmicoccus neobrevipes</i>	-	-	●	-	-	●	●	-	-	-	●	-	-	-	-	-	-	-	-	-	-	-	-
<i>Exallomochlus hispidus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	●	-	-	-
<i>Ferrisia virgata</i>	-	-	-	-	-	●	●	●	●	●	-	-	-	●	-	-	●	-	-	●	-	-	-
<i>Maconellicoccus hirsutus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Nipaeococcus nipae</i>	-	-	●	-	-	-	-	●	●	-	-	-	●	-	-	-	-	-	-	-	-	●	-
<i>Paracoccus marginatus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	●	-	-
<i>Phenacoccus solenopsis</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	-	-	●	-
<i>Planococcus lilacinus</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-
<i>Planococcus minor</i>	-	-	-	●	-	-	●	-	-	-	-	●	-	●	-	-	-	-	-	-	-	-	-
<i>Pseudococcus jackbeardsleyi</i>	-	-	-	-	●	●	●	-	●	-	-	-	-	●	-	-	-	-	-	-	-	-	-
<i>Pseudococcus longispinus</i>	-	●	-	-	-	●	-	-	-	●	-	-	-	-	-	-	-	-	-	-	-	-	●
<i>Rastrococcus iceryoides</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	-
<i>Rastrococcus spinosus</i>	●	-	-	-	●	-	-	●	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Spilococcus mamillariae</i>	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	●	-	-	-	-	-	-	-

Note: Plant families: A. Acanthaceae; B. Adiantaceae; C. Agavaceae; D. Apocynaceae; E. Araceae; F. Arecaceae; G. Asteraceae; H. Cactaceae; I. Euphorbiaceae; J. Heliconiaceae; K. Leguminosae; L. Malvaceae; M. Moraceae; N. Orchidaceae. Plant species: 1. *Pseuderanthemum reticulatum*; 2. *Adiantum incisum*; 3. *Yucca aloifolia*; 4. *Adenium arabicum*; 5. *Plumeria rubra*; 6. *Aglonema* spp.; 7. *Alocasia baginda*; 8. *Anthurium crystallinum*; 9. *Philodendron* sp.; 10. *Syngonium* sp.; 11. *Cyrtostachys renda*; 12. *Dypsis lutescens*; 13. *Veitchia merrillii*; 14. *Chrysanthemum* spp.; 15. *Helianthus annuus*; 16. *Gymnocalycium* sp.; 17. *Codiaeum variegatum*; 18. *Euphorbia pulcherrima*; 19. *Heliconia* spp.; 20. *Bauhinia kockiana*; 21. *Hibiscus rosasinensis*; 22. *Ficus* sp; 23. *Phalaenopsis amabilis*. ●: Present, -: Absent

Paracoccus marginatus

This neotropical species has a host-plant range of 58 families and 189 plant genera (Morales et al. 2024). The body of the adult female body is oval, about 2.0-3.1 mm long (Figure 1.G); the body contents are yellowish; the cuticle is covered with a thin layer of mealy white wax; the dorsum lacks bare areas, a white wax ovisac is formed, and sometimes the ovisac material extends onto the dorsum. Lateral wax filaments number 16 or 17 pairs, all very short. The posterior-most filaments are about 1/8 as long as the body, slightly longer than lateral filaments (Joshi et al. 2022). Unless exposed to heat after death, the body contents soon turn black when preserved in ethanol.

Phenacoccus solenopsis

This new-world species has a host-plant range of 66 families and 226 plant genera (Morales et al. 2024). The body of the adult female is oval-shaped (Figure 1.H), slightly convex when viewed from the side; it is coated with relatively thick wax and looks slightly gray-green. On the dorsum, the body has two longitudinal blackish submedial lines down the thoracic segments, the abdomen is slightly serrated, and it produces a ventral ovisac. The lateral waxy filaments are short and coarse and number 18 pairs. The posterior-most waxy filaments are about 1/7 (Joshi et al. 2022) to 1/4 as long as the body (Mani and Shivaraju 2016). The legs are slightly reddish.

Planococcus lilacinus

This mealybug has a host-plant range of 66 families and 226 genera (Morales et al. 2024). The body of the adult female body is broadly oval, about 2.0-3.5 mm long and 1-2 mm wide (Figure 1.I); the body contents are reddish-brown. The cuticle is covered with thick, powdery white wax, except for a dorsomedial bare area that forms a wide longitudinal line; the dorsum lacks ovisac material. The

lateral wax filaments number 18 pairs, broad; each filament is concave, and the posterior-most filaments are curved; all the wax filaments are subequal in length, each being about 1/8 as long as the body (Mani and Shivaraju 2016). Unless exposed to heat after death, the body contents gradually turn black when preserved in ethanol.

