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RESEARCH PAPER

The Determination Mealybug Species and Natural Enemies in Pitaya Greenhouses in the Mediterranean Region

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Abstract

Pitaya, *Hylocereus* spp. (Caryophyllales: Cactaceae) has been one of the new species cultivated in Türkiye in recent years. There are many limiting factors, including pests, diseases and weeds, to decrease the yield and fruit quality in pitaya (dragon fruit) areas in Türkiye. In addition, the pests of pitaya is not fully studied therefore this research has been conducted to determine mealybug species in pitaya greenhouses in Türkiye. The present study aimed to determine mealybug species and its natural enemies (parasitoids, and predator insects) in pitaya greenhouses in Adana, Mersin, and Antalya between 2021 and 2022. According to results of this study, 2 different mealybug species was determined; *Phenacoccus solenopsis* Tinsley 1898, *Phenacoccus madeirensis* Green, 1923 (Hemiptera: Pseudococcidae) in pitaya greenhouses. Moreover one parasitoid (*Aenasius arizonensis* Girault (Hymenoptera: Encyrtidae), and two different predatory insects from 2 different orders and 2 different families (*Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae), *Nephus includens* Kirsch (Coleoptera: Coccinellidae) were detected within this research. These two invasive mealybug species have wide spectrum host plants and may cause economically important damages to pitaya, if natural enemies cannot work successfully or control strategies do not applied properly in pitaya greenhouses.

1. Introduction

Pitaya or dragon fruit (*Hylocereus* spp.) is known as a new species in the world and studies about this plant have been conducted since the mid-'90s. Pitaya (Dragon fruit) is known as a new species for Türkiye as well. Especially, it has been planted in greenhouses on the coast of the Mediterranean region (Antalya and Mersin) in recent years. In addition, pitaya plantations have been started in the other districts of the Mediterranean region such as Adana, and Muğla in greenhouses (Soydal et al., 2019). Many factors affect negatively and cause yield loss in pitaya production. The pest and diseases cause yield loss and affect the quality of the product. Limited studies were conducted about the pests and diseases of dragon fruit. Eusebio and Alaban (2018) reported the common pests of dragon fruit in the Philippines. According to results of this research, ants, scale insects, mealybugs, borers, and fruit flies caused damage on dragon fruit and all plant parts were affected by these pests. In addition, Duncan et al. (2021) reported the pests and beneficial insects of dragon fruit in Southern Florida (USA) and found that thrips, leaf-footed bugs, aphids, and mealybugs were detected as major pests in pitaya plantation Florida. Moreover, Choi et al. (2013) reported pests list and damage to mango, dragon fruit, and atemoya between 2008 and 2011 in Korea. Rezzeki et al. (2021) observed mealybug species on dragon fruits in Indonesia and they found 4 different species: *Ferrisia virgata*

(Cockerell), *Phenacoccus solenopsis* Tinsley, *Planococcus minor* (Maskell) and *Pseudococcus jackbeardsleyi* Gimpel & Miller. Mealybugs induce damage characterized by dry skin, fruit contraction, wrinkling of the skin, and the secretion of honeydew, leading to the development of sooty molds (Mani and Shivaraju 2014; Nurhafizhah et al. 2020). Major pests are determined as thrips, aphids, mealybug, and Lepidoptera species. *Aphis gossypii* and *Spodoptera litura* were determined as important pests on dragon fruit, ants and aphids generally cause damage on stems, flowers and fruits. Sartiami et al. (2019) conducted a study about mealybug species on dragon fruit in India and 4 mealybug species (*Ferrisia virgata, Planococcus minor, Phenacoccus solenopsis* and *Pseudococcus jackbeardsleyi*) were found on dragon fruit and dragon fruit was recorded as a new host for *P. solenopsis* within this study.

As can be explained above, there were limited studies conducted about the pests of dragon fruit. This study was carried out to determine the mealybug species and its natural enemies in pitaya greenhouses in Adana, Mersin and Antalya provinces in Türkiye between 2021 and 2022. In addition, mealybug species, which were detected on pitaya with the surveys, were identified with the morphological within this study. The results of this study will help to develop control strategies against mealybug species in pitaya plantations in Türkiye.

