



Full Length Article

A New Invasive Species of Genus *Phenacoccus* Cockerell Attacking Cotton in Pakistan

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ABSTRACT

The name *Phenacoccus gossypiphilus* (Abbas *et al.*, 2005) is considered to be a *Nomen nudum*. The same species has also been collected in India, Thailand, Taiwan and in New Caledonia and is morphologically extremely similar to many specimens considered to be *P. solenopsis* Tinsley from the Neotropics. We authors feel that the differences are sufficient to justify that Asian species are different from *P. solenopsis*. The adult female of *P. gossypiphilus* is therefore described and a holotype and paratypes are designated. Keys are provided to separate (a) the new species from similar species of *Phenacoccus* currently known from Asia. In addition, few details regarding the biology of *P. gossypiphilus* on cotton in Pakistan are included. This species is considered to be an important invasive species.

Key Words: Cotton; Pakistan; Invasive *Phenacoccus*; Polyphagous mealybugs; Thailand; Taiwan

INTRODUCTION

In 2005, an apparently un-described species of *Phenacoccus* (Sternorrhyncha: Coccoidea: Pseudococcidae) was found to be a serious pest of cotton in Punjab and Sindh Provinces, Pakistan (Abbas *et al.*, 2005). The infestation was recorded from 11 out of the 18 cotton-growing areas covering 45,000 sq. km (Anonymous, 2005). As Pakistan is the 4th largest exporter of cotton in the world, this outbreak is of major economic importance. Because of its significance, a series of popular and semi-scientific papers have been published, which named this insect as *Phenacoccus gossypiphilus* and provided details regarding its biology and structure. However, none of these papers described the species in detail and neither holotype specimen nor depositories of type material were designated. The purpose of this paper was to officially name this species *P. gossypiphilus* Abbas and Arif and designate a holotype, paratypes and depositories.

MATERIALS AND METHODS

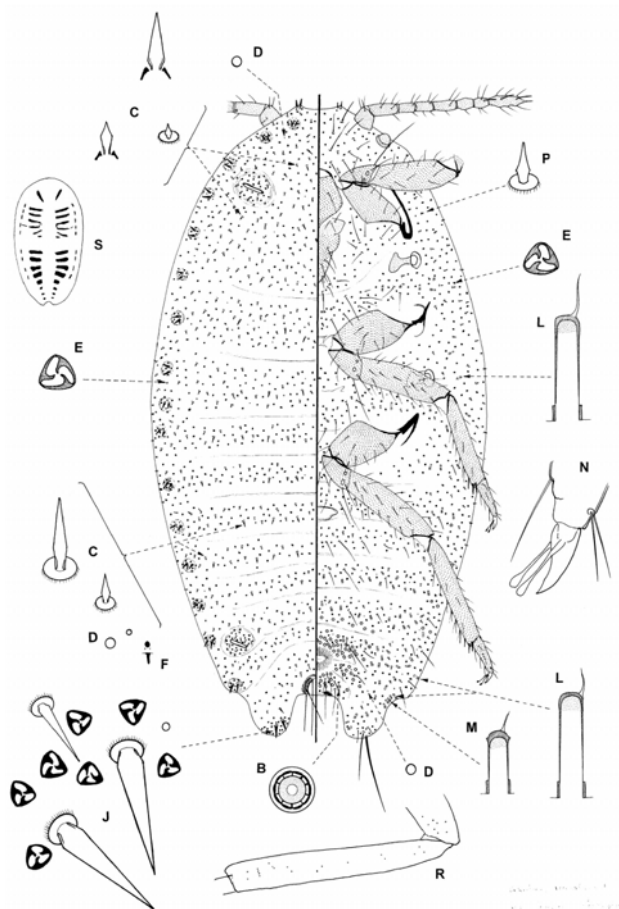
The specimens were slide mounted as described by (Hodgson & Henderson, 2000) except that initially the insects were cleared for three days at room temperature in 10% potassium hydroxide solution. The depositories are IPM Lab, Department of Agricultural Entomology, University of Agriculture, Faisalabad and Pakistan Museum

of Natural History, Islamabad, Pakistan. The figures show the normal layout for illustrating Coccoidea specimens, with the dorsum on the left and the venter on the right of the central figure, with vignettes of important features shown enlarged marginally than the original scale. The conventions used here for the material studied are 3/4ad**, where 3 refers to the total number of slides, 4 to the total number of specimens and the ad** to the stage studied (asterisk refers to female symbol).

