



## Identification keys to live and mounted mealybug (Hemiptera: Pseudococcidae) species associated with cassava in India and their present distribution

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**ABSTRACT:** Assigning correct identity to the species is the most essential requirement for effective management of the mealybug pests. It is even more crucial while sampling an infestation that harbors more than one species of mealybug. Similarly, phytosanitary regulations demand that the commodities like tubers, planting setts, fruits, etc., for export must be free from pests, including mealybugs. Species level identification in the field or at the quarantine station is difficult due to the limited number of identification keys available for segregating mealybug species in their live condition, so it is necessary to generate an identification key to the species of mealybugs associated with cassava as it fosters several mealybug species in a single cluster and recently there has been an outbreak of a mealybug species infesting this crop. A dichotomous key was constructed based on field characters and to authenticate the field level identity, another key based on microscopic morphological characteristics was developed for ten species of mealybugs infesting cassava in India. Thus, mealybugs infesting cassava in India can be differentiated in live and mounted conditions based on the keys developed.

**Keywords:** Diagnostic characters, field identification, *Manihot esculenta*, *Phenacoccus manihoti*

### INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is grown in about 10 states in North-East and southern India. Cassava crop is cultivated predominantly in the southern states of which Tamil Nadu and Kerala together constitute more than 70 per cent of total area and more than 90 per cent of production (Anonymous, 2018). Many insects and mites are known to cause damage and affect cassava cultivation throughout the world. The major pests of cassava include whiteflies, mealybugs and mites. A total of 24 species of mealybug have been reported to infest cassava throughout the world (García Morales *et al.*, 2016). Many of these species are known to cooccur, which makes it even more difficult to assign correct identity to the damage causing species. There are several instances of failed biological programs due to erroneous identity of mealybug species (Watson, 1997). Considering the difficulties in identifying number of mealybug species attacking cassava and their coexistence, a key to the live diagnostic characters is provided. As the live characters are subject to change with age and health of the mealybug females, season and host plants, a key to the mounted characters of the mealybug species is also provided. Both these keys will enable tentative identity in the field and authentic confirmation after mounting them in the laboratory. The keys include all the species

of mealybugs that are of occasional occurrence, those which have regular incidence and recently introduced mealybug species.

### MATERIALS AND METHODS

#### *Collection of insects*

Mealybug species infesting cassava are being collected since 2010. The mealybugs were collected from cassava grown in upland, lowland, as an intercrop with coconut and even from homestead and stray roadside plants. In addition to these, samples are being received, from various ICAR institutes, State Horticulture Departments and State Agricultural Universities, for identification which have been included for this study. On return to the laboratory, some adult female mealybugs were preserved in vials containing 70% ethanol and stored for subsequent preparation on microscope slides.

#### *Photographic illustration and field characters*

Photographs of the live mealybugs were taken using a Leica DFC 420 camera mounted on a Leica M205A stereozoom microscope. The characters used for defining field characters were colour of the derm, posterior wax filaments and its length, absence or presence lateral wax filaments and its length, presence or absence of bare areas on the dorsum, oviparous or ovoviviparous mode

**Table 1. Collection data of different mealybug species infesting cassava from different states of India**

Sl. No.	State	Number of locations/ Number of samples	Number of females examined	Species of mealybug*	Dates of collection	Collected by
1	Odisha	4	24	<i>M. hirsutus</i> (2) <i>N. viridis</i> (2)	18.01.2012	Sunil Joshi, ICAR – NBAIR, Bengaluru
		3	12	<i>Ph. solenopsis</i> (2) <i>Ps. longispinus</i> (1)	28.01.2016	Sunil Joshi, ICAR – NBAIR, Bengaluru
2	Bihar	1	6	<i>Ps. longispinus</i> (1)	20.09.2013	Sunil Joshi, ICAR – NBAIR, Bengaluru
3	Andaman and Nicobar	1	8	<i>Ps. jackbeardsleyi</i> (1)	16.03.2016	Sunil Joshi, ICAR – NBAIR, Bengaluru
4	Karnataka	6	10	<i>M. hirsutus</i> (2) <i>Ph. madeirensis</i> (4)	02.01.2017	Sunil Joshi, ICAR – NBAIR, Bengaluru
		4	5	<i>Pl. citri</i> (4)	12.05.2014	Sunil Joshi, ICAR – NBAIR, Bengaluru
5	Kerala	1	6	<i>Ps. jackbeardsleyi</i> (1)	15.02.2017	Mani Chellappan, KAU, Thrissur
		1	6	<i>Ph. madeirensis</i> (1)	24.07.2017	Sangeetha, B.G., CTCRI, Thiruvananthapuram
		25	108	<i>Ps. jackbeardsleyi</i> (1) <i>Ph. manihoti</i> (11) <i>F. virgata</i> (5)	27.02.2020 to 25.05.2020	Sachin G. Pai, KAU, Thrissur; Joseph Rajkumar, ICAR-CPCRI, Kayamkulam; C. A. Jayprakash, CTCRI, Thiruvananthapuram; Assistant Director of Horticulture; Madhu Subramaniam and Smitha Revi, KAU, Thrissur
		95	194	<i>P. marginatus</i> (8) <i>Ph. manihoti</i> (28) <i>F. virgata</i> (16)	13.10.2020 to 18.01.2021	Madhu Subramaniam and Smitha Revi, KAU, Thrissur
				<i>P. marginatus</i> (43) <i>Ps. jackbeardsleyi</i> (6)		
		52	246	<i>Ph. solenopsis</i> (2) <i>Ph. manihoti</i> (36) <i>P. marginatus</i> (9) <i>F. virgata</i> (6)	01.02.2021 to 26.03.2021	Madhu Subramaniam and Smitha Revi, KAU, Thrissur
		18	62	<i>Ph. solenopsis</i> (1) <i>Ph. manihoti</i> (5) <i>F. virgata</i> (5)		
		68	275	<i>P. marginatus</i> (8) <i>P. marginatus</i> (31) <i>Ph. manihoti</i> (7) <i>F. virgata</i> (24) <i>Ps. Jackbeardsleyi</i> (6)	10.09.2021 to 15.11.2021	Madhu Subramaniam and Smitha Revi, KAU, Thrissur
6	Tamil Nadu	1	12	<i>Ph. solenopsis</i> (1)	28.11.2016	Sunil Joshi, ICAR – NBAIR, Bengaluru
		10	85	<i>Ph. manihoti</i> (10)	01.06.2020	N. Sathiah, TNAU, Coimbatore; S. Jeyarajan Nelson, TNAU, Madurai
		8	59	<i>Ph. manihoti</i> (8)	05.06.2020	Yoganyagi, State Dept. of Horticulture and Plantation Crops, Tamil Nadu; Venkatachalam, Tapioca and Castor Research Station, TNAU, Salem
		11	55	<i>Ph. manihoti</i> (8) <i>Ps. jackbeardsleyi</i> (2) <i>F. virgata</i> (1)	10.06.202 to 25.08.2020	M. Mohan, ICAR-NBAIR, Bengaluru
		28	147	<i>Ph. manihoti</i> (22) <i>F. virgata</i> (2) <i>Ps. jackbeardsleyi</i> (2) <i>P. marginatus</i> (2)	12.10.2020 to 12.07.2021	S. Gnanasambandan, Plant Quarantine Station, Thiruchirappalli M. Mohan and M. Sampathkumar, ICAR – NBAIR, Bengaluru
		14	101	<i>Ph. manihoti</i> (14)	22.07.2021 to 01.11.2021	M. Mohan and M. Sampathkumar, ICAR – NBAIR, Bengaluru
	Total	351	1421			

