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ORIGINAL RESEARCH PAPER

New records of some potential pest mealybugs (Hemiptera: Coccoidea: Pseudococcidae) in Japan

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Abstract Four species of mealybugs, *Dysmicoccus neobrevipes, Phenacoccus defectus, Ph. parvus,* and *Ph. solenopsis* (Hemiptera: Coccoidea: Pseudococcidae) are recorded for the first time from Japan in the Ryûkyû (Ryukyu) Archipelago, with brief biological notes. We discuss some features of these species compared with those of related species, *D. brevipes* and *Ph. solani*, and we consider their potential risks to Japanese agriculture and/or horticulture.

Keywords Introduced pest · *Dysmicoccus neobrevipes* · *Phenacoccus defectus* · *Phenacoccus parvus* · *Phenacoccus solenopsis*

Introduction

In Japan, 71 species of mealybugs belonging to 29 genera are currently recorded (Ben-Dov 2012a, b; Kawai 1980). By our taxonomic study of scale insects (Hemiptera: Coccoidea) in the Ryûkyû (Ryukyu) Archipelago, we found four additional species hitherto unknown in Japan. Here, we report new distributional records for these species in Japan with brief biological notes.

Two of these species, i.e., *Dysmicoccus neobrevipes* and *Phenacoccus solenopsis*, are regarded as serious agricultural pests of economically important plants in some parts of the world (APHIS 2001; Beardsley 1959, 1993; Culik and Gullan 2005; Hodgson et al. 2008; Larraín 2002; Nagrare et al. 2009; Qin et al. 2010). These two introduced species may be potential pests in Japanese agriculture. Therefore, the survey of their distributional records in Japan is useful from both economic and scientific perspectives. We consider their potential risks to Japanese agriculture and/or horticulture.

Two *Phenacoccus* mealybug species reported here (*Ph. solenopsis* and *Ph. defectus*) might have some taxonomic identity problems (see Hodgson et al. 2008). However, in this paper, we follow Williams and Granara de Willink (1992) and treat them as independent species.

Materials and methods

Specimens of the mealybug species used in this study were originally collected and kept by the second author (TU) with a mealybug collection obtained during the survey by Uesato et al. (2011) of the Egyptian fluted scale, *Icerya aegyptiaca*. Additional specimens were collected by both authors and two collaborators, Dr. T. Shimizu and Dr. Y. Higashiura. The mounting method used for these specimens was that described by Kawai (1980). The morphology of the slide-mounted specimens was examined under a phase-contrast light microscope (Olympus BH2-PH). All specimens examined in this study are deposited as voucher specimens in the University Museum (Fujukan), University of the Ryukyus.

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Results

Key to separate four new invasive mealybug species:*Dysmicoccus neobrevipes*, *Ph. defectus, Ph. parvus* and *P. solenopsis* from other mealybugs occurring in the Ryukyu Archipelago (partially adopted and modified from Hodgson et al. 2008, Williams and Granara de Willink 1992 and Williams 2004).

1. Legs present 2
–. Legs absent ..... Genera *Antonina*, *Chaetococcus*, *Porisaccus* and *Serrolecanium*
2. Cerarii completely absent, living in underground ant nests ..... Genera *Eumyrmococcus* and *Xenococcus*
–. Cerarii present, usually living on aerial parts of their host plant 3
3. Cerarii present on anal lobe only ..... Genera *Ferrisia* and *Saccharicoccus*
–. Cerarii present at least on some posterior segments of abdomen 4
4. Ostioles absent ..... Genus *Neoripersia*
–. Ostioles present 5
5. Oral rim tubular ducts present ..... Genera *Maconellicoccus* and *Pseudococcus*
–. Oral rim tubular ducts absent 6
6. Some dorsal setae enlarged, conical to lanceolate, about same size as cerarian setae ..... Genus *Nipaecoccus*
–. Dorsal setae not enlarged, slenderer than cerarian setae 7
7. Claws without denticles 8
–. Claws with denticles ..... 11 (Genus *Phenacoccus*)
8. Anal lobe bar present, cerarii numbering 18 pairs ..... Genus *Planococcus*
–. Anal lobe bar absent, cerarii numbering 7–17 pairs ..... 9 (Genus *Dysmicoccus*)
9. Cerarii numbering 7 pairs. Dorsal oral collar tubular ducts numerous, present in rows across most segments ..... *Dysmicoccus boninsis*
–. Cerarii numbering more than 7 pairs 10
10. Dorsal setae on abdominal segments VII and VIII, longer than other dorsal setae, almost as long as anal ring setae ..... *D. brevipes*
–. Dorsal setae on abdominal segments VII and VIII, short, about same size as other dorsal setae ..... *D. neobrevipes*
11. Multilocular disc pores (MDP) frequently present on dorsum ..... *Phenacoccus madeirensis*
–. MDP absent on dorsum 12
12. Ventral quinquelocular pores present from venter ..... *Ph. parvus*
–. Ventral quinquelocular pores absent from venter 13
13. MDP scattered across full depth of segment VII between anterior and posterior margins; also usually present submarginally on some abdominal segments ..... *Ph. solenopsis*
–. MDP restricted to bands across posterior margin of VII abdominal segments; usually absent submarginally ..... *Ph. defectus*