Planococcus minor

This mealybug has a host-plant range of 86 families and 278 genera (Morales et al. 2024). The body of the adult female body is oval, about 2.0-3.3 mm long and 1.0-2.0 mm wide (Figure 1.J); the body contents are pink to orange-brown. The cuticle is covered with a relatively thin layer of powdery white wax, except for a narrow longitudinal dorsomedial bare area. Ovisac material is usually confined to the venter. The lateral waxy filaments number 18 pairs, short and slightly curved; the posterior-most pair of filaments is more extended and somewhat curved. The legs are reddish brown.

Pseudococcus jackbeardsleyi

This neotropical species has a host-plant range of 55 families and 118 genera (Morales et al. 2024). The body of the adult female body is relatively long and oval, about 2.0-3.5 mm long (Figure 1.K); body contents are grayish brown. The cuticle is covered with a relatively thin layer of powdery white wax and lacks dorsal ovisac material; it has slightly raised dorsomedial and submarginal lines, the dorsomedial line being broader than a submarginal line; the dorsomedial line intersects with horizontal segmental lines, forming darker depressions in the abdominal surface (Joshi et al. 2022). The ovisac is formed beneath the venter of the abdomen. The number of lateral wax filaments is 17 pairs, and the shape is slender (Sartiami et al. 2016); the anal wax filaments are as long as or longer than the body, sometimes being up to twice the body length (Mani and Shivaraju

2016). The legs are yellowish.

Pseudococcus longispinus

This mealybug has a host-plant range of 105 families and 233 genera (Morales et al. 2024). The body of the adult female body is elongated oval, about 2.0-3.2 mm long (Figure 1.L), and slightly convex in lateral view; the body contents are yellowish to grayish. The cuticle is covered with a thin layer of powdery white wax, sometimes leaving

the body color visible. The dorsum is covered with a layer of powdery white wax, with three longitudinal stripes having slightly less wax: one broad dorsomedial stripe and two narrow submarginal stripes. The species does not secrete an ovisac. The lateral wax filaments are slender, number 17 pairs, each about half as long as the body width; the posterior-most filaments are longer, sometimes almost twice as long as the body. The legs are yellowish.

Key to separate adult females of mealybug species found on ornamental plants in West Java, Indonesia