\*Number in the parentheses indicate number of samples of the species

**Table 2. Number of samples of different mealybug species infesting cassava collected from different states of India**

States	Number of samples of mealybug species										Total samples from the state
	<i>Paracoccus marginatus</i>	<i>Phenacoccus manihoti</i>	<i>Ferrisia virgata</i>	<i>Ps. jackbeardsleyi</i>	<i>Ph. solenopsis</i>	<i>Ph. madeirensis</i>	<i>M. hirsutus</i>	<i>N. viridis</i>	<i>Ps. longispinus</i>	<i>Pl. citri</i>	
Kerala	99	87	56	14	3	1	-	-	-	-	260
Tamil Nadu	2	62	3	4	1	-	-	-	-	-	72
Odisha	-	-	-	-	2	-	2	2	1	-	7
Bihar	-	-	-	-	-	-	-	-	1	-	1
A & N	-	-	-	1	-	-	-	-	-	-	1
Karnataka	-	-	-	-	-	4	2	-	-	4	10
Total	101	149	59	19	6	5	4	2	2	4	351

of reproduction, presence or absence of ovisac and colour of the female in alcohol or potash, etc. Maximum efforts were made to photograph the females in exact dorsal position by keeping all the wax filaments intact. The lengths of the posterior and lateral wax filaments were measured while capturing the photos of live mealybug species. All specimens have been deposited in National Insect Museum, ICAR—National Bureau of Agricultural Insect Resources, Bangalore, Karnataka, India.

*Mounting, identification and key preparation*

The preserved specimens were slide-mounted in Canada balsam according to the procedure described in Watson & Chandler (2000) as refined by Sirisena et al. (2013). Terminology for the morphological structures of the adult female follows Williams & Granara de Willink (1992). Slide-mounted adult females were observed through a Nikon Eclipse 80i microscope. Observations on the morphology of the slide-mounted female were based on 1421 specimens mounted on 398 slides. Plates on diagnostic characters of mounted mealybugs were prepared using Photoshop CS2 program. The identification of the test insects was carried out using the keys in the books viz., Mealybugs of Southern Asia (Williams 2004), Mealybugs of Central and South America (Williams and Granara de Willink 1992), and Cox (1989). A dichotomous identification key was prepared and illustrated with photomicrographs to show the unique character of the adult female and key characters of each species.

**RESULTS AND DISCUSSION**

*Identification of the mealybug species and their present distribution and abundance*

Studies on identification of collected mealybug species indicate that there are a total of ten species of mealybug which are infesting cassava in six states of India viz., Karnataka, Kerala, Tamil Nadu, Odisha, Bihar and

Andaman & Nicobar (Table 1). These species are *Ferrisia virgata* (Cockerell), *Maconellicoccus hirsutus* (Green), *Nipaecoccus viridis* (Newstead), *Paracoccus marginatus* Williams & Granara de Willink, *Phenacoccus madeirensis* Green, *Phenacoccus solenopsis* Tinsley, *Planococcus citri* (Risso), *Pseudococcus jackbeardsleyi* Gimpel & Miller and *Pseudococcus longispinus* (Targioni Tozzetti). In addition to these nine species, recently, *Phenacoccus manihoti* Matile Ferrero invaded India through Kerala (Joshi et al., 2020) and has spread to Tamil Nadu and is causing severe damage (Sampathkumar et al., 2021). Of the above listed species of mealybugs only four species viz., *F. virgata*, *P. marginatus*, *Ph. madeirensis* and *Ps. jackbeardsleyi* were of regular occurrence which have been collected fairly regularly. These species have been found to coexist (two to three species) on a single infested leaf, branch or shoot tip. Maximum samples were received/collected from Kerala (260) followed by Tamil Nadu (72). Out of the 351 samples examined (Table 2), maximum specimens belonged to *Ph. manihoti* (149 samples) followed by *P. marginatus* (101), while *F. virgata* and *Ps. jackbeardsleyi* were third and fourth abundant species, respectively. Thus, the collection data clearly reveals that, at present *P. manihoti* is the most predominant species which is closely followed by *P. marginatus* in Kerala. It is apparent from table 2 that samples collected from Kerala had multiple species abundance with *P. marginatus* (99 samples) followed by *Ph. manihoti* (87 samples), *F. virgata* (56 samples) and *Ps. jackbeardsleyi* (14 samples) whereas in Tamil Nadu, *Ph. manihoti* was the principal species (62 samples out of 72 samples examined from this state) with *P. marginatus* infestations in few areas. The species viz., *Ph. solenopsis*, *Ph. madeirensis*, *M. hirsutus*, *N. viridis*, *Ps. longispinus* and *Pl. citri* were of negligible occurrence and were collected from states like Odisha, Bihar and Karnataka.

*Keys to the live and mounted mealybug species*

Field characters of the mealybugs have been well

documented by Green (1922) and Miller *et al.* (2014), however we have modified the characters and illustrated in the form of microphotographs (Fig. 1). The field characters and key to live and mounted mealybug species infesting cassava in India is as given below.

***Ferrisia virgata* (Cockerell)** (Fig. 1A)

Adult female at first dull yellowish orange, afterwards brownish, paler beneath. In each stage, after moulting, the insect is yellowish, gradually assuming the darker shade before the next moult. Dorsum powdered with white mealy secretion which, in older females conceals the colour of the insect except at definite paired patches on the thorax and abdomen, where the derm remains visible. This pattern is very characteristic of the species. Posterior extremity with a conspicuous pair of stout, tapering, waxy tassels, 0.8 times as long as body; the rest of the body with numerous long, fine, straight, glassy filaments. These glassy filaments are extremely fragile, falling off on touch; they are constantly produced. Lateral wax filaments completely absent. The female, during oviposition, rests upon a pad of silky white filaments, and wisps of the same material surround its body.

