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Infestation of the armoured-scale insect *Aulacaspis madiunensis* (Zehntner) (Hemiptera: Diaspididae) on Cycad plants in the Northern districts of Kerala, India

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Abstract

Cycad plants in Kozhikode and Kannur districts of Kerala, India have been facing an alarming threat from the armoured-scale insect *Aulacaspis madiunensis* since January 2023. An in-depth investigation from April 2023 to February 2024 revealed the extent of the problem. Both the endemic species *Cycas circinalis* and the exotic species *C. revoluta* were affected by the pest. In Kozhikode district 8122 *Cycas circinalis* and 94 *C. revoluta* were affected in 23 Grama panchayaths and one municipality. In Kannur district 3856 *Cycas circinalis* and 62 *C. revoluta* were affected in 14 Grama panchayaths and 3 municipalities. The mortality rates of affected *Cycas circinalis* were 0.32% and 0.34% in Kozhikode and Kannur districts respectively. In the case of *C. revoluta*, the rates were 7.45% and 22.58%. Besides, re-infestation was also observed in a sizeable number of plants. This is the first record of *Aulacaspis madiunensis* from Kerala and the first record of this species affecting cycad plants in India. While *Cycas circinalis* is an endangered plant with considerable economic value, *C. revoluta* is an important ornamental plant. Considering the rapidity with which the infestation is spreading, immediate control measures need to be launched to prevent the possible extinction of these 'living fossils' in Kerala.

Keywords: *Aulacaspis madiunensis*, *Cycas circinalis*, *Cycas revoluta*, living fossil, invasive species

Introduction

Cycads are gymnosperms and are considered the oldest and the most primitive assemblages of living seed plants in the world. They originated before the mid-Permian and reached the greatest diversity during the Jurassic-Cretaceous [1,2]. The extant species of cycad species are older than 12 million years [3]. Cycads are often called "living fossils," or evolutionary relics, and are of great scientific and conservation value because of their long evolutionary history [4]. *Cycas* (Cycadales: Cycadaceae), is one of the largest cycad genera with approximately 98 known species [5]. They are slow-growing plants and take 50-100 years to reach the maximum height of 6 to 10 meters. The most abundant native *Cycas* species in Kerala, India is *Cycas circinalis*. This is the first *Cycas* species to be described by Carl Linnaeus in 1753 [6]. It is endemic to South India with its geographical distribution restricted to the Western Ghats and hills of the southern peninsular, as far north-east as Chennai, in the states of Kerala, Karnataka, Tamil Nadu, and Maharashtra [7, 8]. The species is famous among the natives as a multipurpose plant. The seeds of *Cycas circinalis* are used as food and the plants are used as ornamental plants in gardens. The clumps of *C. circinalis* are exploited for their feathery leaves which are sold in the local flower markets. The plants are also cut by the locals to extract the pith from the stem due to its medicinal properties. Besides, it is an endangered species [9] and hence deserves conservation. *Cycas revoluta* is a native of Japan and has been introduced to Kerala as an ornamental plant.

Cycas plants are hardy and there have been no reports of any serious diseases or pest infestation from Kerala until 2022. However, in January 2023, local people from Puliyanambram, Peringathur, Panoor municipality in Kannur district reported a mysterious disease affecting their *Cycas* (*Cycas circinalis*) plants which resulted in the total drying up of leaves.

Similar reports emerged in the subsequent months from Chekkiad and Thuneri Panchayaths of Kozhikode districts, which are adjacent to Peringathoor. Preliminary observations suggested infestation by a scale insect. Considering the importance of the plant species as discussed above, an in-depth investigation into the causes and geographical distribution of the problem was launched in April 2023.

Materials and Methods

Study area: The study was carried out in the affected Grama Panchayaths and Municipalities of Kozhikode and Kannur districts of North Kerala from April 2023 to February 2024.