RESULTS

The identity of the species of *Phenacoccus* attacking cotton in Pakistan. Because the type series of the neotropical species *P. solenopsis* Tinsley lacks multilocular disc-pores along the abdominal submargins (Williams & Granara De Willink, 1992), it was initially thought straightforward to separate the material from Pakistan from *P. solenopsis*. However, during this study, it was pointed out (D.R. Miller (USDA) and D.J. Williams (BMNH), personal communications) that many specimens, which appeared to be otherwise similar to *P. solenopsis* have some multilocular disc-pores submarginally. Such specimens-with the additional multilocular disc-pores on the submargins of the abdomen-are now known to be quite widespread in parts of North, South and Central America and apparently similar specimens were also now known from other parts of Asia and from West Africa.

Fig. 1. Adult female of *Phenacoccus gossypiphilus* from culture kept in screen house, Faisalabad, collected March, 2007. Specimen showing few multilocular disc-pores on ventral submargins of abdomen and fewer oral collar ducts. In this and Fig. 2: A = preantennal pore; B = multilocular pores; C = dorsal lanceolate setae; D = simple (discoidal) pore; E = trilocular pore; F = minute sclerotised pore; G = spinose seta on anterior cerarii; H = spinose setae on more posterior cerarii; J = cerarius C₁₈; L = large oral collar ducts; M = small oral collar ducts; N = claw; P = ventral lanceolate seta, R = metafemur and metatibia showing translucent pores, and S = dorsal view of unmounted specimen in alcohol



After a thorough survey of morphological characters on the material from Pakistan, India and from several other sites in Asia, it was clear that this material from Asia was variable, the variation appeared due to environmental conditions (similar to that shown for other mealybugs by Cox, 1983). Thus, specimens taken from the field tended to have many multilocular disc-pores along the submargins of the abdomen (a mean of about 15 per side (range 12-24) and more oral collar tubular ducts medially on the thorax, whereas specimens studied during the non-cotton-growing season (Nov.-March), taken from cultures in screen houses

but initially collected off cotton in the field, had many fewer multilocular disc-pores (a mean of about 4 per side) and oral collar ducts. Indeed, whereas the field collected specimens appeared to have significantly more multilocular disc-pores on the abdominal submargins than was known on specimens of *P. solenopsis* from the Neotropics, cultured specimens appeared to be identical. Even though the morphological and molecular studies of the *P. solenopsis*-species complex are still ongoing, it has been decided to describe and name this species, because of its great economic importance to the cotton industry on the Indian subcontinent, so that it can be referred to in reports and other articles.

Keys are provided for separating: (i) the new species from other *Phenacoccus* species in Asia and (ii) the instars of the new species. In addition, some ecological information about *P. gossypiphilus* is included regarding its biology in Pakistan and the damage to cotton.

***Phenacoccus cockerell*. *Phenacoccus* Cockerell: Cockerell (1893):**

Type species. *Phenacoccus aceris* Signoret, by subsequent designation by Fernald (1903).