***Maconellicoccus hirsutus* (Green)** (Fig. 1B)

Body elongate oval; red-brown to orange-pink; legs and antenna light yellow; body gradually gets covered by white mealy wax, initially forming a dorsomedial line with thick wax which is thicker at the anal end and tappers towards head; later two pairs of thick wax filaments are produced on the margin of posterior abdominal segments; lateral wax filaments cannot be seen but the marginal area produces thin, hazy curly wax filaments which covers marginal area up o head. Ovisac covers dorsal surface. Occurring on all above-ground parts of plant. Oviparous, eggs pink. Specimens turns black in 70% alcohol.

***Nipaecoccus viridis* (Newstead)** (Fig. 1C)

Adult female, before oviposition, with longitudinal series of stout white cottony tufts covering the dorsum, arranged in six series on the thorax and five on the abdomen. A pair of divergent flattened waxy filaments projects from the posterior extremity. In older examples the tufted appearance of the secretion is lost. Each insect secretes a dense white ovisac, inconspicuously striated both longitudinally and transversely. The resulting mass is subglobular, the insect itself-with its body tilted vertically-forming the anterior quarter. The ovisac on touch forms long sticky tenacious threads. Colour of insect (and of the eggs and young nymph) dull purplish. In boiling potash, the insect assumes a dull bottle-green

shade. Form broadly oval, the anal segment slightly projecting. Legs relatively small.

***Paracoccus marginatus* Williams and Granara de Willink** (Fig. 1D)

Body elongate oval; somewhat flattened dorsoventally; body yellow; legs light yellow; mealy wax covering body, not thick enough to hide yellow body, without bare areas on dorsum, but segmental lines clearly visible; ovisac ventral; with 15 to 17 lateral wax filaments, posterior pair of filaments conspicuously longer, filaments anterior of posterior pair small, inconspicuous on thorax and head, posterior pair about 1/8 length of body. Primarily occurring on foliage of host. Oviparous, eggs cream or light yellow. Body turns black in 70% alcohol.

***Phenacoccus madeirensis* Green** (Fig. 1E)

Body oval; somewhat flattened dorso-ventally; body grayish green; legs and antenna reddish in completely grown up female; covered by thin, white, mealy wax, with two longitudinal lines on submarginal area and two depressed areas around spinal area making middorsal line look a little elevated from the derm; with 4 -5 tiny wax outgrowths arranged horizontally on all abdominal and thoracic segments; with 18 pairs of lateral wax filaments, posterior pairs longest, about 1/8th or less of length of the body. Ovisac is formed with thick white wax in the form of elongated outgrowth from abdomen of the female; eggs yellow. Primarily occurring on foliage of host. Specimens in alcohol with 1 pair of dorsosubmedial dark lines on thorax and abdomen. Surface of lateral filaments rough.

***Phenacoccus manihoti* Matile Ferrero** (Fig. 1F & G)

Body oval, dorsoventrally flattened; irrespective of the age of the female, body colour rosy pink or yellow; completely grown up females with two different body colours can be seen in one single patch of infestation (Fig. 1H); body lightly dusted with fine mealy wax powder but body colour can be seen through; segmentation clearly visible; caudal and lateral wax filaments poorly developed, stub like, formed as wax flakes on the dermal swelling on each body segment, giving wavy appearance to the body margin. Eggs bright yellow; ovisac ventral, thick, cottony; body remains yellow or pink in 70 percent alcohol.

***Phenacoccus solenopsis* Tinsley** (Fig. 1I)

Body oval, often quite large; somewhat rounded in lateral view; dark reddish to almost black; legs reddish



in grown up female; covered by thin, white, mealy wax, with dark dorsosubmedial bare spots on intersegmental areas of thorax and abdomen, these areas forming 1 pair of dark longitudinal lines on dorsum; ovisac absent from dorsum, but well developed ventally; eggs yellow; with 18 pairs of lateral wax filaments, posterior pairs longest, up to 1/7 of length of the body. Surface of lateral filaments rough.

***Planococcus citri* (Risso)** (Fig. 1J)

Body form broadly oval; convex above, flattish below, with the segments more or less puffy. Adult female yellowish, brownish or greyish-yellow above; usually yellowish beneath. The colour on the dorsum is almost completely concealed by a close covering of white mealy powder; there is, usually, however, a median stripe partially free from the secretion, revealing the true colour of the insect. This stripe grows wider with age of the female. The venter is only thinly dusted with mealy powder. There is a complete marginal series of thirty-four short (17 on each side), stout, white, waxy tassels, subequal in length, though rather stouter on the abdominal segments. All wax filaments thick with rough surfaces and curved anteriorly. Between the last pair of tassels is a pair of small processes of a denser and smoother wax, proceeding from the anal orifice.

***Pseudococcus jackbeardsleyi* Gimpel & Miller** (Fig. 1K)

Body oval; slightly rounded in lateral view; body color variable from light yellow to reddish orange; mealy wax covering body, thin enough so that body color shows through; with 4 longitudinal lines on dorsum - two broad dorsomedial line and two thin submarginal lines; dorsomedial lines cross with the horizontal segmental line to form darker depressions on abdomen; ovisac formed with loose long thin wax filaments; eggs pinkish orange; with 17 lateral wax filaments, posterior filament longer than body (almost 2 times the length of the body) and next pair about half as long as posterior pair; lateral filaments as long as body width. Primarily occurring on foliage of host. Surface of lateral filaments rough.

***Pseudococcus longispinus* (Targioni Tozzetti)** (Fig. 1L)

Adult female elongate ovate; slightly rounded in lateral view; at first dull pinkish orange; older examples greyish orange. Legs and antenna yellowish. Dorsum thinly covered with white mealy secretion, almost completely hiding the colour of the insect. Margin with a complete fringe of white tassels (seventeen on each side), which are shorter in front, and increase in length

towards the posterior extremity, the terminal four being exceptionally long, approximately two times as long as the length of the body of the insect. Lateral filaments about half as wide as body. Two short flattened filaments, together forming a tube, proceed from the anal ring, and lie between the long caudal processes. Ventral surface almost nude. With 2 thin longitudinal lines on marginal area; mid dorsal area on dorsum with irregular patch with less wax dusting (looks as though the wax dust has been erased).