***Dysmicoccus neobrevipes* Beardsley, 1959** (Fig. 1)

[Newly proposed Japanese name: Banana-kona-kaigaramusi (kaigaramushi)]

Dysmicoccus neobrevipes Beardsley 1959: 31; Williams and Watson 1988: 67; Williams and Granara de Willink 1992: 157; Williams 2004: 204.

Specimens examined

5 ♀♀, **Japan**: Isigaki Is. (Ishigaki Is.), Tonosiro (Tonoshiro), 22.X.2008, T. Uesato coll., host: *Euonymus japonicus* Thunb. 3 ♀♀, **Japan**: Isigaki Is. (Ishigaki Is.), Ôhama (Ohama), 27.IX.2011, H. Tanaka coll., host: *Musa* spp. 2 ♀♀, **Japan**: Isigaki Is. (Ishigaki Is.), Kabira, 27.IX.2011, H. Tanaka coll., host: *Musa* spp. 2 ♀♀, **Japan**: Isigaki Is. (Ishigaki Is.), Tonoshiro, 22.IX.2011, H. Tanaka coll., host: *Euonymus japonicus* Thunb.

Remarks

This species is similar to the pink pineapple mealybug, *Dysmicoccus brevipes* (Cockerell) in its general appearance. However, *D. neobrevipes* is distinguishable from

Fig. 1 Adult females of *Dysmicoccus neobrevipes*

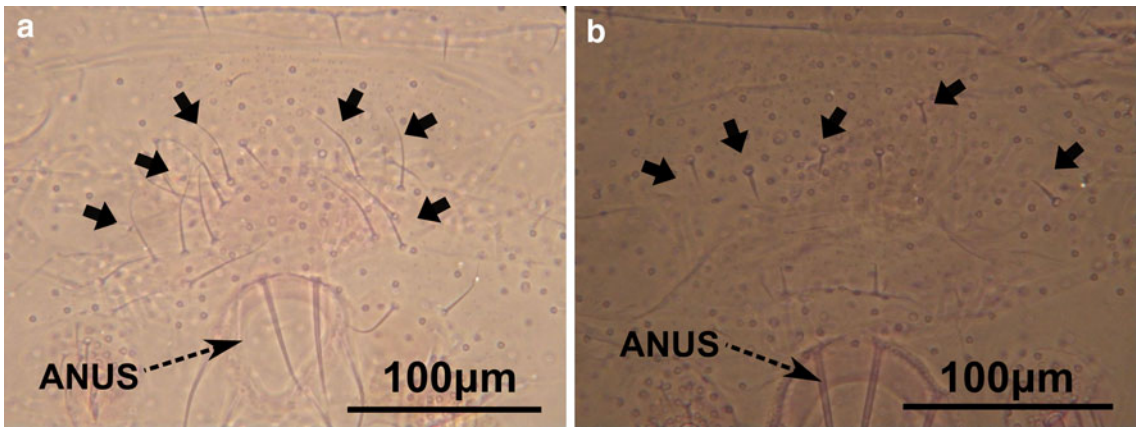

Fig. 2 Comparison of length of dorsal setae on abdominal segments VII and VIII between adult females of *Dysmicoccus brevipes* and *D. neobrevipes*. Some dorsal setae on abdominal segments VII and VIII are indicated by *solid arrows*. **a** *D. brevipes*, **b** *D. neobrevipes*

D. brevipes by the shorter dorsal setae (approximately 10–20 μm) on the dorsum of abdominal segments VII and VIII, as illustrated in Fig. 2 (Williams and Watson 1988; Williams and Granara de Willink 1992; Williams 2004). Detailed morphology of the species was well explicated by Williams and Watson (1988), Williams and Granara de Willink (1992), and Williams (2004).