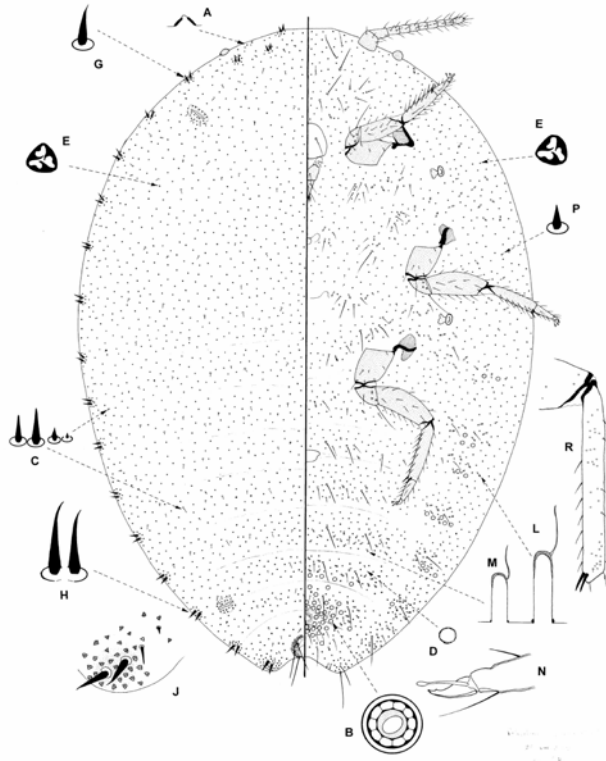
The genus *Phenacoccus* currently contains about 180 species and is one of the largest genera in the Pseudococcidae or mealybugs (Ben-Dov, 1994). Several *Phenacoccus* species are known to be important plant pest and potentially (if not actually) invasive (e.g., *P. aceris*, *P. madeirensis* Green & *P. solani* Ferris).

The genus *Phenacoccus* can usually be diagnosed, based on the adult female, by the following characters: antennae usually 9-segmented; legs well developed, claw with a well-developed denticle; translucent pores absent from hind coxae but sometimes present on femur and tibia; cerarii numbering 1-18 pairs, each with lanceolate setae and trilocular pores, often on protruding membranous areas; dorsal setae usually short and lanceolate, sometimes with trilocular pores close to setal sockets; circulus usually present between abdominal segment III and IV; multilocular pores usually present, often distributed in rows on venter and sometimes on dorsum; quinquelocular pores generally present on venter and occasionally dorsum; oral collar ducts often present on dorsum and venter, either all equal size or dorsal ducts often larger than ventral; oral rim ducts absent; eyes without associated discoidal pores (modified somewhat after Williams, 2004).

The adult female of the described species, as new one, below can be separated from all other known southern Asian *Phenacoccus* species by the following key:

1. Quinquelocular pores present on venter, at least near mouthparts. Most *Phenacoccus* sp. - Quinquelocular pores absent
2. Multilocular pores present on both dorsum and venter *P. kozari* Williams - Multilocular pores restricted to venter
3. Multilocular pores usually present medially on abdominal segments IV-VIII but restricted to bands across the posterior margin of each segment; normally absent from submarginal areas of abdomen; oral collar tubular ducts

Fig. 2. Adult female of *Phenacoccus gossypiphilus* Abbas and Arif from field population collected in Aug. 2007. Specimen showing large numbers of multilocular disc-pores on ventral submargins of abdomen and a greater number of oral collar ducts



very few, mainly restricted to posterior abdominal segments with few or none submarginally but occasionally with 1 or 2 between each anterior spiracle and mesocoxa *P. solani* Ferris - Multilocular pores medially restricted to abdominal segments VI-VIII, but present across full width of segment VII anterior to vulva; multilocular pores often present submarginally on some abdominal segments; oral collar tubular ducts frequent anteriorly on head and also across all thoracic segments.

4. Generally more than 10 multilocular disc-pores and 35 oral collar ducts on each side of abdomen. *P. Gossypiphilus*. Generally with eight or fewer multilocular disc-pores and less than 35 oral collar ducts on each side of abdomen *P. solenopsis* Tinsley (4⁺ Note that whilst this will separate many specimens of the summer generation of *P. gossypiphilus* from *P. solenopsis*, many others fall between these two extremes).

***P. gossypiphilus* Abbas and Arif spec. nov.** *P. gossypiphilus* Abbas et al., (2005): 83 nomen nudum. *P. gossypiphilus* Arif et al. (2007): 3 Nomen nudum.

Material examined: holotype*, Pakistan. Punjab, University of Agriculture, Faisalabad on *Gossypium hirsutum*, 24.ix.2006, G. Abbas (UAF): 1/1ad*.

Paratypes. Data as for holotype 4 ad** in fair to good condition.