**Key to the adult females of mealybugs infesting cassava (Field characters)**

1. With very long posterior wax filaments, which are 0.8 times as long as body or longer than body.....2
- Without very long posterior wax filaments.....4
2. Dorsum with two large submedial longitudinal bare areas on abdomen and three small bare areas on thorax; lateral wax filaments absent but numerous long, fine, straight, glassy filaments can be seen radiating from the body .....*Ferrisia virgata* (Cockerell)
- Bare areas absent from dorsum; lateral wax filaments present.....3
3. Body colour light orange to brown; posterior filament longer than body and next pair about half as long as posterior pair; lateral filaments as long as body width. With four longitudinal lines on dorsum, with two prominent dorsomedial lines enclosing the spinal area and two thinsubmarginal lines; all these lines form darker areas when they cross horizontal segmental lines. Eggs pinkish orange laid in thin ovisac formed with loose wax threads.....*Pseudococcus jackbeardsleyi* Gimpel & Miller
- Body colour greyish yellow or reddish brown; posterior filament longer than body and next pair about half as long as posterior pair; lateral filaments about half as wide as body. With median area on the abdomen very thinly dusted with wax giving illusion of a darker median mark on abdomen; with two thin submarginal lines. Ovoviviparous and hence only crawlers can be seen that are yellowish.....*Pseudococcus longispinus* (Targioni Tozzetti)

4. Colour of the eggs and nymphs yellow but adult female in various shades of yellow, rose pink, orange and dull or dark brown.....5
  - Colour of the eggs, nymphs and adult female bright pink or purple.....9
5. Bare areas on dorsum present.....6
  - Bare areas on dorsum absent.....7
6. Body colour yellow, light orange, brownish or greyish yellow; body covered in white mealy powder, usually a median bare stripe free from the secretion, revealing the true colour of the insect present; with 18 pairs of lateral short, stout, white wax filaments, subequal in length; stouter on the abdominal segments, posterior pair about 1/8 length of body, curved anteriorly; ovisac ventral, eggs yellow.....*Planococcus citri* (Risso)
  - Body large; dull to dark brown; with 18 pairs of lateral wax filaments, posterior pair longest, up to 1/7 of length of the body; with dark dorsosubmedial bare spots on intersegmental areas of one segment of thorax and three segments of abdomen, these areas forming 1 pair of dark longitudinal lines on dorsum; an ovisac of fluffy, loose-textured wax strands is produced; eggs yellow.....*Phenacoccus solenopsis* Tinsley
7. Caudal and lateral wax filaments poorly developed, stub like, formed as wax flakes on the dermal swelling, giving wavy appearance to the body margin; body colour rose pink or dull yellow.....*Phenacoccus manihoti* Matile Ferrero
  - Caudal and lateral wax filaments well developed; body colour variable.....8
8. Body colour yellow, dusted with wax powder; with 15 to 17 lateral wax filaments, posterior pair of filaments conspicuously longer, filaments anterior of posterior pair small, inconspicuous, posterior pair about 1/8 length of body; body turns black in 70 percent alcohol; ovisac ventral; eggs yellow.....*Paracoccus marginatus* Williams and Granara de Willink
  - Body colour greenish gray; covered by thin, white, mealy wax; with 18 wax filaments; posterior pair of filaments conspicuously longer, filaments anterior of posterior pair small, inconspicuous, posterior pair about 1/8 length of body; body remains greenish gray in 70 percent alcohol; ovisac ventral formed of thick elongate cottony sac; eggs yellow.....*Phenacoccus madeirensis* Green
9. Body colour purple; with longitudinal cottony tufts covering dorsum; abdominal margin with nine pairs of lateral wax filaments; posterior filaments flattened and divergent. The female remains tilted vertically forming anterior part of the globular cottony ovisac. The ovisac formed of long sticky tenacious threads; eggs purple; body turns greenish in alcohol .....*Nipaecoccus viridis* (Newstead)
  - Body colour dark pink; mid dorsal area forming thick wax tufts which are broader on abdomen, tapering towards head; two or three pairs of divergent flattened cottony irregular waxy filaments projects from the posterior extremity; remaining margin of the body with hazy wax filaments; ovisac dorsal; eggs bright pink; body becomes dark brown in alcohol.....*Maconellicoccus hirsutus* (Green)

**Key to the adult females of mealybugs infesting cassava (Microscopic characters)**

1. Number of cerarii less than 17.....2
  - Number of cerarii 17 or more.....4
2. Oral rim tubular ducts present across abdominal, thoracic segments and head and on marginal areas of venter; cerarii numbering 4, 6, or rarely 7; antenna 9 segmented; anal lobe bar present .....*Maconellicoccus hirsutus* (Green) (Fig. 3)
  - Oral rim tubular ducts completely absent from dorsum and venter; cerarii number variable; antennal segments less than 9; anal lobe bar present or absent.....3
3. Only anal lobe cerarius present; antenna 8 segmented; anal lobe bar like structure present; dorsal setae knobbed at apex; tubular ducts with orifice surrounded by a circular sclerotized area containing setae.....*Ferrisia virgata* (Cockerell) (Fig. 2)
  - Cerarii on abdomen, meso- and metathorax

## Identification keys to cassava mealybugs

- recognisable (less than 17); antenna 7 segmented; anal lobe bar absent; dorsal setae lanceolate; tubular ducts normal of two .....*Nipaecoccus viridis* (Newstead) (Fig. 4)
4. Antenna less than 9 segmented, claw without a denticle .....5
- Antenna 9 segmented; claw with a denticle .....8
5. Number of cerarii 17; anal lobe bar absent.....6
- Number of cerarii 18; anal lobe bar present.....7
6. Eyes each with an adjacent sclerotized rim containing 4 – 9 discoidal pores.....*Pseudococcus jackbeardsleyi* Gimpel & Miller (Fig. 10)
- Eyes without associated discoidal pores.....*Ps. longispinus* (Targioni Tozzetti) (Fig. 11)
7. Oral rim tubular ducts present; translucent pores restricted to hind coxa with exceptionally high numbers of pores (14 – 62 pores on dorsal surface and 54 - 108 pores on ventral surface) .....*Paracoccus marginatus* Williams and Granara de Willink (Fig. 5)
- Oral rim tubular ducts absent; translucent pores present on hind coxa and tibia but their numbers moderately high.....*Planococcus citri* (Risso) (Fig. 9)
8. Quinquelocular pores entirely absent from dorsum and venter.....*Phenacoccus solenopsis* Tinsley (Fig. 8)
- Quinquelocular pores present.....9
9. Dorsal multilocular disc pores present on medial area as well on marginal areas of abdomen and on margins of thoax; dorsal cerarii present; translucent pores present only on hind tibia; circulus transversely oval with narrow lateral extension; quinquelocular pores

present throughout venter except for last abdominal segment.....

