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Abstract. Thirty-one species of mealybugs (Hemiptera: Pseudococcidae) are reported from South Korea based upon monitoring surveys conducted from 2010 to 2016, along with a dichotomous key to separate them. Six species, *Nipaecoccus nipae* (Maskell), *Palmicultor lumpurensis* (Takahashi), *Planococcus citri* (Risso), *Pseudococcus dendrobiorum* Williams, *Pseudococcus longispinus* (Targioni-Tozzetti), and *Pseudococcus orchidicola* Takahashi, known only to occur in greenhouses, are considered as adventive mealybug species to South Korea; of these, *P. citri* has already established in the exterior environment in South Korea.

Key Words. Mealybugs, dichotomous key, identification, adventive species.

Introduction

Mealybugs (Hemiptera: Pseudococcidae) comprise some of the most serious pests on various agricultural crops and pose serious problems when introduced into new areas of the world without their natural enemies (Kwon et al. 2003a; Miller et al. 2005). They cause direct injury to plants by depleting the plant sap or by injecting plant toxins. In addition, more evidence has been presented concerning the role of mealybugs as vectors of plant viruses (Williams 2004).

Kwon et al. (2003a, b) listed 53 species in 19 genera of mealybugs in the latest catalogue of the mealybugs of the entire Korean Peninsula with characteristics, keys, host plants and distribution based on surveys and previous published records. Their catalogue included 15 species from North Korea reported by Russian entomologists such as Borchsenius (1956), Danzig and Ivanova (1976), and Danzig (1980; 1988) and four species accidentally found in greenhouses on ornamental plants imported into South Korea. Although known only to occur in greenhouses or nurseries in South Korea, mealybugs such as *Nipaecoccus nipae* (Maskell), *Palmicultor lumpurensis* (Takahashi), and *Pseudococcus longispinus* (Targioni-Tozzetti) are of economic significance (Williams 2004), and no comprehensive analysis has been conducted in order to determine if they are adventive or indigenous mealybugs in South Korea. Since then, mealybugs found in greenhouses in South Korea have been cited in papers (Lee 2010; Park 2010; Koo et al. 2017) including a new species, while other species have been synonymized with previously described taxa (Pellizzari and Danzig 2007; García et al. 2017). The purpose of this paper is to provide an updated list of South Korea's mealybug species with an identification key and list adventive mealybug species of South Korea.

Materials and Methods

Information on the number of mealybug species known to occur in the Korean Peninsula and in all zoogeographic regions was gathered from papers reporting South Korea's mealybugs (Paik 1972, 1978; Paik 2000; Kwon et al. 2002; Kwon et al. 2003a, b; Lee 2010; Lee and Suh 2011; Koo et al. 2017) and ScaleNet (García et al. 2017), a website that includes information on species of scale insects that has been published worldwide. Data from monitoring surveys of exterior environments and nurseries/

greenhouses during the past seven years (2010 to 2016) was extracted from the Plant Quarantine Integration System (PQIS) database developed by the Animal and Plant Quarantine Agency (APQA). Codes for the zoogeographic regions recognized are as follows: Palaearctic (PA), Oriental (OR), and Australasian (AU). The nomenclature used here for the Pseudococcidae follows that of the ScaleNet database (García et al. 2017). This paper provides a dichotomous key concerning 31 species of mealybugs from South Korea except for six adventives species. But during this project, *Crisicoccus coreanus* (Kanda) was not collected and we were not able to examine the specimen of this species although it has been documented for the South Korea's fauna of mealybugs. Terminology for the morphological structures used in the key follows that of Williams (2004).

Results

According to the scale insect database ScaleNet (García et al. 2017), there are 1,980 species of mealybugs worldwide. Based on our review of the literature and survey results, there are 31 species in South Korea which represents 2% of all described species. A dichotomous key to the mealybugs in South Korea is provided below for the correct identification of mealybug species by port identifiers at the various stations of the APQA.

As far as we are aware, no mealybug species have been deliberately introduced for biological control into South Korea. *Nipaecoccus nipae* (Maskell), *Palmicultor lumpurensis* (Takahashi), *Pseudococcus dendrobiorum* Williams, *Pseudococcus longispinus* (Targioni-Tozzetti), and *Pseudococcus orchidicola* Takahashi have been reported in South Korea in previous papers and should be considered as adventive species considering the fact that they have not been found in exterior environments for the past seven years (Table 1). *Planococcus citri* (Risso) which is already been established in South Korea causes damage to ornamental plants in greenhouses and is one of most commonly reported mealybugs.