Survey and collection: Surveys were conducted on foot to locate the affected plants with the help of the local people and people's representatives, to collect the affected parts along with the scale insects, to investigate the mode of infestation, and to study the extent of infestation. Completely dried-up plants were re-visited to observe their subsequent condition. Scale insects were collected along with the affected parts and preserved in 70% alcohol for identification.

Identification: Scale insects collected from both *Cycas circinalis* and *Cycas revoluta* were despatched to the Division of Germplasm Collection and Characterization, ICAR-National Bureau of Agricultural Insect Resources, Bangalore, for the identification of the specimens.

Preparation of map: The dot map of the affected area was created by using digital mapping software and Geographic Information System (GIS).

Results

Species identity of the pest: Pest species collected from *Cycas circinalis* and *Cycas revoluta* were identified as *Aulacaspis madiunensis* (Zehntner).

Mode of infestation: Infestation with *A. madiunensis* was observed on plants of all ages. Infestation started at the base of the Rachis/Petiole, and proceeded to the ventral and dorsal sides of pinna/leaflets (infestation was more on the ventral side), megasporophyll and microsporophyll, seeds, stem, and root (rarely). The scale insects covered the whole plant within 45 days of the initial infestation. The infestation led to the complete drying up of leaves (Figures 1 and 2). The dried-up plants were either dead or recovered. In Kozhikode district out of 8122 *C. circinalis* 26 (0.32%) were found dead due to heavy infestation while out of 94 *C. revoluta* 7 (7.45%) were dead. In Kannur district out of 3856 *C. circinalis* 13(0.34%) were dead due to heavy infestation while out of 62 *C. revoluta* 14 were dead (22.58%). The remaining plants recovered and started producing new leaves. Re-infestation occurred in 1356 (16.70%) *C. circinalis* and 2 (2.13%) *C. revoluta* in Kozhikode district while the figures were 920 (23.86%) and 4 (6.45%) respectively in Kannur district.

Geographical distribution: In Kozhikode district 23 Grama Panchayaths and one municipality were affected by *A. madiunensis*. A total of 8122 *Cycas circinalis* and 94 *Cycas revoluta* were affected in the district (Table 1). In Kannur district 14 Grama Panchayaths and 3 municipalities were

affected. The number of *Cycas circinalis* and *Cycas revoluta* were 3865 and 62 respectively. The infestations were similar in degree and extent to those in Kozhikode district (Table 2). The geographical area of *A. madiunensis* in both districts formed a single unit without interruption. The infestation extended from the coastal area in the west to the foothill area in the east. The infestation radiated in all directions from the initial infested sites, i.e. Panoor and Chekkiad (Figure 3).

Table 1: Geographical distribution of *Cycas circinalis* and *Cycas revoluta* affected by *Aulacaspis madiunensis* (Zehntner) in Kozhikode district, Kerala, India

Grama Panchayath/ Municipality	<i>Cycas circinalis</i>	<i>Cycas revoluta</i>
Ayancheri	473	2
Azhiyur	124	
Chekkiad	713	4
Chorode	28	
Edacheri	762	11
Eramala	323	4
Kavilumpara	18	
Kayakkodi	286	5
Kunummal	394	3
Maniyur	13	
Maruthonkara	17	
Nadapuram	738	8
Narippatta	405	6
Onchiyam	204	
Purameri	765	24
Thiruvallur	37	
Thuneri	968	4
Valayam	474	7
Vanimel	588	5
Velom	438	6
Villiappally	112	3
Cheruvannur	13	
Kuttiady	207	2
Vadakara Municipality	22	
Total	8122	94

Table 2: Geographical distribution of *Cycas circinalis* and *Cycas revoluta* affected by *Aulacaspis madiunensis* (Zehntner) in Kannur district, Kerala, India