2. Material and Methods

This research was carried out in pitaya greenhouses in Adana, Mersin and Antalya between July and December in 2021 and 2022. Total pitaya greenhouses were 138.6 ha in Adana, Mersin, and Antalya. Surveys were done according to Bora and Karaca (1970) and it was used to periodic and non-periodic ways to collect mealybug materials from pitaya greenhouses between July and December in three different provinces (Antalya, Mersin, and Adana). Size of pitaya greenhouses was between 0.1-1.8 ha in Adana, 0.05-1.0 ha in Mersin, and 0.1-2.0 ha in Antalya. Table 1 showed the details of surveys in our research. Mealybug samples were collected with plant parts, placed into a paper bag and recorded with location and date. Samples were brought to a laboratory and prepared for identification accordin to Kosztarab and Kozár (1988) method.

Mealybugs were identified morphologically by Associate Prof. Asime Filiz Çalışkan Keçe with a stereo microscope. Synonyms, host plants data were prepared according to ScaleNet (Garcia Morales et al., 2016).

The natural enemies of the mealybug species were determined in this study as well. Mealybug-infected plant parts were taken to a laboratory, parasitized mealybugs mumies were placed into parasitoid box and obtained parasitoids were preserved in 70% alcohol solution for identification (Çalışkan Keçe et al., 2018). In addition, mealybug-infected plant parts with predator insects were cultured to obtain adult individuals for identification (Kahya, 2020). Detected predator species belonging Coccinellidae family were preserved and identified (Uygun, 1981). The identification of predator and parasitoids were also done by Assoc. Prof. Asime Filiz Çalışkan Keçe.

3. Results and Discussion

According to results, 2 different mealybug species were detected *Phenacoccus solenopsis* and *Phenacoccus madeirensis*, belonging the *Phencoccus* genus. These mealybug species and its natural enemies was also reported in Türkiye and Eastern Mediterranean region on different host plants by different researchers (Kaydan et al., 2012; Kaydan et al., 2013; Çalışkan, 2015; Kaydan et al., 2016; Çalışkan et al., 2016; Çalışkan Keçe et al., 2018). The determined mealybug species and its parasitoids and predators during this study were given below:

3.1. *Phenacoccus solenopsis* (Tinsley, 1898)

3.1.1. Synonyms

Phenacoccus cevalliae Cockerell 1902, *Phenacoccus gossypiphilous* Abbas, Arif & Saeed 2005, *Phenacoccus gossypiphilous* Arif, Abbas & Saeed 2007, *Phenacoccus gossypiphilous* Abbas, Arif, Saeed & Karar 2008, *Phenacoccus solenopsis* Tinsley, 1898, *Phenacoccus solenopsis* Weintraub, et al. 2017, *Phenaccocus solenopsis*; Nawaz & Freed 2022.

3.1.2. Examined materials

Türkiye, Mersin, Akdeniz, 13.08.2021, 5 ♀♀, *Hylocereus* spp. (Cactaceae) Collector: M. Yayla**;** Mersin, Erdemli, 13.08.2021, 2 ♀♀, *Hylocereus* pp. Collector: M. Yayla; Adana, Karaisalı, 20.08.2021, 5 ♀♀, *Hylocereus* spp. Collector: M. Yayla; Antalya, Aksu, 25.08.2021, 4 ♀♀, *Hylocereus* spp. Collector: M. Yayla; Antalya, Gazipaşa, 25.08.2021, 6 ♀♀,

Table 1. Survey areas of pitaya greenhouses in Antalya, Adana, and Mersin.

Surveyed provinces	Surveyed greenhouses areas (ha)	Total greenhouses (ha)	The number of surveyed greenhouses
Antalya	2.75	111.5	22
Adana	2.24	11.2	17
Mersin	3.18	15.9	26

Hylocereus spp. Collector: M. Yayla; Mersin, Silifke, 08.09.2021,7 ♀♀, *Hylocereus* spp. Collector: M. Yayla; Adana, Ceyhan, 10.09.2021, 5 ♀♀, *Hylocereus* spp. Collector: M. Yayla; Mersin, Akdeniz, 15.09.2021, 6 ♀♀, *Hylocereus* spp. Collector: M. Yayla; Adana, Çukurova, 17.09.2022, 4 ♀♀, *Hylocereus* spp. Collector: M. Yayla; Mersin, Akdeniz, 13.10.2021, 8 ♀♀, *Hylocereus* spp. Collector: M. Yayla; Mersin, Anamur, 20.10.2022, 4 ♀♀, *Hylocereus* spp. Collector: M. Yayla; Adana, Karaisalı, 21.x10.2021, 9 ♀♀, *Hylocereus* spp. Collector: M. Yayla; Mersin, Akdeniz, 03.11.2022, 3 ♀♀, *Hylocereus* spp. Collector: M. Yayla; Adana, Karataş, 04.11.2021, 2 ♀♀, *Hylocereus* spp. Collector: M. Yayla.

