

Phenacoccus solenopsis Tinsley (Sternorrhyncha: Pseudococcidae), its natural enemies and host plants in Iran

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Abstract

The mealybug *Phenacoccus solenopsis* Tinsley is a geographically widely distributed pest that was unknown in Iran until its recent invasion with potentially serious consequences. A survey of the mealybug *P. solenopsis* distribution, host plants and natural enemies was conducted in 2009 - 2015 in Iran. Samples of infested host plants were transferred to the laboratory in polythene bags and were maintained at room temperature ($25 \pm 5^{\circ}\text{C}$) and R.H. 45-60%, for 4 weeks for further inspection. To date, 219 species belonging to 159 genera and 70 families of host plants, as well as 30 species of natural enemies of the mealybug *P. solenopsis*, have been recorded. Field, laboratory and greenhouse studies indicated that between all its natural predators, *Nephus arcuatus* Kapur and *Hyperaspis polita* Weise were the most successful at reducing populations of *P. solenopsis*. It was concluded that the hymenopterous parasitoid *Aenasius bambawalei* Hayat has the greatest potential as a candidate for use in the control of the pest. This is the first report of an ongoing investigation of distribution occurrence of *P. solenopsis*, with the exception of Hormozgan province, in Iran. It is also the first comprehensive record of the presence in Iran of its host plants and natural enemies.

Key words: *Phenacoccus solenopsis*, Host plants, Natural enemies, Distribution, Iran.

چکیده

شپشک آردآلود پنبه *Phenacoccus solenopsis* Tinsley، دشمنان طبیعی و گیاهان میزبان آن در ایران محمد سعید مصدق، شبنم وفائی، افروز فارسی، سارا ضرغامی، مهدی اسفندیاری، فریده صدیقی دهکردی، اعظم فاضلی نژاد و فاطمه سیف‌الهی

Phenacoccus solenopsis Tinsley یکی از آفات بالقوه با گسترش جغرافیایی وسیع است. در بررسی‌های درسالهای ۹۴-۱۳۸۹، پراکندگی، دشمنان طبیعی و گیاهان میزبان این شپشک در استانهای خوزستان، کهگیلویه و بویر احمد (جنوب غربی)، بوشهر، فارس و هرمزگان (جنوب)، کرمان و یزد (مرکز)، جزایر کیش و قشم در خلیج فارس جمع‌آوری و شناسایی گردید. قسمت‌هایی از گیاهان آلوده قطع و درکیسه‌های پلاستیکی قرار داده و به آزمایشگاه حمل گردید. نمونه‌ها در جعبه‌های پلاستیکی تهیه‌دار قرار و در شرایط اتاق در دمای 25 ± 5 درجه سلسیوس و رطوبت نسبی ۶۰-۴۵ درصد نگهداری و به مدت ۴ هفته برای خروج دشمنان طبیعی روزانه مورد بازدید قرار گرفت. از گیاهان و دشمنان طبیعی جمع‌آوری شده، تاکنون ۲۱۹ گونه میزبان گیاهی متعلق به ۱۵۹ جنس از ۷۰ خانواده از درختان، درختچه‌ها، گیاهان زراعی، سبزیجات، زیتنی و علفهای هرز و ۳۰ گونه از دشمنان طبیعی این شپشک شناسایی گردیده است. مطالعات صحرائی، گلخانه‌ای و آزمایشگاهی نشان می‌دهد که در بین دشمنان طبیعی شکارگر شناسایی شده *Nephus* Kapur و *Hyperaspis polita* Weise به ترتیب از کارایی زیادتری در کنترل این شپشک برخوردار می‌باشند زنبور انگل *Aenasius bambawalei* Hayat از جمله عوامل کنترل مهم بالقوه بیولوژیک *P. solenopsis* است. این اولین گزارش جامع از وجود دشمنان طبیعی، گیاهان میزبان و پراکندگی این شپشک در ایران است.

واژگان کلیدی: *Phenacoccus solenopsis*، میزبانهای گیاهی، دشمنان طبیعی، پراکندگی، ایران

Introduction

Exotic pests, especially those that are polyphagous with a wide host range, establish themselves easily when invading countries lacking their natural enemies. Such species have immense potential to emerge as crop pests causing severe economic damage to a wide range of crops and posing a grave threat to agriculture in the introduced country (Nagrare *et al.*, 2011).

