NOTE

First Report of the Pink Hibiscus Mealybug, *Maconellicoccus hirsutus* (Green) (Hemiptera: Pseudococcidae), in South Carolina

Juang-Horng Chong


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This paper reports the first detection of pink hibiscus mealybug (PHM), *Maconellicoccus hirsutus* (Green) (Hemiptera: Pseudococcidae), in South Carolina. The first observation of *M. hirsutus* was a small isolated infestation of three potted hibiscus plants, *Hibiscus rosa-sinensis* L. (Malvaceae), about 60 cm in height. The infestation was detected by the author in September 2009 at a residential property in Little River, Horry County, SC. The author was alerted by the homeowner’s inquiries about mealybug control on tropical hibiscus. The infested terminals and leaves were distorted and showed the characteristic ‘bunchy-top’ deformation as described by Kairo et al. (2000). Numerous second- and third-instar nymphs and young adult females were harbored within the deformed terminals. No ovipositing female mealybugs were observed, suggesting that the infestation was in its initial stage of establishment. No sign of parasitism or predation was observed.

Samples were collected from the infested plants and specimens were identified as *M. hirsutus* by the author based on morphological characteristics (Miller 1999, 2005). The identification was subsequently confirmed by Glenn D. Landau (USDA-APHIS, Columbia, SC) and Gregory A. Evans (USDA-APHIS, Beltsville, MD). Voucher specimens are deposited at the Clemson University Arthropod Collection and with USDA-APHIS (Beltsville, MD).

The infested plants were destroyed by a plant health inspector from Clemson University Department of Plant Industry (DPI) the day after the initial detection. The infested plants were purchased by the homeowner at a local home improvement store about one month before the detection. Trace-back conducted by DPI determined that the infested plants originated from a nursery in Homestead, FL. The infestation at Little River is being eradicated (NAPIS 2010). The detection of *M. hirsutus* in SC may have significant economic implications for the agriculture in the state. To date, no quarantine or other regulatory activities against *M. hirsutus* have been imposed by DPI and USDA-APHIS in SC.

1Accepted for publication 30 September 2010.
2Department of Entomology, Soils, and Plant Sciences, Clemson University, Pee Dee Research and Education Center, 2200 Pocket Road, Florence, SC 29506. E-mail: juanghc@clemson.edu
Maconellicoccus hirsutus was first described as Phenacoccus hirsutus Green by E. E. Green (1908) based on specimens collected in India on an undetermined shrub. Ezzat (1958) re-described the species as M. hirsutus. Seven other Maconellicoccus species are known from the Oriental, Australasia, and Afrotropical Regions. They are M. australensis (Green & Lidgett), M. lanigerus (Fuller), M. leptospermi Williams, M. multipori (Takahasi), M. ramchesis Williams, M. tasmaniae Williams, and M. ugandae (Laing) (Ben-Dov 1994, Williams 1986). Williams (1986, 2004) suggested that M. hirsutus is native to southern Asia. Currently, M. hirsutus is found in 91 countries and territories in Afrotropical, Australasia, Nearctic, Neotropical, Oriental, and Palaeartic regions. An established infestation of this pest has not been detected in Europe.

Miller (1999) provided a list of characteristics that may help to distinguish M. hirsutus from other common mealybug species, but he cautioned users to obtain positive identification based on slide-mounted specimens. Maconellicoccus hirsutus can tentatively be identified based on its external appearance. Adults are usually less than 4 mm in length, pink in color, and exude pink to red body fluids when crushed between the fingers. Maconellicoccus hirsutus does not have conspicuous, long waxy lateral and caudal filaments, which distinguishes this species from other commonly encountered pink-bodied mealybug species, such as Planococcus citri (Risso) (citrus mealybug), Pseudococcus maritimus (Ehrhorn) (grape mealybug), Pseudococcus viburni Signoret (obscure mealybug), and Dysmicoccus brevipes (Cockerell) (pineapple mealybug).