Other material. Pakistan, Multan, Baha ud Din Zakariya University, on *G. hirsutum*, 13.xii.2005, G. Abbas: 3 ad** from cotton field of U. college of Agriculture, Punjab, Muzaffar Garh, (at Shehr Sultan) 22. vii. 2006, Abbas: *G. hirsutum* 4 ad**, Punjab, Bahawalpur (at Sui Wehar) 25.vii.2006, Abbas: *G. hirsutum* 2 ad**, Punjab, Rajanpur (at Jampur) 4.iv.2006, Abbas: Aksun *Withania somnifera* 2 ad**

Adult female. Figs. 1 and 2; described from about 10 well-stained specimens in fair to good condition.

Un-mounted material. Material in alcohol pale yellow to almost orange; dorsally with a series of dark markings as follows: with a pair of "exclamation marks" on head, about six pairs of transverse markings across pro- and mesothorax, possibly absent on the metathorax and then with pairs of dark transverse markings on each abdominal segment; also with a submarginal line of dash marks on thorax and abdomen. Ventrally, circulus dark.

Mounted material. Oval in outline, 2.0–4.3 mm long, 1.1–2.75 mm wide; anal lobes moderately developed; antennae normally 9 segmented; legs well developed; circulus present, generally oval, occasionally slightly constricted laterally; with 18 pairs of distinct cerarii; oral collar ducts restricted to venter; quinquelocular pores absent; multilocular pores present medially and laterally on venter of abdomen; claw with a poorly-developed denticle.

Dorsum. Derm membranous, with frequent small to minute lanceolate setae, ranging from about 3 µm long (less than width of basal socket) to about 8 µm long; frequent throughout dorsum. Trilocular pores each about 5 µm wide, frequent throughout and fairly evenly distributed; generally with a few trilocular pores loosely clustered around largest dorsal setae. Simple (discoidal) pores sparse to very sparse but present throughout, most about 2 µm wide; without discoidal pores on eyespot margins. With 2-5 small convex pores close to dorsal margin of each scape. Minute sclerotised pores, each about 1 µm wide, sparse throughout. With 18 pairs of cerarii, each on a distinct convexity on young specimens but convexities disappearing on more mature specimens; each cerarius with 2 lanceolate spinose cerarian setae (spines on C₁ each about 18-21 µm long, those on C₁₈ about 33-36 µm long) and each with 5-9 trilocular pores; without auxiliary setae. Ostioles membranous, each lip with 13-28 trilocular pores plus 2-6 small lanceolate setae. Oral rim ducts, oral collar ducts and multilocular pores absent. Anal ring 70–99 µm wide, with six setae, each about 140-175 µm long.

Venter. Derm membranous, with frequent long fine setae, many more than 50 µm long and some on head and medially on abdomen up to about 128-150 µm long; inner cisanal setae 87-133 µm long, outer cisanal setae 70-91 µm long; long anal lobe setae each 200-230 µm long; auxiliary anal lobe seta 115-125 µm long; each anal lobe lightly sclerotised around cerarial setae. Small lanceolate setae, similar to those on dorsum, frequent laterally and sparsely throughout rest of venter. Trilocular pores as on dorsum.

Simple (discoïdal) pores slightly larger than those on dorsum, sparse throughout; minute sclerotised pore also sparse throughout. Oral rim ducts absent. Oral collar ducts of two sizes present: (i) larger ducts each 13-15 µm long and about 4 µm wide, distributed as follows: 0-2 near anterior margin of head between scapes; 0-2 on either side or just anterior to clypeolabral shield and submedially on each side with 0-3 between procoxae and anterior spiracle, 9-13 between anterior spiracle and mesocoxa, 4-7 between posterior spiracle and metacoxae; and with 4-12 submarginally on abdominal segments I-VI, and some marginally on segments VII and VIII; and (ii) smaller oral collar ducts, each 11-13 µm long and about 4 µm wide, present in transverse bands medially across abdominal segments V and VI and mediolaterally on VII and VIII; generally a few present medially on IV but rare or entirely absent on III; also near margin between abdominal segments VI and VII and VII and VIII. Quinquelocular pores absent. Multilocular pores quite large, each 8-9 µm wide with 10 loculi, present medially as follows (totals across segment): post-vulva 11-22; laterad to vulva 5-12; VII 27-52 spread throughout full length of segment; VI 0-14, mainly along posterior margin, occasionally with up to 2 near anterior margin; VI-II 0; also present laterally as follows: VIII 0; VII 0-1; VI 0-2; V 0-5; IV 2-5; III 0-5, II 0-6, I 0-2 and metathorax 0; mean number per side ranging from 0-32, mean 14. Circulus oval, often with a small constriction on each side, probably without a transverse membrane medially, present between segments III and IV, rather variable in size, 140-180 µm wide. Eyespot: lens 40-58 µm wide; socket 70-75 µm wide.