The genus *Phenacoccus* currently contains about 208 species and is one of the largest genera in the Pseudococcidae or mealybugs (Ben-Dov *et al.*, 2015). Several *Phenacoccus* species are known to be important plant pests and potentially invasive. *Phenacoccus solenopsis* Tinsley, known as solenopsis (cotton) mealybug, originated from the southwestern United States and was first described from New Mexico (Tinsley, 1898). A century later, in 1990, it was reported on cotton in Texas (Fuches *et al.*, 1991). It remained in the U.S. until 1992 when it began spreading to South America, Asia, and India, (Dhara Jothi *et al.*, 2008). It was intercepted in the United Kingdom in 2007, on menthe leaves shipped from Ghana (Muniappan,

2011). Subsequently it was identified in China (Wu & Zhang, 2009; Wang *et al.*, 2010) and Africa (Muniappan *et al.*, 2009, 2012) before reaching Australia (Queensland), Cambodia and Indonesia in early 2010 (Muniappan *et al.*, 2009; Charleston & Murray, 2010). Between 2006 and 2008 the solenopsis mealybug caused severe damage to cotton in Pakistan and India (Dutt, 2007 a, b).

Phenacoccus solenopsis is a polyphagous pest, widely distributed geographically, with the potential to cause serious damage to a range of plants belonging to over 50 families, including the Cucurbitaceae, Fabaceae, Malvaceae, and Solanaceae (Hodgson *et al.*, 2008; Muniappan *et al.*, 2009). In Pakestan, it has so far been recorded on 55 host species in 18 plant families (Abbas *et al.*, 2010) while in India 166 host plant species belonging to 51 families comprising 78 weeds, 27 ornamentals, 18 trees, 17 vegetables, 12 field crops, 8 fruit plants and 4 spice plants have been recorded in three agro-ecosystems (Nagrare *et al.*, 2011). Furthermore, a total of 43 host plant species have been also reported in the province of Hormozgan, Southern Iran (Fallahzadeh *et al.*, 2014; Moghaddam, 2013).

Numerous biological agents have been reported that are active on *P. solenopsis* in different countries. Several species of predator such as *Coccinella* spp., *Chrysoperla* sp., *Geocoris* sp., *Orius* sp. and spiders have been recorded actively feeding on mealybug populations (Nagrare *et al.*, 2011; Sahito *et al.*, 2011). In Hormozgan, Sothern Iran, a total of 8 species in 5 genera belonging to 3 subfamilies of the coccinellid family have been reported on *P. solenopsis* (Fallahzadeh *et al.*, 2013). The first detailed record of the presence of the hymenoptera parasitoid *Aenasius bambawalei* Hayat on *P. solenopsis* in Iran was reported from Khuzestan province, southwest by Mossadegh *et al.* (2013). Later on it was reported from Hormozgan (Fallahzadeh *et al.*, 2014). Two groups (Bodlah *et al.*, 2010; Tanwar *et al.*, 2011) have reported that the parasitoid *A. bambawalei* plays a as key role in reducing mealybug infestation.

The first recorded incidence of *P. solenopsis* in Iran was reported by Mogghadam & Bagheri (2010) when it was observed on *Hibiscus rosa-sinensis* L. in Bandar Abbas and Minab, Hormozgan, south Iran.

The work described in the present communication comprises the first report of an ongoing investigation into the extent to which *P. solenopsis*, as well as its natural enemies and predators, are present in Iran.

Material and methods

Host plants and natural enemies of *P. solenopsis* were collected and identified during the period July 2009 to June 2015 in the provinces of Khuzestan and Kohgiluyeh va- Boyerahmad, (southwestern Iran), Fars, Bushehr, Hormozgan (Southern Iran), Kerman and Yazd (Central Iran), and the islands of Kish and Gheshm (Persian Gulf). Samples of infested material were cut from host plants and transferred to the laboratory in a polythene bag each. They were maintained at room temperature ($25\pm 5^{\circ}\text{C}$) and R.H. 45-60%, for 4 weeks for further inspection. The majority of the work for this investigation was done in Khuzestan.

Results

1-Distribution

Phenacoccus solenopsis was observed in the provinces of Khuzestan, Fars, Bushehr, Kerman and Yazd as well as on the islands of Kish and Gheshm in the Persian Gulf (fig. 1). It was first observed infesting *H. rosa-sinensis* in Bushehr (Asalooyeh and Bushehr city, April, 2009), in Shames-Abbad, Dezful (05 July 2009) and was later recorded on different host plants in the cities of Mahshahr (23 September, 2011), Ahwaz (10 November 2011), and Behbahan (11 November 2013), Endimeshk (June, 2014), Khuzestan (fig. 2). It was also recorded in the provinces of Fars (Shiraz, September, 2012, November, 2013; Lar, November, 11, 2013), Kerman (June, 2012; May, 2013; November, 2013), Yazd (May 2014 and September 2014), Kohgiluyeh va- Boyerahmad (Gachsaran and Basht, Sept., 2014) and the islands of Kish (26 March, 2012) and Gheshm (Nov. 22 2013) in the Persian Gulf on *H. rosa-sinensis* and several other host plants.