Gramma Panchayath/Municipality	<i>Cycas circinalis</i>	<i>Cycas revoluta</i>
Chokli	585	3
Kadirur	193	
Kunnothparamba	687	5
Mokeri	210	
New Mahe	18	2
Pattiam	124	
Thrippangottoor	730	6
Chittariparamba	16	
Panniannur	168	2
Kottayam	52	
Mangattidom	17	
Pinarayi	14	7
Vengad	24	
Dharmadam	12	
Panoor Municipality	965	31
Koothuparambu Municipality	34	
Thalassery Municipality	16	6
Total	3865	62

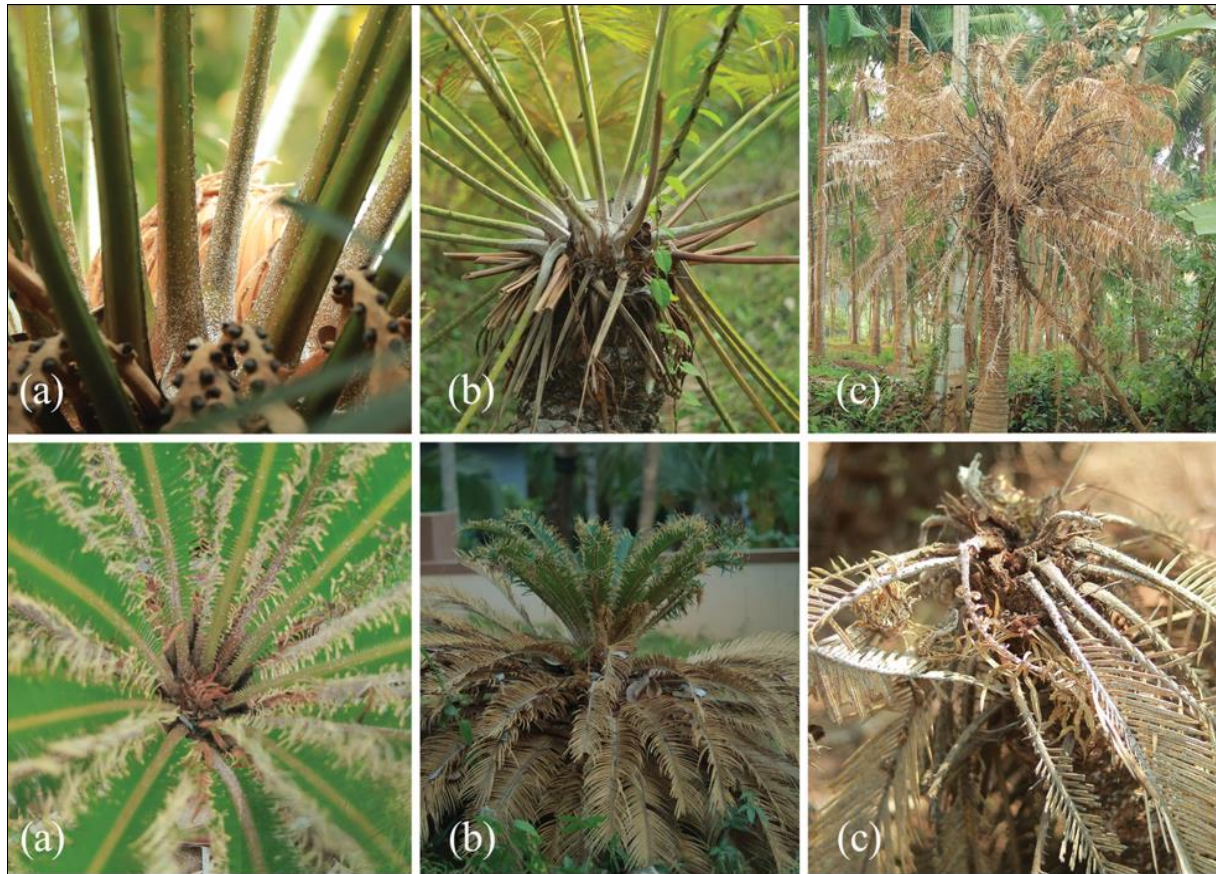


Fig 1: Three stages of infestation with *Aulacaspis madiunensis* on Cycad plants. Above: *C. circinalis*; Below: *C. revoluta*