Although we conducted extensive searches for mealybug species in other some Okinawa Islands [Kouri Is., Okinawa Is., Yagati (Yagachi) Is.] and Kume Island during our taxonomic study of mealybugs in the Ryûkyû (Ryukyu) Archipelago, we collected *D. neobrevipes* only in Ishigaki Island.

Associates

We frequently observed some exotic ants, especially the big-headed ant, *Pheidole megacephala* (Fabricius), and the bicolored pennant ant, *Tetramorium bicarinatum* (Nylander), attending *D. neobrevipes* at Isigaki (Ishigaki) island.

Phenacoccus defectus **Ferris,** 1950 (Fig. 3)

[Newly proposed Japanese name: Nise-nasu-kona- kaigaramusi (kaigaramushi)]

Phenacoccus defectus Ferris 1950: 137; Williams and Granara de Willink 1992: 354.

Specimens examined

10 ♀♀, **Japan**: Okinawa Is., Ginowan, Ganeko, 30.IX.2011, H. Tanaka coll., host: *Ruellia brittoniana* Leonard ex Fernald.

Remarks

Phenacoccus defectus is closely related to the *Solanum* mealybug, *Ph. solani* Ferris, in its general morphology, and it is difficult to separate the former from the latter strictly by morphology of adult females (Hodgson et al. 2008). However, *Ph. defectus* differs from *Ph. solani* in that it lacks MDP on ventral abdominal segments IV and V (Hodgson et al. 2008). *Phenacoccus defectus* also resembles *Ph. parvus* Morrison, but the former lacks quinquelocular pores on the ventral surface; on the other hand, the latter frequently has quinquelocular pores on the venter (Williams and Granara de Willink 1992). *Ph. defectus* also resembles *Ph. solenopsis* Tinsley and is also difficult to separate from the latter from adult female morphology alone (Hodgson et al. 2008). At least, however, typical individuals of the species have a relatively small circulus (Fig. 4) and fewer MDP on ventral abdominal segment VII (Fig. 5) (*Ph. solenopsis* usually has a relatively large circulus and more abundant MDP on abdominal segment VII)