Hylocereus spp. was determined as a host plant for *Phenacoccus solenopsis* during this study. This invasive pest is widespread in the world and determined in 210 genus from 64 families of host plants (Garcia Morales et al., 2016). *Phenacoccus solenopsis* was determined as a pest in pitaya greenhouses in Adana, Mersin, and Antalya. Moreover, *P. solenopsis* were detected in pitaya other parts of the world (Rezeki et al., 2021; Sartiami et al., 2019) In addition, parasitized mealybug mummies were found during survey (Figure 1).

3.2. *Phenacoccus madeirensis* (Green, 1923)

3.2.1. Synonyms

Phenacoccus grenadensis Green & Laing, *Phenacoccus harbisoni* Peterson, *Phenacoccus gossypii* Tranfaglia.

3.2.2. Examined materials

Türkiye, Adana, Karaisalı, 20.08.2021, 2 ♀♀, Hylocereus spp. Collector: M. Yayla; Antalya, Kepez, 03.09.2021, 2 ♀♀, *Hylocereus* spp. Collector: M. Yayla; Antalya, Alanya, 03.09.2021, 4 ♀♀, *Hylocereus* spp. Collector: M. Yayla; Mersin, Silifke, 08.09.2021, 3 ♀♀, Hylocereus spp. Collector: M. Yayla; Mersin, Akdeniz, 15.09.2022, 2 ♀♀, Hylocereus spp. Collector: M. Yayla; Mersin, Akdeniz, 13.10.2021, 2 ♀♀, Hylocereus spp. Collector: M. Yayla; Adana, Karaisalı, 21.10.2022, 2 ♀♀, Hylocereus spp. Collector: M. Yayla. *Hylocereus* spp. was determined as a host plant for *Phenacoccus madeirensis* during this study. Maderia mealybug is known as one of the most widespread invasive mealybug species and is found on 210 genus from 64 families of the host plant (Garcia Morales et al., 2016). *P. madeirensis* was

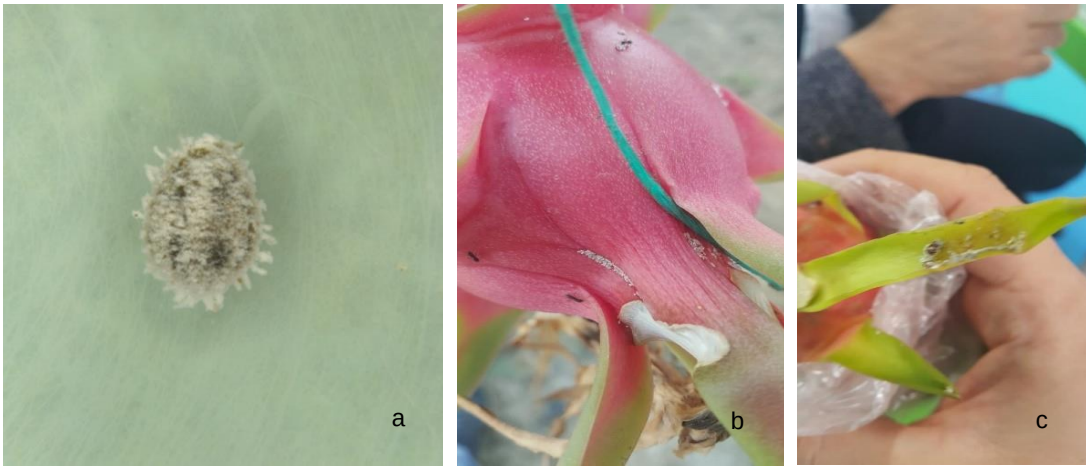

Figure 1. Adult female of *Phenacoccus solenopsis* (a), the adult and nypmphal stages of *Phenacoccus solenopsis* on pitaya fruit (b), parasitized adult mealybug mummy (c).


Figure 2. Adult female of *Phenacoccus madeirensis.*

Table 2. Detected parasitoids and predator species of *Phenacoccus solenopsis* in pitaya greenhouses in Adana, Antalya, and Mersin.