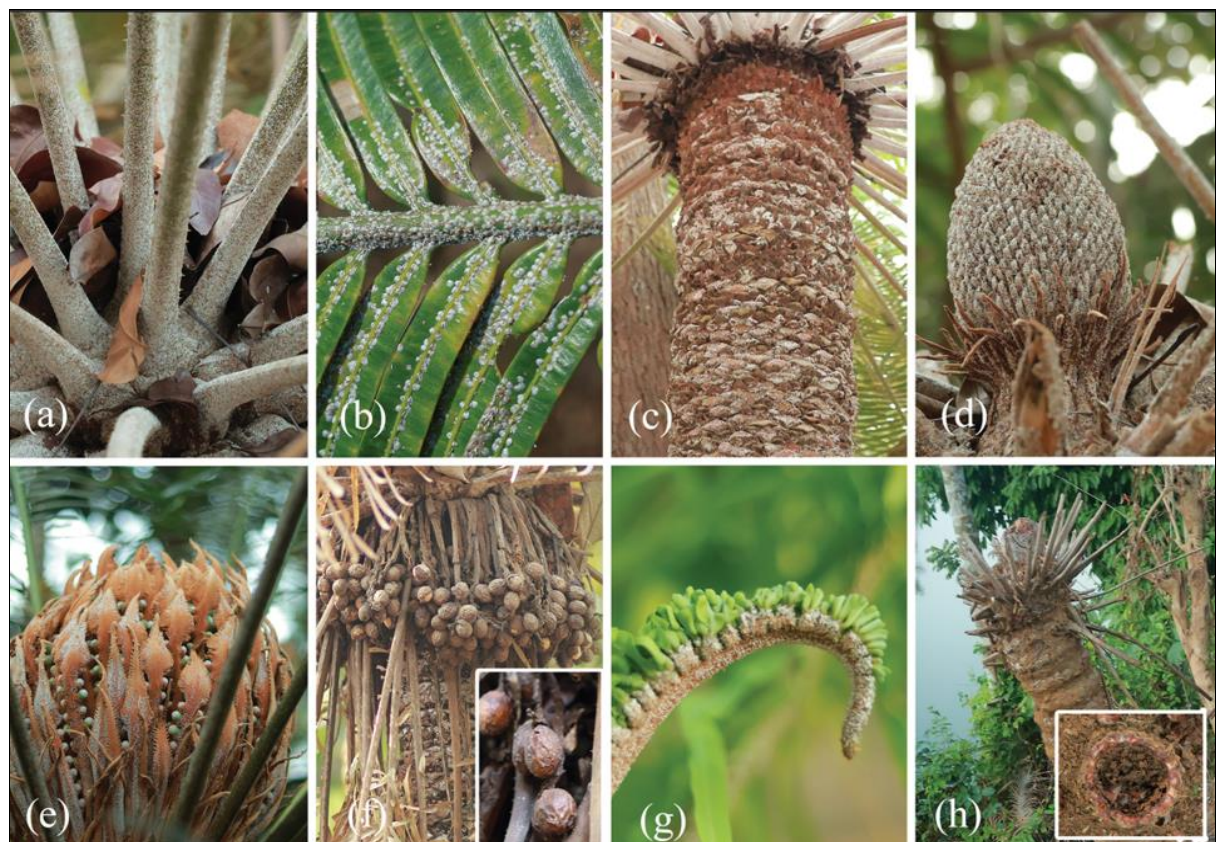


Fig 2: *Cycas circinalis*: Infestation with *Aulacaspis madiunensis*: (a) Rachis (b) Leaf (c) Stem (d) Micro strobilus/Male cone (e) Mega strobilus/Female cone. (f) Seeds (g) Regenerating leaves after infection (h) Dead plant