Antennae 9 segmented (rarely 8-segmented, with a pseudo-segmentation in segment IV &/or apical segment undivided); each antenna 475-580 µm; non-apical flagellar segments each with 4-7 setae; 2 preapical segments also with a fleshy seta; apical segment with 10-13 hair-like setae, 3 fleshy setae and 4 stiff setae near apex; apical seta about 34-43 µm long. Clypeolabral shield about 185-200 µm long; labium about 220-265 µm long, with 11 pairs of setae. Spiracles: width of anterior peritremes 47-66 µm, posterior peritreme 62-91 µm. Metathoracic legs: lengths (µm): coxa 260-330; trochanter + femur 430-485; tibia 327-400; tarsus 125-135; claw 36-43; number of setae: coxa 9-13; trochanter 4-6 (longest about 150-170 µm); femur 20-30; tibia 28-36 (tibia with two spurs, each 33-40 µm long); tarsus 7-10; min translucent pores rather few on posterior margin of distal end of metafemur but frequent along metatibia. Tarsal digitules both setose; claw digitules slightly longer than claw and both capitate; claw with only a small denticle, not obvious. Vulva obvious, between segments VII and VIII.

Comment. In completely lacking quinquelocular pores, the adult female of *P. gossypiphilus* differs from all other *Phenacoccus* species known from southern Asia apart from *P. solani*, to which species it keys out in the key to adult female *Phenacoccus* species in Williams (2004). However,

it differs from the latter species in several important features (character-states on *P. solani* in brackets): (i) two sizes of ventral oral collar ducts present (one size); (ii) several oral collar ducts present on all thoracic segments (absent or very few posterior to each spiracle & absent medially on meso & metathorax); (iii) multilocular disc-pores quite abundant medially anterior to vulva, present across full length of segment VII (many fewer, present only along posterior margins); (iv) multilocular pores only present medially on segments VI, VII and VIII (also present medially on segments V & IV); (v) some multilocular pores generally present laterally on some or all abdominal segments II-VII (generally entirely absent, rarely on VI & VII) and (vi) a few translucent pores present on distal end of femur - although these can be hard to see and might actually be absent on some specimens (absent).

Name derivation. This species is named after the host plant on which it is a pest: *Gossypium* (Gr. *gossypion*: cotton) and *philo* from the Greek *philia*, love or affection for.

General discussion. Rather few species of *Phenacoccus* are known, which share the following characters: (i) total absence of quinquelocular pores; (ii) absence of multilocular disc-pores dorsally and (iii) presence of 18 pairs of cerarii. As far as the authors have been able to determine, only three species currently share these characters: *P. defectus* Ferris, *P. solani* Ferris and *P. solenopsis*. Of these, only *P. solani* is currently known from southern Asia (Williams, 2004) but all three are present in Central and South America (Williams & Granara De Willink, 1992; Ben-Dov *et al.*, 2007). Williams and Granara De Willink (1992) discuss at some length the difficulty of separating these three species as all three are somewhat variable.