Key to mealybug species in South Korea (slide-mounted adult females)

1. Antennae with 1–2 segments; legs absent or reduced **2**
— Antennae with 5–9 segments; legs usually well-developed **3**

2(1). Ventral abdominal multilocular disc pores abundant, with six or more pores on abdominal segment IV in area within the cluster of disc-like pores .... ***Antonina crawi* Cockerell**
— Ventral abdominal multilocular disc pores abundant, with five or fewer pores on abdominal segment IV in area within the cluster of disc-like pores .... ***Antonina nakaharai* Williams and Miller**

3(1). Claws with denticle; quinquelocular pores present **4**
— Claws without denticle; quinquelocular pores absent **13**

4(3). Each cerarius with 6–30 conical setae .... ***Ceroputo pilosellae* Šulc**
— Cerarius with 2–5 conical setae **5**

5(4). Antennae with 6–7 segments; quinquelocular pores of two sizes .... ***Brevennia pulveraria* (Newstead)**
— Antennae with 8–9 segments; quinquelocular pores of one size **6**

6(5). Oral collar tubular ducts each with orifice at apex of projecting tubercle (crateriform ducts) present **7**
— Oral collar tubular ducts, if present, not of this type **9**

7(6). Crateriform ducts of two sizes (large and small) present on dorsum; primarily on trees 8
— Crateriform ducts of one size present on dorsum; on *Zoysia* (Poaceae) .... ***Heliococcus zoysiae*** **Kwon, Danzig and Park**

8(7). Crateriform ducts numerous on dorsum and small crateriform ducts surrounding large crateriform ducts; primarily found on *Rubus* (Rosaceae) .. ***Heliococcus kurilensis*** **Danzig**
— Crateriform ducts scant on dorsum, not arranged in small crateriform surrounding large crateriform ducts; primarily found on *Pueraria* (Fabaceae) and *Alnus* (Betulaceae) .... ***Heliococcus bohemicus*** **(Šulc)**

9(6). Multilocular disc pores on dorsum forming small clusters and surrounding one minute oral collar tubular duct .... ***Peliococcus chersonensis*** **(Kiritshenko)**
— Multilocular disc pores, if present on dorsum, not arranged in cluster surrounding one minute oral collar tubular duct **10**

10(9). Body circular; oral collar tubular ducts with an apically widened channel .... ***Coccura comari*** **(Kunow)**
— Body oval; oral collar tubular ducts with a cylindrical channel **11**

11(10). Oral collar tubular ducts evenly scattered on entire surface of body; with small and short setae on dorsum **12**
— Oral collar tubular ducts forming a band along body margin and grouped on thorax and abdomen of dorsum; with large and distinct setae on dorsum .... ***Phenacoccus rubicola*** **Kwon, Danzig and Park**

12(11). Circuli 2–5 (3); body 3.5–5.0 mm long; found on many hosts .... ***Phenacoccus aceris*** **(Signoret)**
— Circuli 1–3 (2); body 1.9–2.2 mm long; primarily found on *Rhododendron* .... ***Phenacoccus azaleae*** **Kuwana**

13(3). Cerarii numbering 18 pairs **14**
— Cerarii numbering less than 17 pairs **15**

14(13). Slender setae present on dorsum; oral collar tubular ducts 0–1 on margin of dorsal abdominal segments .... ***Planococcus citri*** **(Risso)**
— Lanceolate setae present on dorsum; oral collar tubular ducts 2–4 on margin of dorsal abdominal segments .... ***Planococcus kraunhiae*** **(Kuwana)**

15(13). Auxiliary setae in all cerarii **16**
— Auxiliary setae only on anal lobe cerarii **18**

16(15). Oral rim tubular ducts present **17**
— Oral rim tubular ducts absent .... ***Paraputo wistariae*** **(Green)**

17(16). Several dorsal oral rim tubular ducts present on abdomen; more than 300 multilocular disc pores on ventral abdomen .... ***Pseudococcus comstocki*** **(Kuwana)**
— Dorsal oral rim tubular ducts absent from abdomen; about 100 multilocular disc pores on ventral abdomen .... ***Pseudococcus cryptus*** **Hempel**