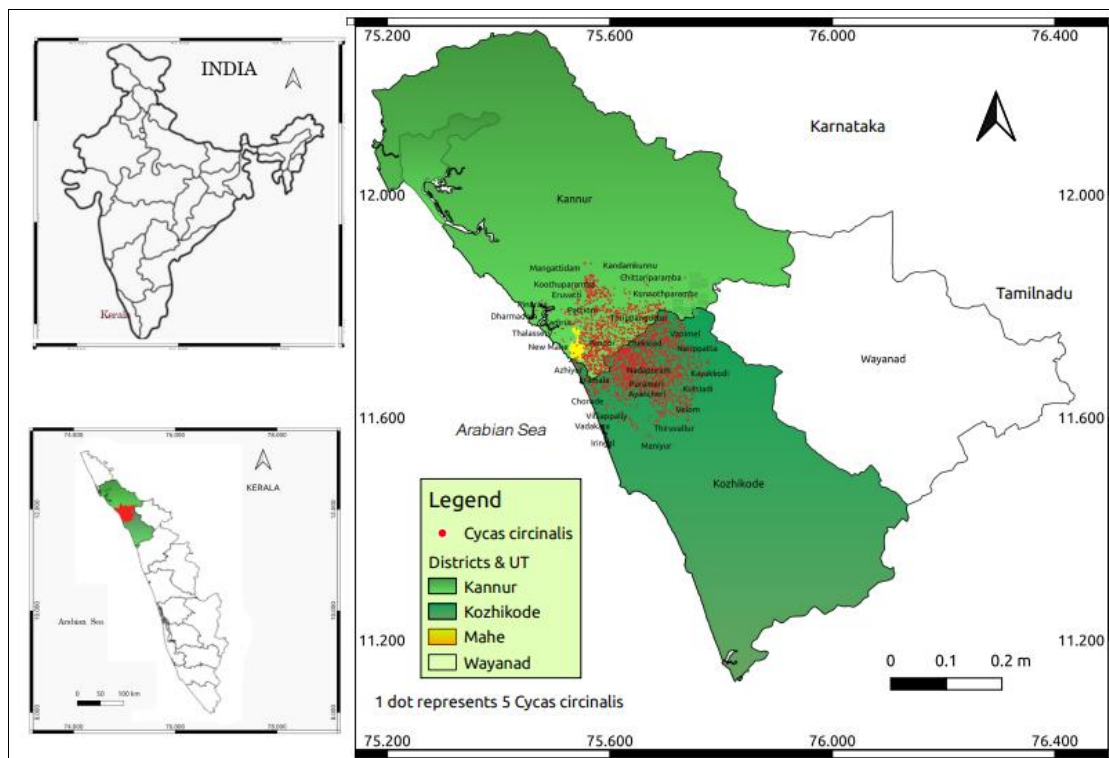


Fig 3: Geographical distribution of Cycad plants infested with *Aulacaspis madiunensis* in North Kerala districts

Discussion

The present study has revealed the alarming state of infestation by the scale insect *Aulacaspis madiunensis* (Zehntner), on the Cycad plants *Cycas circinalis* and *C. revoluta* in Kozhikode and Kannur districts of North Kerala. Starting from a single spot of Panoor municipality in Kannur district in January 2023, the infestation rapidly expanded to include 37 Grama Panchayaths and 4 municipal towns in Kozhikode and Kannur districts by February 2024. The impact of the infestation on the plants was also alarming, as plants of all age groups were infested, all the infested plants were completely dried up, and some of them even died. It is a relief to note that the mortality was very low (0.32-0.34%) in the case of the native species *C. circinalis* compared to *C. revoluta* (7.45-22.58%). The mortality in *C. revoluta* is also not of less concern as it will devastate the ornamental plant business. Another matter of concern is the re-infestation in a large number of plants. Repeated infestations are likely to increase the mortality rate.