Variation between various lots of material. Multilocular disc-pores are unknown along the abdominal submargins of *P. defectus* and most *P. solani*. They are also absent from the submargin of the type series of *P. solenopsis* (as illustrated by Williams & Granara De Willink, 1992). As indicated above, *P. gossypiphilus* is distinguishable from the type series of *P. solenopsis* in having the multilocular disc-pores present on the submargins of some abdominal segments. However, many other (non-type) collections of *Phenacoccus* have been made available from North and South America and from the Gulf of Mexico, which are also considered to be *P. solenopsis* and these have many multilocular disc-pores on the abdominal submargins. Some of this material is almost certainly the material referred to by Williams and Granara De Willink (1992). It is clear that, if all of this material does represent *P. solenopsis*, then *P. gossypiphilus* and *P. solenopsis* (based on this wider understanding of the latter species) are very similar - indeed, no distinguishing character could be discovered to separate the greenhouse form of *P. gossypiphilus* from many *P. solenopsis* despite an exhaustive search of all growth stages. To make matters more complicated, several lots of material from Asia (Thailand, Taiwan & New Caledonia) show a similar frequency of multilocular pores on the submargin to that

noted for *P. solenopsis* and *P. gossypiphilus* and have the same distribution of oral collar ducts. Therefore, it would appear that, on the basis of the present understanding of *P. gossypiphilus* and *P. solenopsis*, specimens of these two species can only be distinguished when the former species is from the field during the hot, cotton-growing season.

Records of *Phenacoccus* species of Malvaceae. Eleven species of *Phenacoccus* have currently been recorded off Malvaceae but only 5 have so far been found on *Gossypium* (Ben-Dov *et al.*, 2007): *P. gossypii* Townsend and Cockerell, which is mainly known from the USA, Mexico and the Bahamas, but has fairly recently been recorded from the Western Palaearctic and Japan; *P. madeirensis* Green, which is now known to be cosmopolitan and has recently been recorded from Pakistan, the Philippines and Vietnam in southern Asia (Williams, 2004); *P. parvus*, also rather cosmopolitan and now known from Indonesia, India, the Maldives, Singapore and Thailand (Williams, 2004); *P. similis* Granara De Willink, only known from the Neotropics and *P. solenopsis* Tinsley, apparently restricted to the Nearctic and Neotropics. Apart from *P. solenopsis* (discussed above), these species should all be easily separable from *P. gossypiphilus* as they all have quinquelocular pores on the venter; in addition, *P. gossypii* and *P. madeirensis* also have quinquelocular pores and multilocular pores on the dorsum.

Brief summary of biology and damage to cotton in Pakistan. Since 2005, outbreaks of *P. gossypiphilus* have been recorded in most of the major cotton growing regions (Sindh & Punjab) of Pakistan, namely Bahawal Pur, Dera Ghazi Khan, Faisalabad, Layyah, Lodhran, Multan, Muzaffar Garh, Rajan Pur, Toba Tek Sing and Khanewal, Rahim yar Khan, Bahawalnagar, Vehari, Rajan pur, Jhang, Okara, Kasur, Lahore, Rawalpindi, Tando Allah Yar, Mir Pur Khas, Nawab Shah, Sanghar, Thatta, Badin and in Sindh to Karachi.

P. gossypiphilus is mainly found on the young growth, including twigs, leaves, flower buds and petioles but can occur even on the stems in heavy infestations. The infested plants become stunted, growth appears to stop and most plants look dehydrated. In severe outbreaks, the bolls fail to open and defoliation occurs (including the loss of flower buds, flowers & immature bolls). In addition, the plants become covered in a dense mat of sooty moulds, which grows on the large amount of exuded honeydew. This honeydew also attracts ants (Formicidae: Hymenoptera) of several species.

In the summer, the entire mealybug colony is covered in white, sticky, elastic, woolly wax, most of which is the ovisacs on the adult females. These contain many crawlers (1st-instar nymphs), which eventually disperse to other parts of the same plant or get carried on the wind to other areas. It appears that *P. gossypiphilus* is able to overwinter successfully on a range of weeds and other plants close to the cotton fields. In Pakistan, the cotton is planted out in May and June and harvested in November-December. Even

though these cotton crops are followed by wheat in the rotation cycle, the weed populations provide a major source for quick infestation to the young growth of the new years cotton crop.

CONCLUSION

Although *P. gossypiphilus* appears to be very similar to (& often indistinguishable from) *P. solenopsis* from New World, this important species needs to be named. Because of the high importance of this invasive species, great caution should be exercised regarding similar material arriving from Pakistan (& possibly other neighbouring Asian countries) at ports of entry round the world.

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