*Ph. madeirensis* Green (Fig. 6)

- Dorsal multilocular pores present only on marginal areas of abdomen and thorax; dorsal cerarii absent; translucent pores completely absent from hind legs; circulus ox-yolk-shaped; quinquelocular pores present throughout the venter but crowded just anterior to clypeolabral shield numbering 32-68.....*Ph. manihoti* Matile-Ferrero (Fig. 7)

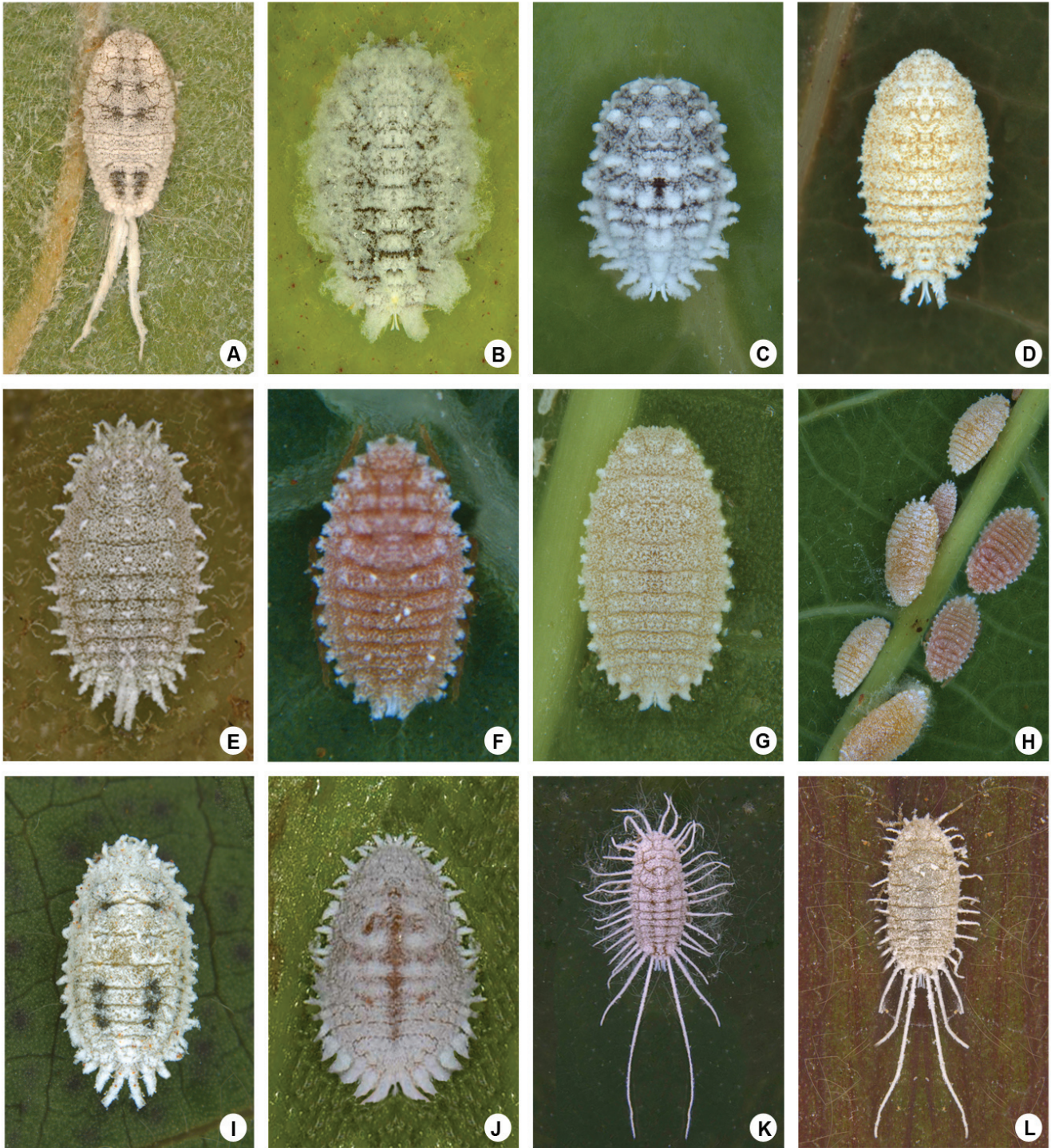
### CONCLUSION

The data on collection and identification of mealybugs infesting cassava thus indicates that at present, *Ph. manihoti* is the predominant species which is closely followed by *P. marginatus*. Samples collected from Kerala had multiple species abundance with *P. marginatus* being the major species followed by *Ph. manihoti*, *F. virgata* and *Ps. jackbeardsleyi* whereas in Tamil Nadu, *Ph. manihoti* was the principal species with *P. marginatus* infestations in few areas. The species viz., *Ph. solenopsis*, *Ph. madeirensis*, *M. hirsutus*, *N. viridis*, *Ps. longispinus* and *Pl. citri* were of negligible occurrence and were collected from states like Odisha, Bihar and Karnataka on cassava grown in homestead and stray roadside plants. The key to the live mealybugs will be useful to the field technicians, state horticultural officers and quarantine & phytosanitary regulators. The key to the mounted characters of mealybug will be useful to the entomologists for confirmation of tentatively identified mealybugs at field level by field technicians.

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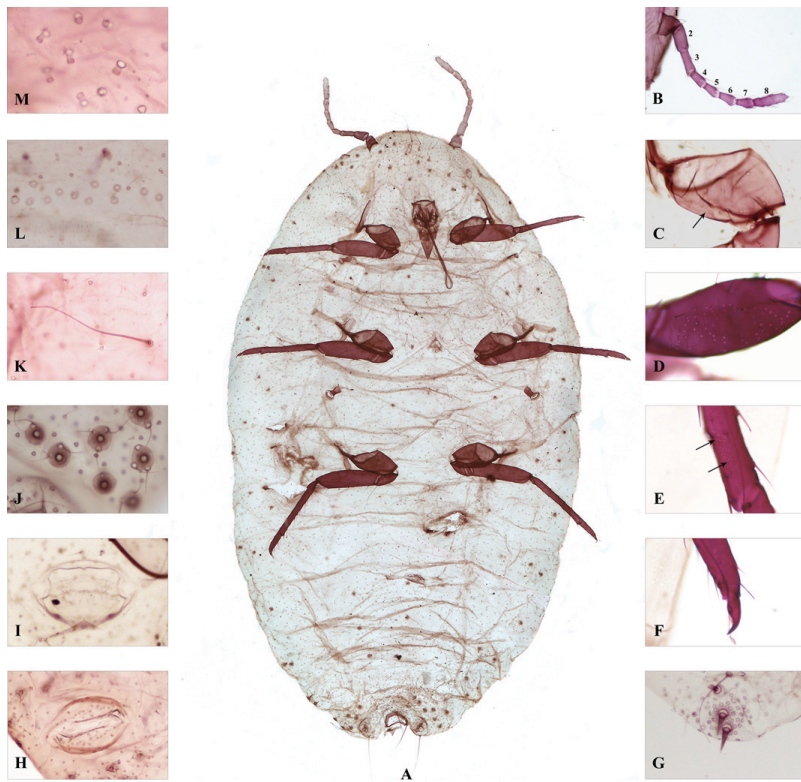
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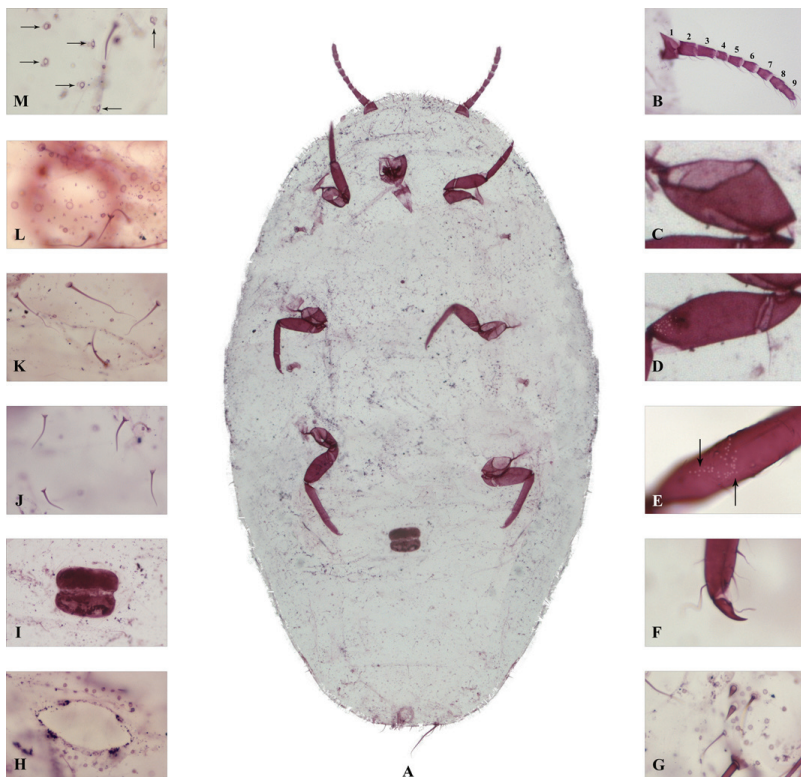