18(15). Oral rim tubular ducts present on dorsum or/and venter **19**
— Oral rim tubular ducts absent or rarely present **23**

19(18). Body color turns black in alkali (KOH); oral collar tubular ducts grouped on margin of dorsum and venter **20**
— Body color turns green in alkali (KOH); oral collar tubular ducts grouped rarely present on margin of dorsum and venter **21**

20(19). Multilocular disc pores present on dorsum; multilocular disc pores mixed with oral collar tubular ducts on ventral margin of thorax .... ***Atrococcus altaicus* Matesova**
— Multilocular disc pores absent from dorsum; multilocular disc pores without on ventral margin of thorax .... ***Atrococcus paludinus* (Green)**

21(19). Multilocular disc pores present on dorsum; multilocular disc pores grouped on head and thoracic margin .... ***Spilococcus jejuensis* Kwon, Danzig and Park**
— Multilocular disc pores absent from dorsum; multilocular disc pores absent from head and thoracic margin **22**

22(21). Dorsal oral rim tubular ducts forming transverse rows on abdominal segments I to VI; circulus absent .... ***Spilococcus flavidus* (Kanda)**
— Dorsal oral rim tubular ducts present several on medial and marginal regions; circulus present .... ***Spilococcus pacificus* (Borchsenius)**

23(18). Multilocular disc pores present on dorsum **24**
— Multilocular disc pores absent from dorsum **29**

24(23). Oral collar tubular ducts with a flange covering about one-half of duct length **25**
— Oral collar tubular ducts short without a flange of such type **26**

25(24). Circulus numbering one .... ***Balanococcus takahashii* McKenzie**
— Circuli numbering three .... ***Balanococcus tangi* (Wu)**

26(24). Circuli numbering three; antennae with 6 segments .... ***Mirococcopsis orientalis* (Maskell)**
— Circulus numbering one; antennae with 7–8 segments **27**

27(26). Circulus hour-glass shaped or divided by intersegmental line **28**
— Circulus small and round .... ***Trionymus radicum* (Newstead)**

28(27). Circulus hour-glass shaped; cerarii numbering one pair .... ***Saccharicoccus isfarensis* (Borchsenius)**
— Circulus divided by intersegmental line; cerarii numbering two pairs .... ***Trionymus perrisii* (Goux)**

29(23). Circulus absent **30**
— Circulus present .... ***Crisicoccus matsumotoi* (Siraiwa)**

30(29). Cerarii numbering 2–3 pairs; multilocular disc pores present on abdominal segment V of venter .... ***Crisicoccus coreanus* (Kanda)**
— Cerarii numbering 4–7 pairs; multilocular disc pores absent from abdominal segment V of venter .... ***Crisicoccus pini* (Kuwana)**

Discussion

This work provides an updated list of 31 mealybug species in South Korea. To date six species are considered as adventive mealybug species to South Korea; of these, *P. citri* is already established in the South Korea's exterior environment. Most adventive mealybugs are usually found on imported plants and may get settled into the South Korea's environment, either in greenhouses or outdoor settings. Therefore, preventive measures are required to overcome this challenge. Furthermore, the South Korea's weather is becoming warmer and numerous imported subtropical and tropical crops are being grown in greenhouses. The most effective approach to block the introduction of an adventive species is to identify mealybug species found on commodities entering the country and regularly updating the list of the mealybug species known to occur in South Korea.

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Table 1. List of adventive mealybugs in South Korea.

Scientific name	In exterior environment	In nursery/ greenhouse	Earliest record in Korea	Principal hosts	Regional origin
Nipaecoccus nipae (Maskell)	-	yes	Nakayama 1933	polyphagous	AU
Palmicultor lumpurensis (Takahashi)	-	yes	Kwon et al. 2003b	bamboo	OR
Planococcus citri (Risso)	Yes (established)	yes	Nakayama 1933	polyphagous	PA
Pseudococcus dendrobiorum Williams	-	yes	Kwon et al. 2002	orchid	AU
Pseudococcus longispinus (Targioni-Tozzetti)	-	yes	Kwon et al. 2002	polyphagous	PA
Pseudococcus orchidicola Takahashi	-	yes	Koo et al. 2017	*Heteropanax*	OR