2-Host plants

To date, altogether 219 species of host plants belonging to 159 genera and 70 families of trees, bushes, field crops, vegetables, ornamentals and weeds have recorded in the areas surveyed. Of these, 217 species were noted in Khuzestan, 3 in Fars, 21 in Bushehr, 4 in Kerman, 2 in Yazd, 1 in Kish and 1 on Gheshm Islands. (table 1). With the exception of *Gossypiumhirsutum* L. and *Mangifera indica* L., found in Kerman, all other host plant species were common to the areas studied. 60% of the host plant species identified belonged to the families shown in Table 2 with the remaining 40% belonging to another 54 families.

3-Natural enemies

Number 1 to 28 (table 3) were apparent from the beginning of infestation and gradually increased in number over time. It appeared from field, laboratory and greenhouse studies that, amongst the natural predators identified, *N. arcuatus* and *H. polita* were the most successful at reducing populations of *P. solenopsis*.

The hymenopterous parasitoid, *A. bambawalei* (Hayat, 2009), appeared first at low density, on *Althaea officinalis* and *H. rosa-sinensis*, in Dezful (June 2011). Later (August 2011) it was apparent on different host plants in Mahshahr and eastern Ahwaz (October 2011). The identity of the parasitoid was subsequently confirmed by Professor Hayat from samples sent to him in India.

Once the presence of a parasitoid had been recognized, insecticidal control of *P. solenopsis* was discontinued at specified locations especially in east of Ahwaz in order to study the effect of the parasitoid on mealy bug populations. A rapid rise in population density of *A. bambawalei* was observed at eastern Ahwaz leading to 95% parasitism of *P. solenopsis* by October 29, 2012. Mealy bug mummies containing parasitoid pupae were also visible covering the branches, leaves and stems of the different plants infested with mealy bug colonies (fig. 3). There had been a trace only, of *P. solenopsis*, on 2 out of 62 host plants in that area previous to this. From December 6, 2012 to May 24, 2013, no trace of the mealy bug was found in that region. Meanwhile, mealy bug parasitization in other parts of Ahwaz, as well as in Mahshahr, increased and ranged from 40-70%. By August 6, 2013 no trace of *P. solenopsis* could be found in Dezful too. *A. bambawalei* was recorded subsequently in Hormozgan (Bandar-Abbas, November 11, 2013), Fars (Lar, November 11, 2013), Bushehr (August 20, 2014), Kerman (Jiroft, May, 2015), Kohgiluyeh va- Boyerahmad (Gachsaran and Basht, May, 2015) and on Gheshm Island (November, 22, 2013).

A second parasitoid, *Promuscide unfasciiventris* Girault (Chalcidoidea: Encyrtidae), was recorded along with *A. bambawalei* in Dezful and Ahwaz on 3 October, 2012 and 29 October, 2012 respectively. Later it was observed in Hormozgan (Bandar-Abbas, November 11, 2013), Fars (Lar, November 11, 2013) and Gheshm Island (22 November, 2013). *P. unfasciiventris* has been reported as a primary parasitoid of coccids (Sureshan & Narendran, 2005). This species had been reported before and recently as a hyperparasitoid on the encyrtid too (Hayat 1998; Hayat 2009).

All of the predators and parasitoids listed in Table 3 were recorded in Khuzestan. In Hormozgan, *N. arcuatus* *H. polita*, *Nephus* sp., *A. bambawalei* and *P. unfasciiventris*, in Bushehr, *N. arcuatus*, *Nephus* sp., *H. polita* and *A. bambawalei*, in Kerman, *A. bambawalei*, in Kohgiluyeh va- Boyerahmad, *H. polita* and *A. bambawalei* only, were recorded while *N. arcuatus* only, was recorded on Kish Island. *C. septempunctata*, *Scymnus (P.) argutus*, *Anthocoris* sp., *A. bambawalei* and *P. unfasciiventris* were recorded in Fars and *A. bambawalei* on Gheshm Island.