Maconellicoccus hirsutus has a long history as a serious pest of agricultural, horticultural, and fiber crops in southern Asia and Egypt (Williams 1986), as well as in the newly introduced regions such as the Caribbean (Kairo et al. 2000). The pest status of M. hirsutus is accentuated by its ability to infest more than 330 plant species (Chang & Miller 1996, ScaleNet 2010). Some are important agricultural, horticultural, fiber and food crops, including avocado, beans, cassava, citrus, coffee, cotton, eggplants, fig, grape, hibiscus, mango, peanut, soybean, squash, pumpkin, sugarcane, and many ornamental plants. The most recent rise in the status of M. hirsutus as an important pest of cotton was reported from Pakistan (Mohammad 2010) and India (Goswami 2007). Maconellicoccus hirsutus can also use many non-crop plant species as hosts, which allow the mealybugs to establish a reservoir outside of the areas of control and quarantine, and complicates its area-wide management. If left uncontrolled, M. hirsutus could potentially cause $750 million/yr and $5 billion over 10 yr to agriculture in the United States (Moffitt 1999).

Kairo et al. (2000, and references therein) provided a review of the economic impact of M. hirsutus infestations in the Caribbean. The estimated economic losses caused by M. hirsutus, which include crop losses, costs of control, and impact on trade, were $18.3 million (USD) in Grenada (1995–1998), $280,000 in St. Kitts (1995–1997), $5.1 million in Trinidad (1995–1997), $67,000 in St. Lucia and St. Vincent, and $3.4 million in the Grenadines. An infestation in Puerto Rico was under successful biological control, and thus they avoided significant economic losses (Michaud 2003). Assessment of the economic impacts of M. hirsutus invasion in other regions is not available.

The most distinguishing symptom of M. hirsutus infestation is the presence of ‘bunchy-top’ deformation, formed by distorted leaves and shoots as a result of M. hirsutus feeding (Kairo et al. 2000). This ‘bunchy-top’ symptom is not restricted to
hibiscus, but also is exhibited by other host plants such as citrus and cotton (Meyerdirk et al. 2001). Mealybugs of all stages, as well as predators and parasitoids, can be found within the ‘bunchy-top’ (Vitullo et al. 2009). The ‘bunchy-top’ injury is permanent, and the distortion will remain on the infested terminal until all the leaves mature and drop off. Heavily infested leaves, flowers, and fruits often abort prematurely. The infestation does not usually inhibit development of new terminals or leaves. If the infestation is eliminated, new growth from the previously infested terminal or from another healthy terminal does not exhibit such ‘bunchy-top’ symptom. Wax deposits and ovisacs produced by the mealybugs often envelope the infested terminals. Infested plants often appear stunted and covered with honeydew and black sooty mold. A recent study by Vitullo et al. (2009) showed that the expression of ‘bunchy-top’ deformation depended on the mealybug density and the hibiscus cultivars. Other damage symptoms on various host plants include branch dieback, branch stunting and distortion, fruit and flower deformation, and damages associated with honeydew and sooty mold (Meyerdirk et al. 2001).

Mani (1989) provided a review of the biology of *M. hirsutus* and included a summary on the developmental duration extracted from various works. More recently, Chong et al. (2008) showed that female *M. hirsutus* required 66, 31, 29, and 33 d to develop from egg to adulthood at 20, 25, 27, and 30°C, respectively, when reared on excised hibiscus cuttings in the laboratory. The complete development of female *M. hirsutus* from egg to adulthood and from hatching to death required thermal units of 347 and 680 degree-days, respectively (Chong et al. 2008). Females produced 260–300 eggs in 8–11 d at 20–27°C (Chong et al. 2008). Developmental time, survivorship, and reproductive capacity differ among various host plants (Babu & Azam 1987, Persad & Khan 2002, Serrano & Lapointe 2002). Life table analyses suggest that the doubling time of a *M. hirsutus* population was between 5.8 (Chong et al. 2008) and 8.8 d (Persad & Khan 2002), and the intrinsic rate of increase was between 0.08 (Persad & Khan 2002) and 0.12 $\varphi\varphi$/day (Chong et al. 2008).