Fig. 3 Adult females of *Phenacoccus defectus*

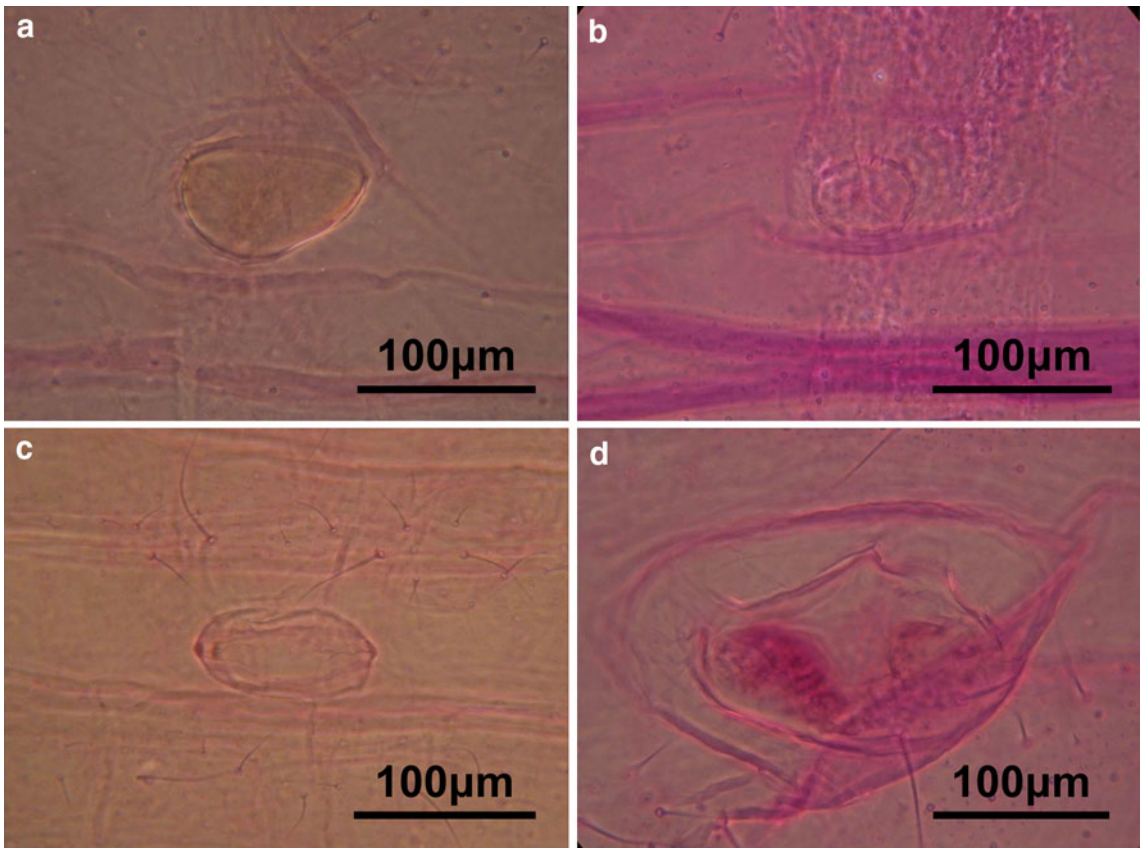

Fig. 4 Comparison of shape and size of circulus on venter among adult females of several *Phenacoccus* species. **a** *Ph. solani*, **b** *Ph. defectus*, **c** *Ph. parvus*, **d** *Ph. solenopsis*

(Hodgson et al. 2008). Detailed morphology of the species was well explicated by Ferris (1950) and Williams and Granara de Willink (1992).

Associates

We frequently observed some exotic ants, especially the yellow crazy ant, *Anoplolepis gracilipes* (Smith), the big-headed ant, *Pheidole megacephala* (Fabricius), and the Japanese white-footed ant, *Technomyrmex brunneus* (Forel) attending the mealybug in urban areas of Okinawa Island.

***Phenacoccus parvus* Morrison, 1924**

[Newly proposed Japanese name: Hime-nasu-kona- kaigaramusi (kaigaramushi)]

Phenacoccus parvus Morrison 1924: 147; Williams and Watson 1988: 158; Williams and Granara de Willink 1992: 379; Williams 2004: 604.

Phenacoccus surinamensis Green 1933: 51.

Specimens examined

5 ♀♀, **Japan**: Okinawa Is., Naha, Maji, 26.IX.2007, T. Uesato coll., host: *Solanum spirale* Roxb.

Remarks

This species resembles *Ph. defectus*, *Ph. solani*,, and *Ph. solenopsis* in its general morphology. *Ph. parvus* has quinquelocular pores on its ventral surface; however, *Ph. defectus*, *Ph. solani*, and *Ph. solenopsis* do not have the pores on their venter (Hodgson et al. 2008; Williams and Granara de Willink 1992; Williams 2004). Detailed morphology of the species was well explicated by Williams and Watson (1988), Williams and Granara de Willink (1992), and Williams (2004).

***Phenacoccus solenopsis* Tinsley, 1898** (Fig. 6)

[Newly proposed Japanese name: Kuroten-kona- kaigaramusi (kaigaramushi)]

Phenacoccus solenopsis Tinsley 1898: 47; Williams and Granara de Willink 1992: 388; Hodgson et al. 2008: 4.

Phenacoccus cevalliae Cockerell 1902: 315.

Specimens examined

1 ♀, **Japan**: Okinawa Is., Ginowan, Ganeko, 27.IX.2009, H. Tanaka coll., host: *Gynura bicolor* (Roxb. ex Willd.) DC., 10 ♀♀, Okinawa Is., Itoman, Nisizaki (Nishizaki), ?.IV.2011,