- 1(0) Cerarian setae numbering more than 12 per cerarius, each enlarged seta with tip truncate. Circulus subrectangular, short but very wide. Venter with quinquelocular pores 2
- Cerarian setae numbering fewer than 9 per cerarius, each enlarged seta with the tip pointed. Circulus quadrate/ oval, about as wide as long. Venter without quinquelocular pores 3
- 2(1) Cerarian setae set on membranous cuticle; some cerarii tend to merge together. Anterior ostioles absent. Anal ring surrounded by a row of extra-long flagellate setae *Rastrococcus iceryoides*
- Cerarian setae set on sclerotized cuticle; cerarii all separate. Anterior ostioles present. Anal ring not surrounded by a row of extra-long flagellate setae *Rastrococcus spinosus*
- 3(1) With only 1 pair of cerarii, situated on anal lobes. Specialised oral rim ducts present, each very large and with a flat, sclerotised rim containing several flagellate setae *Ferrisia virgata*
- With 4-18 pairs of cerarii. If oral rim ducts present, each duct quite small and with an unsclerotised raised rim; if rim associated with setae, these are located outside the rim 4
- 4(3) With oral rim ducts present on dorsum at least 5
- Without any oral rim ducts 14
- 5(4) Cerarii numbering 16 or 17 pairs 6
- Cerarii numbering 4-15 or 18 pairs 8
- 6(5) Oral rim ducts are confined to the margins/ submarginal of the body *Paracoccus marginatus*
- Oral rim ducts present in medial areas of the dorsum as well as near margins 7
- 7(6) Most or all cerarii each associated with 2 or 3 dorsal oral rim ducts of 2 sizes. Oral rim ducts are not closely associated with flagellate setae. Anal lobe cerarius sclerotization is larger than anal ring. Eye without a sclerotized rim *Pseudococcus longispinus*
- Only about 50% of cerarii each associated with just one dorsal oral rim duct. Oral rim ducts are all of similar size, with some closely associated with 1 or 2 flagellate setae. Anal lobe cerarius sclerotization is smaller than an anal ring. Eye with a sclerotized rim containing several discoidal pores *Pseudococcus jackbeardsleyi*
- 8(6) Cerarii numbering 4-16 pairs 9
- Cerarii numbering 17 or 18 pairs (occasionally more) 11
- 9(8) Antenna with seven segments. Dorsal setae conical. Circulus is small and more-or-less circular. Cerarii present on abdomen only, numbering 6 or 7 (occasionally 8) pairs. *Nipaeoccus nipae*
- Antenna with 8 or 9 segments. Dorsal setae are slender, spinose, or flagellate. Circulus oval or quadrate. Cerarii numbering 4-18 pairs (occasionally more), present on the abdomen and sometimes on the thorax and/ or head. 10
- 10(9) Antenna with eight segments. Dorsum with oral rim ducts widely spaced. Cerarii numbering 8-13 pairs, with at least seven pairs on the abdomen. Venter of anal lobe without sclerotized bar *Spilococcus mamillariae*
- Antenna with nine segments. Dorsum with numerous oral rim ducts in dense transverse rows across all segments. Cerarii numbering 4-6 (occasionally 7) pairs, all on the abdomen. Venter of the anal lobe with a partial sclerotized bar *Maconellicoccus hirsutus*
- 11(8) Venter of anal lobe without sclerotized bar. Dorsal setae lanceolate. Circulus shape variable, oval to anvil-shaped. Antenna with 9 (occasionally 8) segments *Phenacoccus solenopsis*
- Venter of anal lobe with sclerotized bar. Dorsal setae slender, stiff or flagellate. Circulus is oval to quadrate. Antenna with 8 segments 12
- 12(11) Abdominal cerarii, each containing only two conical setae. Dorsal setae are slender, about the same length as ventral setae or shorter. Venter of the anal lobe with sclerotized bar not connected to any other cuticular sclerotization 13
- Abdominal cerarii, each containing four or more conical setae. Many dorsal setae are thick and flagellate, longer than ventral setae. Venter of the anal lobe with sclerotized bar on the inner edge of the triangular area of cuticular sclerotization *Exallomochlus hispidus*
- 13(12) Dorsal setae flagellate is about the same length as ventral setae. Ventral margins of thorax with numerous oral collar ducts *Planococcus lilacinus*
- Dorsal setae are stiff and shorter than ventral setae. Ventral margins of the thorax with very few or no oral collar ducts *Planococcus minor*
- 14(4) Dorsum of abdominal segment VIII with a median group of extra-long flagellate setae and discoidal pores larger than a trilocular pore. Cerarii on anterior abdominal segments, each containing only two conical setae *Dysmicoccus brevipes*
- Dorsum of abdominal segment VIII with normal-length setae and a few discoidal pores. Cerarii on anterior abdominal segments, each containing more than two conical setae *Dysmicoccus neobrevipes*

Rastrococcus iceryoides

This mealybug has a host-plant range spanning 33 families and 86 genera (Morales et al. 2024). The body of the adult female body is broadly oval, slightly convex in lateral view, about 2.5-4.0 mm long (Figure 1.M); the body contents are yellowish. The cuticle is covered with thick, flocculent white wax, with three prominent medial dorsal tufts on the head and thorax; sometimes the midline of the abdomen has a longitudinal median ridge of wax with bare areas on either side. A white fluted ovisac is secreted from the venter of the abdomen. The lateral wax filaments are long and smooth and number 17 pairs; each lateral filament is broad at the base or rounded and thick, tapering towards the apex; together, the lateral filaments form a plate-like fringe; the anterior filaments are each about 1/2 as long as the body width, whereas the posterior filaments are each about 1/4 as long as the body (Mani and Shivaraju 2016). The legs are yellow-brown.

Rastrococcus spinosus

This mealybug has a host-plant range covering 19 families and 25 genera (Morales et al. 2024). The body of the adult female body is slightly elongated oval, about 3.5-4.5 mm long (Figure 1.N); the body contents are yellowish green. The cuticle is well coated with powdery white wax, except for the dorsum, which has a broad longitudinal bare area on the midline. The lateral wax filaments number 17 pairs, each filament at least equal to or slightly longer than the body width; the anterior filaments are longer than the body; the posterior filaments are much longer, being about twice as long as the body. The legs are yellowish.