Adult males use a sex pheromone released by virgin adult females to locate mates (Serrano et al. 2001). The sex pheromone was identified as a 1:5 mixture of (R)-lavandulyl (S)-2-methylbutanoate and (R)-maconellyl (S)-2-methylbutanoate (referred to as maconelliol) (Zhang et al. 2004). The isolation, identification, and synthesis of *M. hirsutus* sex pheromone facilitated the development of an effective tool in *M. hirsutus* management. Currently, sticky traps baited with sex pheromone bait are the main monitoring tools for *M. hirsutus*. Baits loaded with synthetic sex pheromone were shown to be effective in attracting male *M. hirsutus* (Zhang & Amalin 2005).

Using pheromone-baited sticky traps, Hall et al. (2008) showed that the *M. hirsutus* populations at three locations in central and southern Florida increased from July to October. In the Imperial Valley of California, *M. hirsutus* population generally peaked from March to October (Roltsch et al. 2006). In Australia, the crawlers were most active in the spring and summer (Goolsby et al. 2002). These studies suggested that mealybug populations peak in late summer into early fall and that *M. hirsutus* phenology differs across locations.

Borchert et al. (2005) predicted that *M. hirsutus* could complete at least one generation throughout much of North America, with as many as 10 generations in the southernmost locations of the United States. The distribution could be
restricted by freezing conditions (Borchert et al. 2005). The cold-hardiness and over-wintering stage of *M. hirsutus* are unknown, thus, the ability to accurately predict the distribution of this species is limited. Chang & Miller (1996) suggested that *M. hirsutus* is most likely to establish in Alabama, Arizona, Georgia, Louisiana, Mississippi, South Carolina, and Texas. After examining the prediction parameters and conclusions of Borchert et al. (2005), Chong et al. (2008) suggested that the distribution of *M. hirsutus* might extend into Canada.

*Maconellicoccus hirsutus* invaded Hawaii in 1983 (Beardsley 1985). Introduction to the continental USA began in the Imperial Valley of California in 1999 (CDFA 1999), followed by Florida in 2002 (Hoy et al. 2002), Louisiana in 2006 (LDAF 2006), Texas in 2007 (Bogran & Ludwig 2007), Georgia in 2008 (Horton 2008), North Carolina in 2009 (NAPIS 2010), and most recently in South Carolina in 2009. Short distance dispersal of *M. hirsutus* is accomplished by the active movement or wind dispersal of crawlers, or the movement of contaminated personnel and tools. Global spread of *M. hirsutus* is likely the result of the trade of live horticultural products from infested areas. Despite the best quarantine efforts in Florida, infested hibiscus plants from there were detected in retail outlets in Kansas and Louisiana, but PHM did not establish (Hodges 2005). However, establishments of PHM in landscapes using infested plants were confirmed in Georgia (Horton 2008) and South Carolina.

Phytosanitary practices, such as the use of irradiation (Jacobsen & Hara 2003), methyl bromide (Zettler et al. 2002), hot water immersion (Hara & Jacobsen 2005), and vapor heat treatment (Follet 2004), were effective in killing *M. hirsutus* on the surface of fruits and thus allowed for the export of selected commodities from infested areas in Hawaii. However, these methods are not suitable for use on live ornamental plant materials.

In nursery production, insecticides are the main tools for managing *M. hirsutus* populations under quarantine requirements. Soil drenches of neonicotinoids (dinotefuran, imidacloprid and thiamethoxam) or foliar applications of organophosphates (acephate and chlorpyrifos), pyrethroids (bifenthrin), neonicotinoids (acetamiprid), or insect growth regulators (buprofezin) are recommended by the University of Florida for the quarantine treatment of *M. hirsutus* in nurseries (Osborne 2005). Foliar applications of organophosphates (acephate and chlorpyrifos), synthetic pyrethroid (bifenthrin), neonicotinoids (acetamiprid and imidacloprid), or insect growth regulators (buprofezin and pyriproxyfen) also are recommended for preventive treatment (Osborne 2005). Chemical management of *M. hirsutus* is hindered by the waxy deposit on the mealybug bodies, which reduces penetration of the chemical solution. The cryptic behavior of mealybugs to congregate in protected parts of a plant also makes thorough coverage difficult. Sagarra & Peterkin (1999) suggested that insecticide applications, even in combination with the burning of infested plant materials, were not effective in reducing *M. hirsutus* population or slowing the spread of this species throughout the landscape.