**Fig. 1.** Mealybug species infesting cassava A. *Ferrisia virgata* (Cockerell); B. *Maconellicoccus hirsutus* (Green); C. *Nipaecoccus viridis* (Newstead); D. *Paracoccus marginatus* Williams and Granara de Willink; E. *Phenacoccus madeirensis* Green; F. *Phenacoccus manihoti* Matile Ferrero rosy pink female; G. *P. manihoti* yellow female; H. Both pink and yellow females of *P. manihoti* in one infestation patch I. *Phenacoccus solenopsis* Tinsley; J. *Planococcus citri* (Risso); K. *Pseudococcus jackbeardsleyi* Gimpel and Miller; L. *Pseudococcus longispinus* (Targioni Tozzetti)

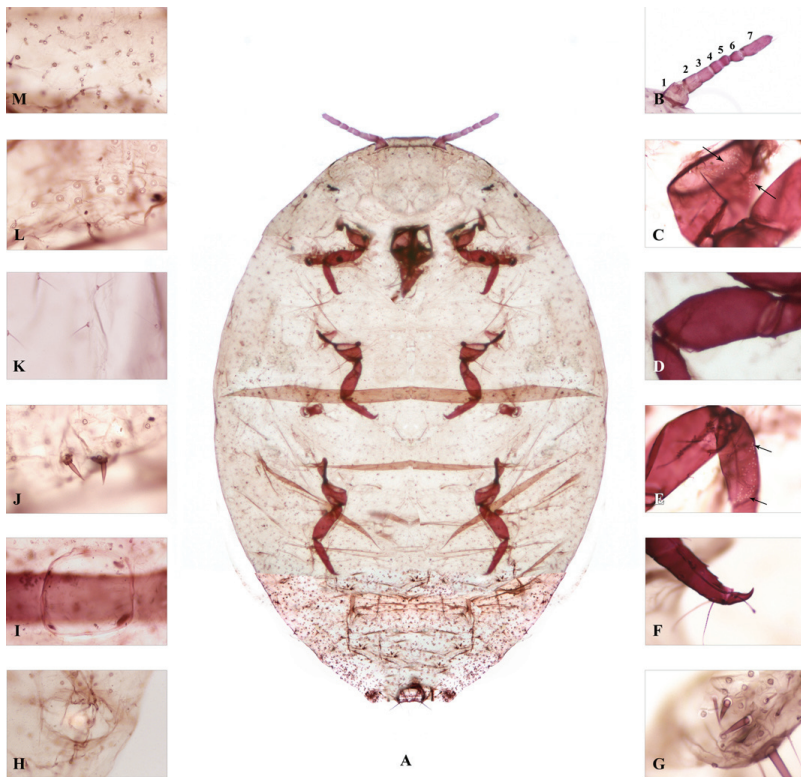




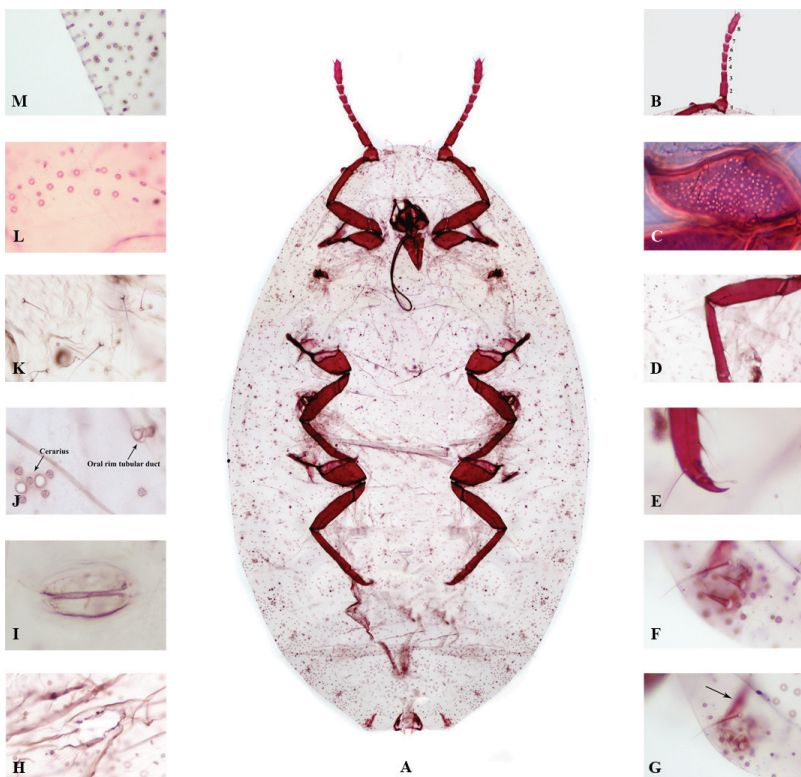
**Fig. 2.** Diagnostic characters of a slide-mounted adult female of *Ferrisia virgata* (Cockerell): A. Body derm; B. Eight segmented antenna; C. Translucent pores on hind coxa; D. Translucent pores on hind femur; E. Translucent pores on hind tibia; F. Claw without a denticle; G. Anal lobe cerarii with two stout conical setae and few auxiliary setae; H. Ostiole with inner lips moderately sclerotized; I. Circulus moderately developed and divided by intersegmental line; J. Dorsal ducts with setae situated within boarder of rim; K. Dorsal setae slender and slightly knobbed at apex; L. Ventral multilocular disc pores in row on abdominal segment VI; M. Ventral oral tubular ducts in marginal group