A number of coccinellid parasitoids and other hyperparasitoids were collected and identified in addition to those recorded as predators and parasitoids of *P. solenopsis*, namely:

1-*Chartocerus (Matritia)* sp. near *kurdjumovi* (Nikolskaya) (Hym. Signiforidae). It has been also reported as a hyperparasitoid of *Nipaeococcus viridis* (Newstead) (Asadeh & Mossadegh, 1993; Novin *et al.*, 2000), *Maconelliococcus hirsutus* (Green) (Alizadeh *et al.*, 2013) in Khuzestan and *Planococcus ficus* in Fars (Fallahzadeh *et al.*, 2008).

2-*Pachyneuron muscarum* (L.) (Hym.:Pteromalidae). It has been also reported as a hyperparasitoid of *N.viridis* in Khuzestan ((Asadeh & Mossadegh, 1993).

3-*Prochiloneurus indicus* (Shafee, Alam and Agarwal), (Hym. : Encyrtidae).

4-*Prochiloneurus bolivari* (Mercet) (Hym.: Encyrtidae) as a hyperparasitoid. It has been also reported on *Planococcus ficus* in Fars(Fallahzadeh *et al.* 2008) and *Maconellicoccus hirsutus* (Green) in Khuzestan (Alizadeh *et al.*, 2013).

5- *Homalotylus quaylei* Timberlake (Hym.: Encyrtidae) as a larvalparasitoid of *N. arcuatus* and *H. polita* . It has been reported previously as a larval parasitoid of *N. arcuatus* (Zarghami *et al.*, 2012; Alizadeh *et al.*, 2013); *Nephus includens* Kirsch predator of *N. viridis* (Asadeh & Mossadegh, 1993; Novin *et al.*, 2000) from Khuzestan.

Discussion

The results of this study indicate that the mealybug *P. solenopsis* is spreading rapidly within Iran. From its first appearance in Bandar Abbas and Minab, Hormozgan on 1 January 2009 (Moghadam & Bagheri, 2010) and later on, in this survey in 2009 in Bushehr (April) and Shames-Abbad, Dezful (July), in Fars (Shiraz, September, 2012, November, 2013; Lar, November, 11, 2013), Kerman (June, 2012; May, 2013; November, 2013), in the Islands of Kish (26 March, 2012)in 2013 in Ghesm) in the Persian Gulf,in Yazd (May 2014 and September 2014) and Kohgiluyeh va- Boyerahmad (Sept., 2014).It was observed spreading and infesting a range of different host plant species on agricultural land, green houses and within cities in the provinces of Khuzestan, Fars, Kerman, Yazd, Bushehr, Kohgiluyeh va- Boyerahmad as well as the islands of Ghesm and Kish (Persian Gulf). Its rapid spread can be attributed to its short life cycle (12-14 generations a year), its high survival rate, being able to withstand long periods without a host, and its tolerance of cold weather. It is easily spread within fields by wind, water, birds, human beings, farm equipment, other insect species and animals, and potentially between fields also. The identification within Khuzestan of 217 host plant species capable of supporting infestations by *P. solenopsis* is likely to have serious consequences for agriculture in Khuzestan and probably other Iranian provinces, too.

The present situation in all infested areas is that populations of *P. solenopsis* are gradually being kept under control by the presence of several parasitoids, predominantly *A. bambawalei*, and several coccinellid beetle predators. Field, laboratory and greenhouse studies all indicated that of the predators identified, *N. arcuatus* and *H. polita*, were most successful at reducing populations of *P. solenopsis*. *A. bambawalei* with its short life cycle, great potential for searching out its host, parasitization capacity and long lifespan, is one of the best examples of the successful biological control of *P. solenopsis* by a hymenopterous parasitoid. The application of a suitable bioagent immediately the first signs of infestation by *P. solenopsis* are observed is clearly desirable. *A. bambawalei* is an obvious candidate for this through a program of mass rearing and application in the field, green houses and other places where infestation is occurring. Awareness and early detection of the pest, coupled with the immediate implementation of biological control methods, are likely to be of benefit by both minimizing economic loss caused by the invader and by preventing or delaying its spread. The application of insecticides that destroy its parasitoids and predators, on the other hand, may well result in outbreaks of mealy bug and the development of pest resistance.

This is the first comprehensive report of the occurrence of *P. solenopsis* in the provinces of Khuzestan, Fars, Kerman, Yazd, Kohgiluyeh va- Boyerahmad ,and Bushehr, as well as on the Kish and Ghesm islands (Persian Gulf), Iran. Furthermore, we present here the first detailed record of the presence in Iran of its host plants and natural enemies.