Spilococcus mamillariae

Appearance in life (Figure 1.O): The body of the adult female body is broadly oval, about 2.5-3.5 mm long and 1.5-2.7 mm wide; the body contents are grayish-green to almost gray-blackish. The cuticle is covered by a thin layer of white powdery wax; it makes the body color visible; the dorsum lacks bare areas. The lateral wax filaments are not visible; the short posterior wax filaments are present. The legs are brownish.

Diagnosis of slide-mounted adult female (Figure 2): antennae each eight segmented, total antennal length about 200-350 μm . Cerarii numbering 8-12 pairs, each containing two conical setae 7-11 μm long and 1.75-2.30 μm wide at base; abdominal cerarii numbering 6 or 7 pairs, each consisting of two conical setae; many cerarii on thorax and head indistinct. Eyes not associated with discoidal pores. Circulus oval is about 96-112 μm wide, with an intersegmental line present. Anterior and posterior pairs of ostioles are present, each ostiole about 76-81 μm wide. The anal lobe is somewhat developed, membranous, without a ventral bar; each anal lobe cerarius contains two conical setae, each about 12-14 μm long and 2.0-3.5 μm wide at base, 3 or 4 flagellate auxiliary setae, each about 20-30 μm long, and several trilocular pores. Apical seta on anal lobe about 120-128 μm long. Legs are well developed; hind leg with numerous translucent pores on the coxa, and the distal

half of the tibia has translucent pores that appear compact and grouped. Each claw with a plantar denticle. Length of hind trochanter+femur about 237-267 μm and length of tibia+tarsus about 255-281 μm , claw about 23-26 μm long. The ratio of lengths of hind tibia+tarsus to trochanter+femur 0.93-0.95:1. Anal ring 68-69 μm wide, bearing six setae, each 73-101 μm long and 2-3 μm wide.

Dorsum with short, stiff setae, each about 7-15 μm long. Trilocular pores, each about 2.7-3.5 μm in diameter, are numerous and evenly distributed. Oral rim tubular ducts all of similar size, numerous near margins, many also present in submedian and median areas of thorax and abdomen, forming bands across segments on meso- and metathorax and abdomen, usually each transverse row across abdominal segments IV-VIII about 7.5-9.2 μm wide.

Venter with flagellate setae of varying lengths, each about 20-59 μm long. Trilocular pores are the same size as on the dorsum but slightly fewer and more patchily distributed. Oral rim tubular ducts are the same size as on the dorsum, few on the head but more numerous on the thorax and abdomen, near margins, and in submarginal areas. Multilocular disc pores present on the abdomen, forming single to double rows across each segment as far forward as segment III or IV; oral collar tubular ducts, each 6.8-7.5 μm long and 2.5-3.3 μm wide, also forming a single row across each abdominal segment as far forward as segment III.

Host plant: Mealybug *S. mamillariae* mainly feeds on succulent host plants belonging to Cactaceae, Aizoaceae, Epacridaceae, Euphorbiaceae, and Malpighiaceae and can be a pest. It was found in a greenhouse full of cacti, *Gymnocalycium* sp. (Cactaceae), in West Java (Figure 3).

Natural enemies

Based on field observations, the natural enemies of mealybugs found on ornamental plants in Java were predators and parasitoids (distinguished by their manner of feeding). The predators belonged to the order Coleoptera, family Coccinellidae, and order Neuroptera, family Chrysopidae (Table 3, Figure 4).

The Hymenopteran parasitoids collected comprised four species belonging to the family Encyrtidae and one species of Eulophidae. Encyrtidae can parasitize both nymphal and adult stadia of mealybugs. They are endoparasitoid koinobionts that allow the host to remain alive after being parasitized so that the parasitoid continues to develop and reproduce until a specific time (Cuny and Poelman 2022). Members of the family Eulophidae have a wide host range; most are primary parasitoids, and development is solitary, either internal or external. There are few associations between eulophids and coccids, such as mealybugs, as primary or secondary parasitoids (Gordh et al. 1999), e.g. *Aprostocetus* is a genus whose hosts include Pseudococcidae (Siqueira et al. 2019). The hyperparasitoids that play a crucial role in regulating the populations of primary parasitoids are from the families Aphelinidae (one species) and Encyrtidae (two species) (Table 4, Figure 5).