**Fig. 3.** Diagnostic characters of a slide-mounted adult female of *Maconellicoccus hirsutus* (Green): A. Body derm; B. Nine segmented antenna; C. Hind coxa without translucent pores; D. Translucent pores on hind femur; E. Translucent pores on hind tibia; F. Claw without a denticle; G. Anal lobe cerarii with two conical setae; H. Ostiole well developed but with lightly sclerotized inner lips; I. Circulus quadrate to oval divided by intersegmental line; J. Dorsal setae slender and flagellate; K. Ventral setae flagellate but longer than dorsal setae; L. Ventral multilocular pores present from abdominal segment III to VIII; M. Oral rim tubular ducts on dorsum and on margin on venter

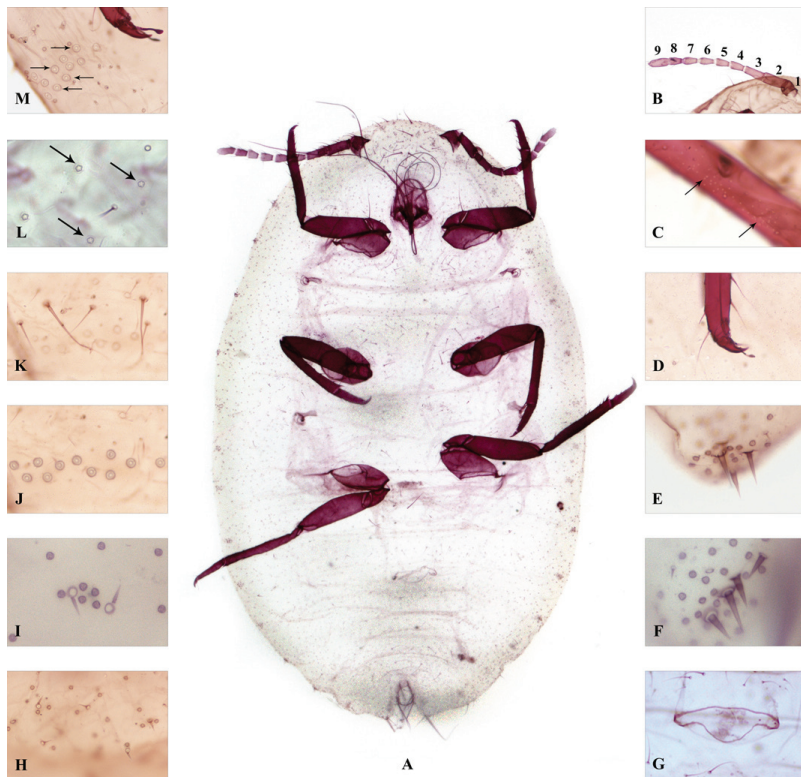


**Fig. 4.** Diagnostic characters of a slide-mounted adult female of *Nipaecoccus viridis* (Newstead): A. Body derm; B. Seven segmented antenna; C. Translucent pores on hind coxa; D. Hind femur without translucent pores; E. Hind tibia with translucent pores; F. Claw without a denticle; G. Anal lobe cerarii with lanceolate setae and an auxiliary seta; H. Ostiole moderately developed with moderately sclerotized inner lip; I. Circulus round to quadrate, not divided by intersegmental line; J. Dorsal setae short and lanceolate; K. Ventral setae slender and flagellate; L. Ventral multilocular pores usually numerous on venter; M. Ventral oral collar tubular ducts of two types, similar to those on dorsum



**Fig. 5.** Diagnostic characters of a slide-mounted adult female of *Paracoccus marginatus* Williams and Granara de Willink: A. Body derm; B. Eight segmented antenna; C. Dorsal surface of hind coxa with around 40 and ventral surface with around 80 translucent pores; D. Femur and tibia without translucent pores; E. Claw without a denticle; F. Anal lobe cerarii with two conical setae and 2-3 auxiliary setae; G. Ventral surface of anal lobe with conspicuous anal bar; H. Ostiole moderately developed with lip weakly sclerotized; I. Circulus wide divided by intersegmental line; J. Dorsal oral rim tubular ducts associated with cerarii; K. Ventral surface with flagellate setae; L. Ventral multilocular pore bands on abdominal segment VI – VIII; M. Ventral oral collar tubular ducts in marginal clusters





**Fig. 6.** Diagnostic characters of a slide-mounted adult female of *Phenacoccus madeirensis* Green: A. Body derm; B. Nine segmented antenna; C. Translucent pores only on hind tibia; D. Claw with a denticle; E. Anal lobe cerarii with three lanceolate setae and one small seta; F. Ocular cerarii with 3 – 4 setae; G. Circulus mushroom shaped; H. Dorsal setae short and lanceolate with 1 or 2 trilocular pores; I. Dorsal cerarii on submedial areas and midline of abdomen and thorax; J. Dorsal multilocular disc pores in transverse rows; K. Ventral setae flagellate; L. Quinquelocular pores on venter; M. Multilocular disc pores across the abdominal segments and in group in margin on venter