Aulacaspis is a large genus of scale insects that belong to the family Diaspididae, one of the most successful scale insect families owing to the protective wax scale produced by female insects^[10]. The species under the genus *Aulacaspis* are concentrated in the tropical and subtropical forests of Asia. The majority of their hosts are woody angiosperms. However, a few gymnosperms and grasses belonging to the family Poaceae, have also been reported as serving as their hosts. So far, only a single species, *Aulacaspis yasumatsui*, has been recorded as infesting cycads exclusively.^[11] However, four more species have been occasionally recorded from Cycads, viz., *A. madiunensis* (Zehntner), *A. mischocarpi* Cockerell and Robinson, *A. rosae* Bouche, and *A. zunyiensis* Wei and Jing. *A. madiunensis*, *A. mischocarpi* and *A. rosae* are oligophagous to polyphagous but the full host range for *A. zunyiensis* is not known^[12]. Hence, it is a surprise to notice the extent of damage caused by *A. madiunensis* (Zehntner) only on cycads in Northern Kerala districts. This species was

originally described from Java as a pest of sugarcane and recorded as occurring on sugarcane in Asia, Africa, and Australia. Various Poaceae other than sugarcane have also been recorded as host plants^[11]. The first report of *A. madiunensis* infestation in India was on sugarcane variety Co 62175 in Srikakulam District, Andhra Pradesh, in 1977. This was also the first record of the diaspidid in the country^[13]. However, there has not been any report on the occurrence of this species in the state of Kerala. Hence, this is the first-ever record of *A. madiunensis* from Kerala and also the first record of its infestation on Cycad plants in the whole country. Besides, such large-scale infestations by this species on Cycad plants have not been reported anywhere in the world. Several questions need to be answered on the origin of the present infestation and its rapid spread in the study areas. Since there is no sugarcane farming anywhere in the vicinities of the affected geographical area, such a source can be easily ruled out. *C. revoluta* is an introduced species often imported from other countries. There were instances of interception of six species of *Aulacaspis* including *A. madiunensis* (not on cycad plants) at the port of entry of the Republic of Korea between 1996 and 2005. Among the six species *A. yasumatsui* Takagi was found on Cycad plants from Malaysia and Taiwan^[14]. Hence, such an introduction of *A. madiunensis* with *C. revoluta* or any other imported plants to Kerala is a possibility. The rapid spread and severe infestation also point to the possibility of a recent introduction. A case in point to corroborate this hypothesis is the differences in the degree of infestations of the cycad-specific scale insect *A. yasumatsui* Takagi in its native range of distribution and in a new area where it was introduced. *A. yasumatsui* was first discovered in Thailand on *C. revoluta* plants in 1972. Its native range is from the Andaman Islands to Vietnam. Within its native range, the infestations are not lethal to the host plants. The accidental introduction of *A. yasumatsui* to Miami, Florida, USA in 1994 led to widespread infestations and became a lethal threat to Cycad plants^[12]. The present study also has

revealed a similar picture. Unless the uninterrupted march of this lethal pest is curtailed immediately, this invasive pest species will likely exterminate *Cycas circinalis*, an endemic and endangered species in Kerala. Experiences during the infestation of *A. yasumatsui* in Florida should be an eye-opener for all those who are concerned with the control of agricultural pests in the state. As per the report, typical horticultural protocols to control *A. yasumatsui* were ineffective in Florida, and the insect rapidly extended its invasive range further ^[15]. Hence, novel strategies need to be developed to tackle the havoc wreaked by this invasive species in the state.

Conclusion

Our study comprehensively investigated the infestation of *Aulacaspis madiunensis* on *Cycas circinalis* and *Cycas revoluta* plants in Kozhikode and Kannur districts of North Kerala. Through detailed surveys, collection, and identification processes, we confirmed the pest species responsible for the infestation. The mode of infestation was observed across various plant parts, leading to significant mortality rates in affected plants. Geographically, the infestation spread extensively across multiple Grama Panchayaths and municipalities, highlighting the urgent need for effective pest management strategies. Our findings provide crucial insights into the distribution, impact, and management of *A. madiunensis* infestations in cycad plants in these regions.

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