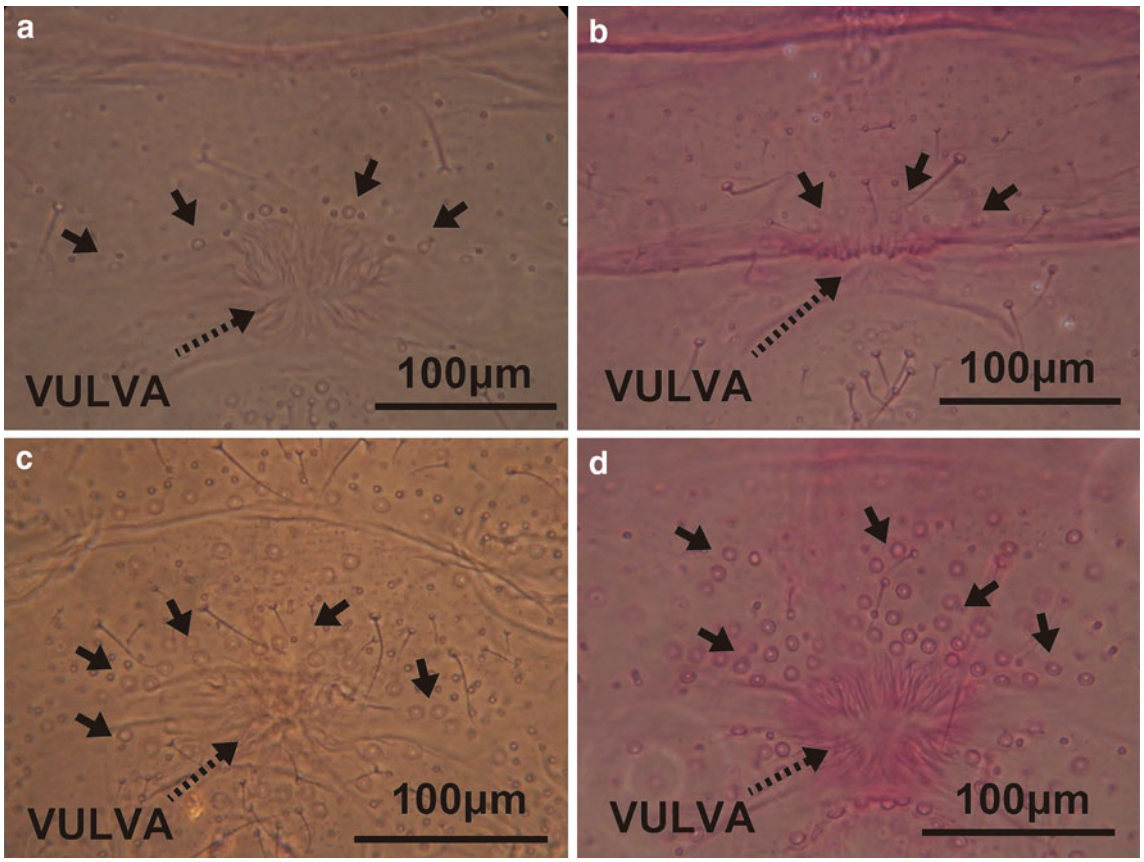

Fig. 5 Comparison of distribution of multilocular disc pores (MDP) on abdominal ventral segment VII among adult females of several *Phenacoccus* species. Some MDP are indicated by *solid arrows*. **a** *Ph. solani*, **b** *Ph. defectus*, **c** *Ph. parvus*, **d** *Ph. solenopsis*

Fig. 6 An adult female of *Phenacoccus solenopsis*

Toru Shimizu coll., host: unknown, (laboratory strain; first generation of the strain was collected from same locality on 9.X.2009. Host plant of the individuals was not recorded). 5 ♀, **Japan**: Isigaki Is. (Ishigaki Is.), Ohama, 27. IX.2011, H. Tanaka coll., host: *Helianthus annuus* L.

Remarks

Phenacoccus solenopsis resembles *Ph. solani* and *Ph. defectus* in its general appearance and is difficult to separate from the latter two species strictly by the morphology of adult females (Hodgson et al. 2008). However, typical individuals of *Ph. solenopsis* are distinguishable from them because of a relatively large circulus (Fig. 4) and more abundant MDP in a broad band on ventral abdominal segment VII (Fig. 5) and in the marginal area of several ventral abdominal segments (but MDP in *Ph. solenopsis* are occasionally lacking in these areas). In contrast, *Ph. solani* and *Phenacoccus defectus* usually do not have MDP on the marginal areas of the venter, and MDP on ventral abdominal segment VII are usually infrequent. *Ph. solenopsis* also resembles *Ph. parvus*. However, unlike *Ph. parvus*, it lacks quinquelocular pores on the venter (Williams and Granara de Willink 1992; Williams 2004; Hodgson et al. 2008). Detailed morphology of the species

was well explicated by Williams and Granara de Willink (1992) and Hodgson et al. (2008).