Detected predatory insects			
Order	Family	Species	Collected locations
Neuroptera	Chrysopidae	*Chrysoperla carnea* Stephens	Adana, Mersin, Antalya
Coleoptera	Coccinellidae	*Nephus includens* Kirsch	Adana, Mersin, Antalya
Detected parasitoid insects			
Order	Family	Species	Collected locations
Hymenoptera	Encyrtidae	*Aenasius arizonensis* Girault	Adana, Mersin

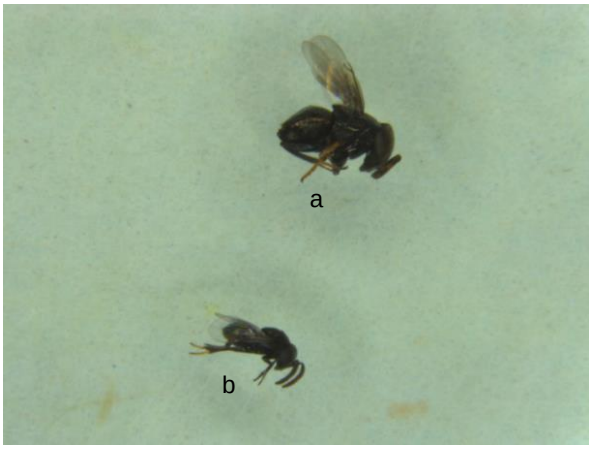

Figure 3. Female (a) and male (b) of *Aenasius arizonesis*.

detected as a pest in pitaya greenhouses in Adana, Mersin and Antalya (Figure 2).

In addition, parasitoids and predators of mealybugs were determined during this research. According to the results, one parasitoid and two different predator species were detected in pitaya greenhouses infected with *Phenacoccus solenopsis.* The list of predators and parasitoids were given in Table 2 with locations. In addition, Figure 3 demonstrated adult (a) female and (b) male of *A. arizonensis* (parasitoid). There were many studies conducted about the predators and parasitoids of *P. solenopsis* and *P. madeirensis.* According to result of these studies *A. arizonensis* was found most common and important parasitoids in Türkiye and other countries in the world (Hayat, 2009; Chen et al., 2011; Tanwar et al. 2011; Suroshe et al., 2013; Çalışkan Keçe et al., 2018). This parasitoid is a solitary endoparasitoid of this mealybug species, and the parasitism rate of *A. arizonensis* was varied between from 30% to 80% in field surveys in India and Türkiye (Aga et al., 2016; Kahya et al., 2021). Moreover, predator species of *P. solenopsis* has been determined. Different Coccinellidae and Chrysopidae species were detected within some survey studies in Türkiye and other countries (Hanchinal et al., 2010; Attia and Awadallah, 2016; Kahya et al., 2018). In addition, some laboratory studies were conducted about some Coccinellid and Chrysopid predators. Khan et al. (2012) Khan et al. (2012) conducted a study to assess the predatory potential of *C. carnea* and *Cryptolaemus montrouzieri* Mulsant (Coleoptera: Coccinellidae) against the first nymphal stage of *P. solenopsis*. Both predators were observed to have the capacity to feed on this stage. In addition, Ibrahim (2018) observed feeding potential of *C. carnea* against *P. solenopsis* on cotton under semi-field condition and results showed that 5 larvae of *C. carnea* can feed with 100 nymphs of *P. solenopsis.* As can be seen above studies, *A. arizonensis* had potential to use against *P. solenopsis* successfully. The main advantage of this parasitoid is solitary and widespread in Türkiye. Further studies may be conducted against *P. solenopsis* in pitaya greenhouses. In addition, *C. carnea* and *N. includens* is known as predator insects and both may feed with *P. solenopsis* and *P. madeirensis*. Moreover, more studies may be done for both mealybugs with the use of these detected predators under semi-field and field conditions within biological control and Integrated Pest management programs.

4. Conclusion

Pitaya, *Hylocereus* spp, will become one of the most economically important agricultural products and plantation areas will increase in the Mediterranean Region of Türkiye. In addition, dragon fruit has the potential to increase polyculture in Adana, Antalya, and Mersin provinces. Pests and diseases of pitaya should be determined in our region and further studies should be conducted to prevent yield loss due to pests and diseases. This research may be the first step to determine pests of pitaya in Türkiye. As a result of this study, 2 different invasive mealybug species (*P. solenopsis*, and *P. madeirensis*) were determined as a pest on pitaya fruit. Moreover, parasitoid (*A. arizonensis*) and predator species (*N. includens*, and *C. carnea*) of

these mealybug species were also detected in this research. The effectiveness of these natural enemies and other pests and diseases of pitaya should be considered in further studies.

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