Mass production and release of *A. bambawalei* in Khuzestan province is in progress.

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Table 1. Host plants recorded for *P. solenopsis* in Iran.

Type of Plant	Number of species
Ornamentals	108
Fruit plants	22
Trees	5
Vegetables	16
Field crops	7
Weeds	61
Total	219

Table 2. Number of *P. solenopsis* host plant species identified and the families to which they belong.

Host plant family	Number of species
Amarantaceae	5
Araceae	6
Asteraceae (Compositae)	24
Bignoniaceae	5
Celastraceae	5
Convolvulaceae	10
Crucifereae (Brassicaceae)	6
Cucurbitaceae	3
Graminae	20
Labiatae	4
Leguminosae	5
Liliaceae	4
Malvaceae	8
Moraceae	3
Rutaceae	7
Solanaceae	12

Table 3. Natural enemies of mealybug *P. solenopsis* identified and their distribution.

Natural enemies	Distribution
Predators:	
A-Coccinellidae: Coleoptera	
<i>Chilocorus bipustulatus</i> (L.)	Khuzestan
<i>Clistothethus arcuatus</i> Rossi	Khuzestan
<i>Coccinella septempunctata</i> (L.)	Khuzestan and Fars
<i>Exochomus nigripennis</i> Erichson	Khuzestan
<i>Hyperaspis polita</i> Weise	Khuzestan and Hormozgan (Bandar Abbas), Kohgiluyeh va-Boyerahmad and Khuzestan
<i>Hyperaspis vinciguerrae</i> Capara	Khuzestan
<i>Hyperaspis</i> sp.	Khuzestan
<i>Nephus arcuatus</i> Kapur	Khuzestan, Hormozgan (Bandar Abbas) and Kish Island
<i>Nephus includes</i> Kirsch	Khuzestan
<i>Nephus</i> sp. nr. <i>Fenestratus</i> (Sahlberg)	Khuzestan
<i>Nephus nigricans</i> Weise	Khuzestan
<i>Nephus</i> (<i>Sidis</i>) <i>hiekei</i> Fursch	Khuzestan
<i>Nephus</i> spp.	Khuzestan and Hormozgan (Bandar Abbas)
<i>Scymnus pallipes</i> Mulsant	Khuzestan
<i>Scymnus</i> (<i>Pullus</i>) <i>argutus</i> Mul.	Fars (Lar)
<i>Scymnus</i> (<i>Scymnus</i>) <i>apetzi</i> Mul.	Khuzestan
<i>Scymnus</i> (<i>S.</i>) <i>flavicollis</i> (Redtenbacher)	Khuzestan
<i>Scymnus</i> (<i>S.</i>) <i>levaillanti</i> Mulsant	Khuzestan
<i>Scymnus syriacus</i> (Marseul)	Khuzestan
B-Chrysopidae: Neuroptera	
<i>Chrysoperla carnea</i> Stephens	Khuzestan
<i>Chrysoperla</i> sp.	Khuzestan
C- Cecidomyiidae: Diptera	
<i>Dicrodiplosis manihoti</i> Harrison.	Khuzestan
D-Anthocoridae: Hemiptera:	
<i>Anthocoris</i> sp.	Khuzestan and Fars
Parasitoids:	
E-Encyrtidae: Hymenoptera	
<i>Anagyrus dactylopii</i> (Howard)	Khuzestan
<i>Anagyrus agraensis</i> Sarawat	Khuzestan
<i>Anagyrus diversicornis</i> Mercet.	Khuzestan
<i>Anagyrus mirzai</i> Agarwal & Alam	Khuzestan
<i>Anagyrus</i> nr <i>kamali</i> Moursi	Khuzestan
<i>Aenasius bambawalei</i> Hayat	Khuzestan, Fars, Hormozgan, Bushahr, Fars, Kerman (Jiroft), Hormozgan, (Bandar Abbas), Kohgiluyeh va- Boyerahmad (Gachsaran and Basht) and Gasham Island
<i>Promuscidea unfasciiventris</i> Girault	Khuzestan, Hormozgan (Bandar Abbas) and Fars (Lar)



Fig. 1. The bold lines show distribution of *P. solenopsis* in Iran.



Fig. 2. Infestation of *H. rosa-sinensis* by *P. solenopsis*. (Photo., original)



Fig. 3. *P. solenopsis* mummies containing *A. bambawalei* pupae on *A. officinalis* (Photo., original)

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