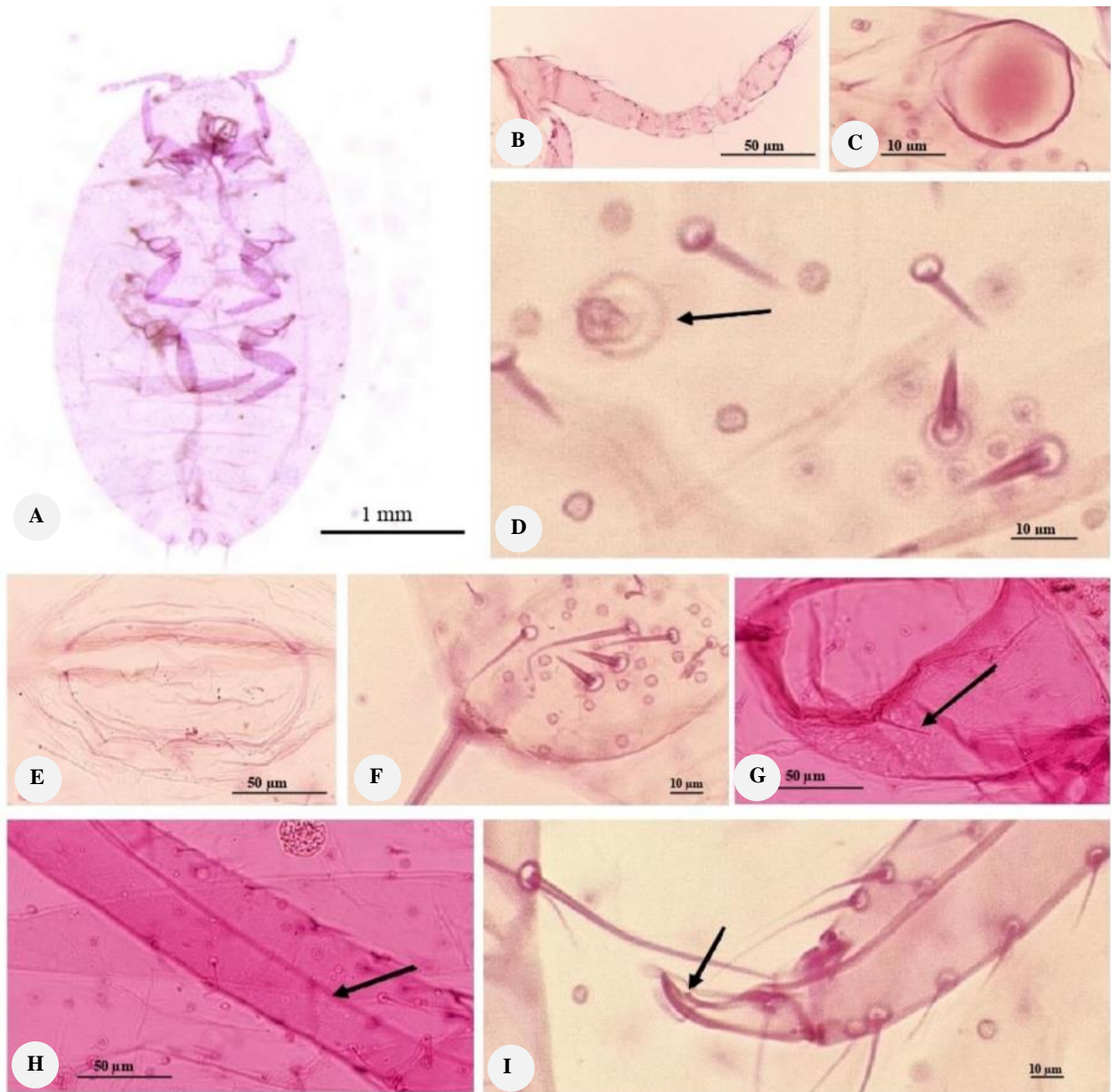


Figure 2. Morphological characters of *Spilococcus mamillariae*. A. whole body; B. antenna with 8 segments; C. eye; D. ventral oral rim tubular duct (indicated by an arrow); E. circulus; F. membranous anal lobe; G. numerous translucent pores on hind coxa (indicated by an arrow); H. a few translucent pores on hind tibia (indicated by an arrow); I. claw with a denticle (indicated by an arrow)



Figure 3. *Spilococcus mamillariae* infestation on cactus; note the sooty mold surrounding the mealybugs