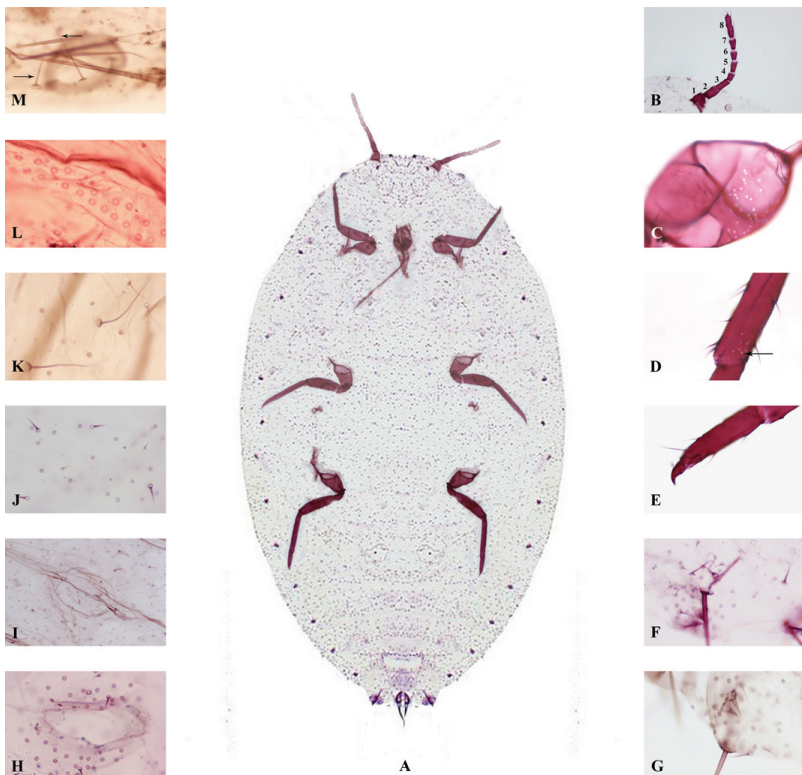


**Fig. 7.** Diagnostic characters of a slide-mounted adult female of *Phenacoccus manihoti* Matile Ferrero: A. Body derm; B. Nine segmented antenna; C. Claw with a denticle; D. Hind coxa, femur, tibia without translucent pores; E. Circulus ox-yoke-shaped; F. Ostiole moderately developed; G. Anal lobe cerarius with two lanceolate setae and few trilocular pores situated on raised derm; H. Ventral side of head anterior to clypeus with more than 30 quinquelocular pores; I. Dorsal setae of three different sizes distributed randomly on dorsum, some setae each associated with one trilocular pore; J. Ventral setae long and flagellate; K. Multilocular disc pores in rows across mid-regions of abdominal segments V-IX and on dorsal margin of abdomen and thorax; L. Small oral collar tubular ducts anterior to multilocular pores on median area of abdomen; M. Groups of larger oral collar tubular ducts on margin of abdomen, thorax and head

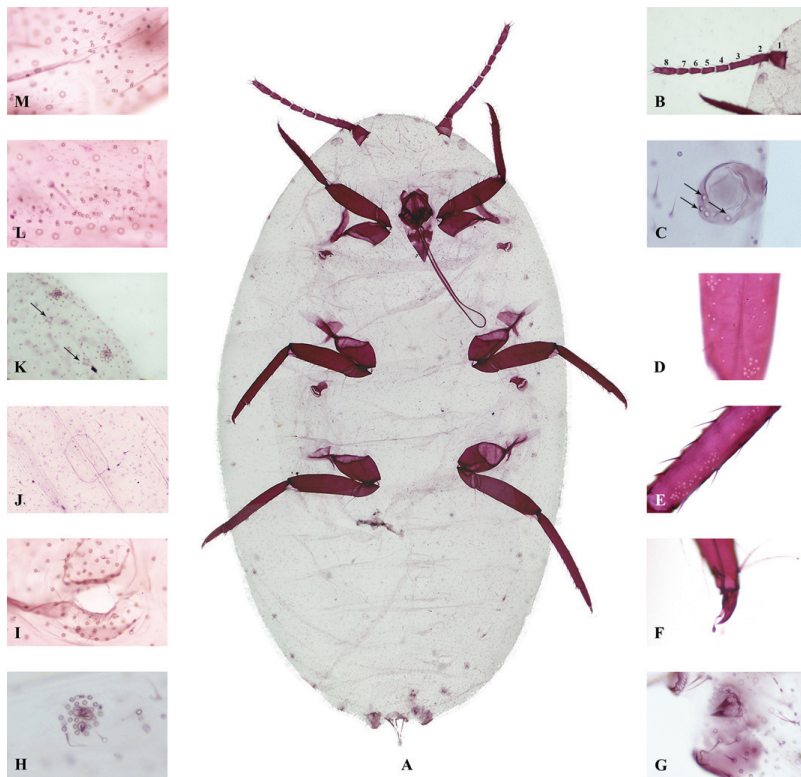




**Fig. 8.** Diagnostic characters of a slide-mounted adult female of *Phenacoccus solenopsis* Tinsley: A. Body derm; B. Nine segmented antenna; C. Translucent pores absent from hind coxa but present on femur; D. Translucent pores on hind tibia; E. Claw with a denticle; F. Anal lobe cerarius with two conical seta and one small shorter seta; G. Anterior cerarian setae same as anal lobe cerarius but smaller in size; H. Ostiole with inner lip weakly sclerotized; I. Circulus moderately large; slightly produced laterally; J. Dorsal setae short and pointed; K. Ventral setae long flagellate; L. Ventral multilocular disc pores normally present on segments IV to VIII; M. Multilocular disc pores on submarginal area of abdomen



**Fig. 9.** Diagnostic characters of a slide-mounted adult female of *Planococcus citri* (Risso): A. Body derm; B. Eight segmented antenna; C. Translucent pores on hind coxa; D. Translucent pores on hind tibia; E. Claw with a denticle; F. Anal lobe bar and bar seta; G. Anal lobe cerarius with 2 conical setae; H. Ostiole well developed with inner lip moderately sclerotized; I. Circulus quadrate and divided by intersegmental line; J. Dorsal setae flagellate but much shorter than ventral setae; K. Ventral setae long, slender and flagellate; L. Multilocular disc pores in a single row across abdominal segment IV to VII; M. Cisanal setae shorter than anal ring setae



**Fig. 10.** Diagnostic characters of a slide-mounted adult female of *Pseudococcus jackbeardsleyi* Gimpel and Miller: A. Body derm; B. Eight segmented antenna; C. Eyes with sclerotized rim containing six discoidal pores; D. Translucent pores on posterior surface of hind femure; E. Translucent pores on hind tibia; F. Claw without a denticle; G. Anal lobe cerarius with two short conical setae situated on sclerotized area; H. Cerarii C7 with three conical setae; I. Ostiole with inner lip slightly sclerotized; J. Circulus divided by intersegmental line; K. Dorsal oral rim tubular ducts present singly behind each frontal cerarius; L. Ventral multilocular disc pores on abdominal segment V to VII; M. Ventral oral collar tubular ducts in marginal groups



**Fig. 11.** Diagnostic characters of a slide-mounted adult female of *Pseudococcus longispinus* (Targioni Tozzetti): A. Body derm; B. Eight segmented antenna; C. Eye without discoidal pores; D. Translucent pores on hind femur; E. Translucent pores on hind tibia; F. Claw without a denticle; G. Anal lobe cerarius with 2 conical setae on sclerotized area; H. Penultimate cerarius on sclerotized area almost as big as anal ring; I. Cerarii on head (C1 and C3) usually bearing 3 – 4 conical setae; J. Ostiole prominent but with weakly sclerotized lip; K. Circulus wide, divided by intersegmental line; L. One large and two small type oral rim tubular ducts associated with dorsal cerarius; M. Dorsal large type oral rim tubular ducts submarginally and submedially on thorax

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