Biological control plays a significant role in the management of *M. hirsutus* in the landscape. Six predator species from the families Coccinellidae (Coleoptera), Cecidomyidae (Diptera), and Drosophilidae (Diptera), and 22 hymenopteran parasitoid species from the families Aphelinidae, Encyrtidae, Platygasteridae, Pteromalidae, and Signophoridae were recorded as natural enemies of *M. hirsutus* (ScaleNet 2010). Among these predators and parasitoids, three species
are used in large-scale biological control programs against *M. hirsutus* in many parts of the world. They are the mealybug destroyer, *Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae), and the parasitoids, *Anagyrus kamali* Moursi and *Gyranusoidesa indica* Shafee, Alam & Agarwal (both Hymenoptera: Encyrtidae). *Cryptolaemus montrouzieri* was introduced from Australia mainly for the biological control of the citrus mealybug, and it has established viable populations in California, Florida, and many tropical and subtropical countries (Gordon 1985). *Anagyrus kamali* was introduced from China (supplemented with a strain from Hawaii) and *G. indica* was introduced from Egypt, Pakistan, and Australia (Roltsch et al. 2006). Publicly-funded mass rearing facilities of the parasitoids have been established in California, Florida, Puerto Rico, Mexico, and other countries to supply parasitoids for inoculative or augmentative releases in the infested areas. No insectary is known to produce the parasitoids for purchase by homeowners and interested individuals. As stated by Kairo et al. (2000), the impacts of biological control programs in the Caribbean have been positive for the local economies.

The combination of *C. montrouzieri*, *A. kamali*, and *G. indica* has significantly reduced the initial *M. hirsutus* populations and maintained the subsequent populations below damaging levels in the Caribbean and the United States. Large numbers of *C. montrouzieri*, *A. kamali*, *G. indica*, and another coccinellid, *Scymnus coccivora* Ramakrishna Ayyar (not established), were released in the Caribbean and resulted in dramatic reductions in *M. hirsutus* populations and economic losses due to PHM infestations (Kairo et al. 2000). Less than 80% of the hibiscus plants sampled in Puerto Rico were infested after the introduction of the biological control agents (Michaud & Evans 2000). The release of the parasitoids, in combination with an existing population of *C. montrouzieri*, reduced the *M. hirsutus* population in Miami, FL by as much as 90% within the first year (D. Amalin, Univ. Florida, pers. comm.). Similarly, the releases of the parasitoids in California reduced *M. hirsutus* population by 95% within the first year (Roltsch et al. 2006). *Cryptolaemus montrouzieri*, *A. kamali*, and a parasitoid *Allotropa* sp. near *mecrida* (Walker) (Hymenoptera: Platygasteridae) have successfully suppressed the *M. hirsutus* populations on the Marianna Islands to non-damaging levels with the parasitism rate as high as 60% (Reddy et al. 2009). When biological control programs are employed, the use of insecticides should be limited in order to reduce the negative impact of these applications on the biological control agents.

*Maconellicoccus hirsutus* is a significant pest of agricultural and horticultural crops worldwide. Its introduction to South Carolina may have significant economic and ecological implications for the state, but the biology and ecology of *M. hirsutus* are still largely unknown. Based on the current body of knowledge and existing examples, successful management of *M. hirsutus* through an integrative approach is possible. Initial infestations can be detected by using pheromone-baited sticky traps, followed by identification of the infested location with visual observations of infested terminals or ‘bunchy-top’. Chemical management will remain the main management tool against *M. hirsutus* in production nurseries in compliance with quarantine requirements. In the landscape, release of biological control agents, particularly *C. montrouzieri*, *A. kamali*, and *G. indica*, is a viable option for management.
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