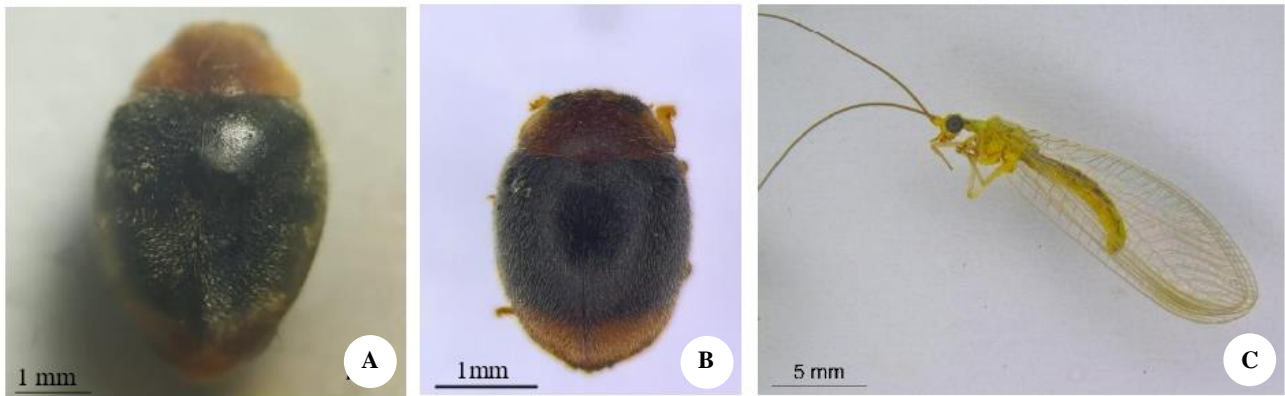


Figure 4. Predators found in mealybugs on ornamental plants: A. *Cryptolaemus montrouzieri*; B. *Scymnus* sp.; C. *Plesiochrysa ramburi*

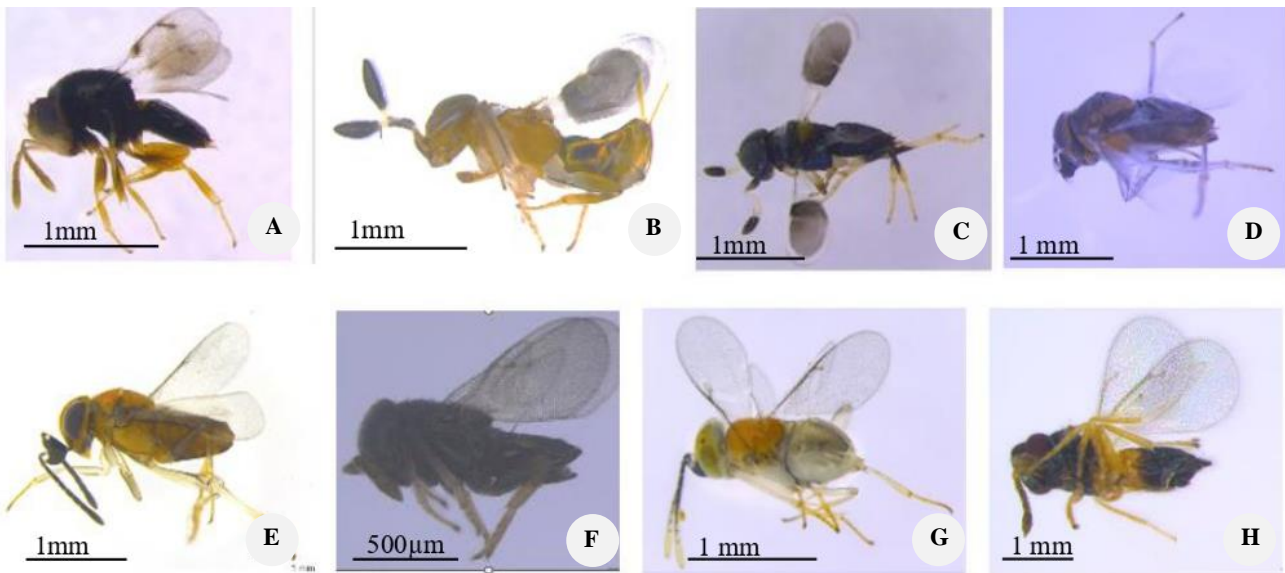


Figure 5. Hymenopteran hyperparasitoids and parasitoids found in mealybugs on ornamental plants; A. *Promuscidea unfaciiventris*; B. *Prochiloneurus* sp; C. *Prochiloneurus nagasakiensis*; D. *Anagyrus pseudococci*; E. *Anagyrus mirzai*; F. *Bleparys insularis*; G. *Gyranusoidea tebygi*; H. *Aprostocetus* sp.