Natural enemies

In Okinawa Island, the mealybug is frequently parasitized by an encyrtid parasitoid wasp, *Aenasius* sp. This wasp may have some suppression effect on the mealybug population in Okinawa Island (T. Uesato, unpublished data). The appearance of this wasp resembles that of *Aenasius bambawalei* Hayat, which was described and recorded from *Ph. solenopsis* in India (Hayat 2009). However, it remains unclear whether or not the Japanese *Aenasius* sp. is the same species of the Indian *A. bambawalei* (Y. Higashiura, personal communication).

Specimens of other species examined for comparison

Dysmicoccus brevipes. 5 ♀♀, **Japan**: Okinawa Is., Taira, Higasi-son (Higashi-son), 25.VII.2010, H. Tanaka coll., host: *Ananas comosus* (L.) Merr.
Phenacoccus solani. 5 ♀♀, **Japan**: Honshû, Yamaguti Pref. (Yamaguchi Pref.), Yamaguti (Yamaguchi), ?.I.2011, Y. Higashiura coll., host: *Solanum melongena* L., [laboratory strain, first generation of the strain was collected in Ôutimihori (Ouchimihori), Yamaguti (Yamaguchi), Yamaguti (Yamaguchi) Pref., Japan, on ?.XI.2010, host: *S. melongena* L.].

Discussion

Two of the mealybug species reported in this study, *Ph. solenopsis* and *D. neobrevipes*, are regarded as serious pests in some parts of the world (APHIS 2001; Beardsley 1959, 1993; Culik and Gullan 2005; Hodgson et al. 2008; Larraín 2002; Nagrare et al. 2009; Qin et al. 2010). *Phenacoccus solenopsis* is a serious polyphagous pest species, especially for cotton, in the south Asian region. In Pakistan, this species occurs across at least 45,000 km^2 of cotton fields (Anonymous 2005). In the Punjab area (Pakistan), cotton growers used huge amounts of pesticides (US$121.4 million worth) during two months in 2007 to suppress the outbreaks of the mealybug (Dutt 2007; Hodgson et al. 2008). Cotton fields affected by mealybugs, including *Ph. solenopsis,* also showed considerable yield reduction (up to 40–50 %) in some parts of India (Nagrare et al. 2009). On the other hand, *D. neobrevipes*, known as a major vector of Pineapple mealybug wilt-associated viruses (PMWaVs) (Sether et al. 1998), which are complex of viruses in the genus *Ampelovirus*, cause mealybug wilt of pineapple, a devastating disease found in all major pineapple-growing regions of the world (Rohrbach et al. 1988; Sether and Hu 2002). Mealybug wilt of pineapple can severely reduce crop yield (Sether and Hu 2002); therefore, *D. neobrevipes* is regarded as a serious pest of pineapple (Beardsley 1959, 1993).

It is still unclear whether the two pest species of mealybugs, *Ph. solenopsis* and *D. neobrevipes*, would threaten agriculture and/or horticulture in the Japanese environment. However, distribution of PMWaVs in Japan has already been reported (Ikeshiro et al. 2004), and damage to cultivated pineapple in Japan caused by PMWaVs may also increase with occurrence of *D. neobrevipes*, although another mealybug vector of PMWaVs (*D. brevipes*) is already distributed (Kawai 1980; Ben-Dov 2012a, b). Fortunately, it seems that these species have not yet caused serious agricultural and horticultural damage in Japan, and their distribution may be restricted to several isolated islands. However, it is important to continue to monitor the trends in their population dynamics and to investigate their distribution in the Ryûkyû (Ryukyu) Archipelago to evaluate their potential risks to agriculture and horticulture.

At present, we consider that taxonomical study and faunal survey of Japanese mealybugs are quite insufficient, especially in the Ryûkyû (Ryukyu) Archipelago. We will continue the survey of exotic mealybugs and scale insects in the Ryukyu, as some dangerous species have already been introduced there. Under the condition of increased movement of agricultural products and industrial materials around the world, the risks of biological invasions of pest species threatening Japanese agriculture and ecosystems may be increasing. Further taxonomic study and survey of scale insects, including mealybugs, may be important from the perspective of plant quarantine and/or biological conservation.

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