Table 3. Predators of mealybugs (Hemiptera: Pseudococcidae) found on ornamental plants in Java, Indonesia

Predators	Prey	Ornamental plants	Location
Coleoptera			
<i>Cryptolaemus montrouzieri</i>	<i>Nipaeococcus nipae</i>	<i>Anthurium crystallinum</i>	Bogor Tengah
	<i>Rastrococcus spinosus</i>	<i>Plumeria rubra</i>	Tanah Sareal
<i>Curinus coeruleus</i>	<i>Planococcus lilacinus</i>	<i>Veitchia merrillii</i>	Dramaga
	<i>Planococcus minor</i>	<i>Euphorbia pulcherrima</i>	Sukaesmi
<i>Cheilomenes sexmaculata</i>	<i>Nipaeococcus nipae</i>	<i>Cyrtostachys renda</i>	Tanah Sareal
	<i>Paracoccus marginatus</i>	<i>Hibiscus rosasinensis</i>	Pacet
<i>Illeis</i> sp.	<i>Paracoccus marginatus</i>	<i>Helianthus annuus</i>	Cisarua (Sirnarasa)
<i>Nephus</i> sp.	<i>Ferrisia virgata</i>	<i>Codiaeum variegatum</i>	Bogor Tengah
<i>Scymnus</i> sp.	<i>Dysmicoccus neobrevipes</i>	<i>Philodendron</i> sp.	Tanah Sareal
	<i>Nipaeococcus nipae</i>	<i>Heliconia</i> spp.	Bogor Tengah
	<i>Paracoccus marginatus</i>	<i>Hibiscus rosasinensis</i>	Jalan Raya Cifor
Neuroptera			
<i>Plesiochrysa ramburi</i>	<i>Nipaeococcus nipae</i>	<i>Cyrtostachys renda</i>	Tanah Sareal
	<i>Ferrisia virgata</i>	<i>Hibiscus rosasinensis</i>	Dramaga

Table 4. Hymenopteran hyperparasitoids and parasitoids of mealybugs (Hemiptera: Pseudococcidae) found on ornamental plants in Java, Indonesia

Family	Hyperparasitoid / Parasitoid	Mealybug host	Ornamental host-plants	Location
Aphelinidae	<i>Promuscidea unfaciativentris</i> (H)	<i>Exallomochlus hispidus</i>	<i>Bauhinia kockiana</i>	Cisarua (Sirnarasa)
Encyrtidae	<i>Prochiloneurus</i> sp. (H)	<i>Planacoccus minor</i>	<i>Euphorbia pulcherrima</i>	Sukaresmi
	<i>Prochiloneurus nagasakiensis</i> (H)	<i>Paracoccus marginatus</i>	<i>Helianthus annuus</i>	Cisarua (Sirnarasa)
Eulophidae	<i>Anagyrus pseudococci</i>	<i>Planacoccus lilacinus</i>	<i>Ficus</i> sp.	Tanah Sareal
	<i>Anagyrus mirzai</i>	<i>Pseudococcus longispinus</i>	<i>Anthurium crystallinum</i>	Tenjolaya
	<i>Blepyrus insularis</i>	<i>Ferrisia virgata</i>	<i>Syngonium</i> sp.	Taman Sari, Kemang
	<i>Gyranusoidea tebygi</i>	<i>Rastrococcus spinosus</i>	<i>Plumeria rubra</i>	Tanah Sareal
	<i>Aprostocetus</i> sp.	<i>Rastrococcus spinosus</i>	<i>Pseuderanthemum reticulatum</i> .	Tanah Sareal

Note: (H): Hyperparasitoid

Discussion

Mealybugs are obligate plant parasites; some species attack multiple hosts and can become pests. Their colonies foul host-plant surfaces with unsightly wax deposits and sugary honeydew excretions. Honeydew deposits can become a medium for sooty fungal growth, making the host plants appear blackened and reducing their market value. The present study found that *F. virgata*, *N. nipae*, and *Ps. jackbeardsleyi* are the most common mealybug species on ornamental plants in West Java. They were observed to form colonies, each containing a single species, mainly on the plant's lower leaves, stems, and hidden parts. It was rare to find more than one colony per plant, and if a plant had more than one colony, they were usually located at different sites, e.g., on the leaves or stems. Mealybugs can cause economic damage to many crops, resulting in losses estimated at 10-60%, depending on the crop (Diwan et al. 2020), and influenced by food availability, biology, environment, control management, and natural enemies (Omkar 2021).

Mealybug *S. mamillariae*, which generally attacks Cactaceae, was described from England (U.K.) in 1884 (Bouché 1884) and then first reported from France and Italy in 1929. Between 1933 and 2022, this cactus pest spread to more than 24 countries, including Brazil, Czechia, Italy, Mexico, New Zealand, and Slovenia, being found in greenhouses in temperate countries (CABI 2019; Morales et al. 2024). Its presence has never been reported in Indonesia, yet it is not included in the Indonesian quarantine plant pest regulation list. In the present study, *S. mamillariae* was found in two locations, namely Cisarua (Gadog) and Pacet District. The mealybugs prefer to feed at the top of the plant or on young flowers, where they suck plant juices and cause the attacked tissues to wither and dry out.

Members of the genus *Spilococcus* closely resemble those of *Chorizococcus*. However, *Spilococcus* possess 6-17 pairs of cerarii, with at least 6 pairs located on the abdomen. In contrast, members of *Chorizococcus* have only 1-5 pairs of cerarii, primarily on the abdomen (although in some species one pair occurs on the head) (Zarkani et al. 2023). In addition, many species of *Spilococcus* are found on Cactaceae, whereas most of the species assigned to *Chorizococcus* feed on plants belonging to the family Poaceae (Williams 2004). Notably, this is the first species of *Spilococcus* identified in Indonesia and

Southeast Asia. The means by which it arrived in Indonesia remains unclear, but it was probably brought in unintentionally introduced on live cactus plants imported through trade.

Two groups of natural enemies are associated with mealybugs, i.e. predators and parasitoids. The Coleopteran family Coccinellidae members are the most common predators, attacking nymphal and adult mealybugs and voraciously consuming mealybug eggs. Many mealybug-consuming Coccinellid larvae produce waxy filaments that resemble those of mealybugs. Among the six Coccinellid predatory species found, *C. montrouzieri* is widely and reliably used to control various mealybug species in many countries; however, it has poor tolerance to cold temperatures (Mani and Shivaraju 2016).

Another important type of mealybug predator is larval lacewings; an adult female green lacewing can lay about 100-200 eggs, singly or in small groups. Second and third-instar lacewing larvae prefer to eat second-instar nymphs of mealybugs (Mani and Shivaraju 2016). However, the third instar showed significantly more predation (Fanani et al. 2023).

The Encyrtid primary parasitoids *A. pseudococci*, *A. fusciventris*, *B. insularis*, and *G. tebygi*, play an essential and influential role in controlling mealybugs; Eulophid wasps also attack mealybugs but play only a minor role in their control. The feeding behavior of adult parasitoid wasps is to bite mealybug nymphs and suck their body fluids. Mealybugs attacked by parasitoids may be recognized because they become shaped like small pupae and are a slightly darker color than healthy mealybugs. The pupating parasitoid wasp turns the host mealybug yellow or somewhat orange and causes it to become hardened or mummified when it is dead.

The hyperparasitoids *P. unfaciativentris*, *P. nagasakiensis*, and *Prochiloneurus* sp. attack primary parasitoids in their larval or pupal stages within parasitized mealybugs. Most hyperparasitoids have a variety of wasp hosts, such as primary parasitoids attacking the scale insect families Pseudococcidae, Coccidae, Coccinellidae, and some Encyrtidae. Hyperparasitoids are attracted to the sex pheromones and honeydew produced by mealybugs; they can impact the performance of primary parasitoids by reducing their diversity and abundance. However, in response to hyperparasitoids, adult female primary

parasitoids will increase the area they search for hosts to avoid laying all their eggs in the same mealybug colony to elude hyperparasitoid attacks (Poelman et al. 2022).

In conclusion, the characteristics of the wax secretions of each mealybug species differ subtly in life, so the appearance can sometimes be used as an indication of the likely species' identity. However, making slide mounts of adult females and identifying them using morphological keys is essential for authoritative identification. The most common species found attacking ornamental plants in Western Java was *F. virgata*. The discovery of a new country species record, *S. mamillariae* on cacti, highlights the need to monitor mealybugs on ornamental plants in Indonesia regularly. Further investigation is needed to understand the potential impact of *S. mamillariae* on cactus plants and other hosts and the plant quarantine implications of its presence for exporting ornamental plants to other countries. The identifications of the natural enemies found, both predators and parasitoids, provide important information that can be used to implement sustainable biological control.

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