RESEARCH ARTICLE

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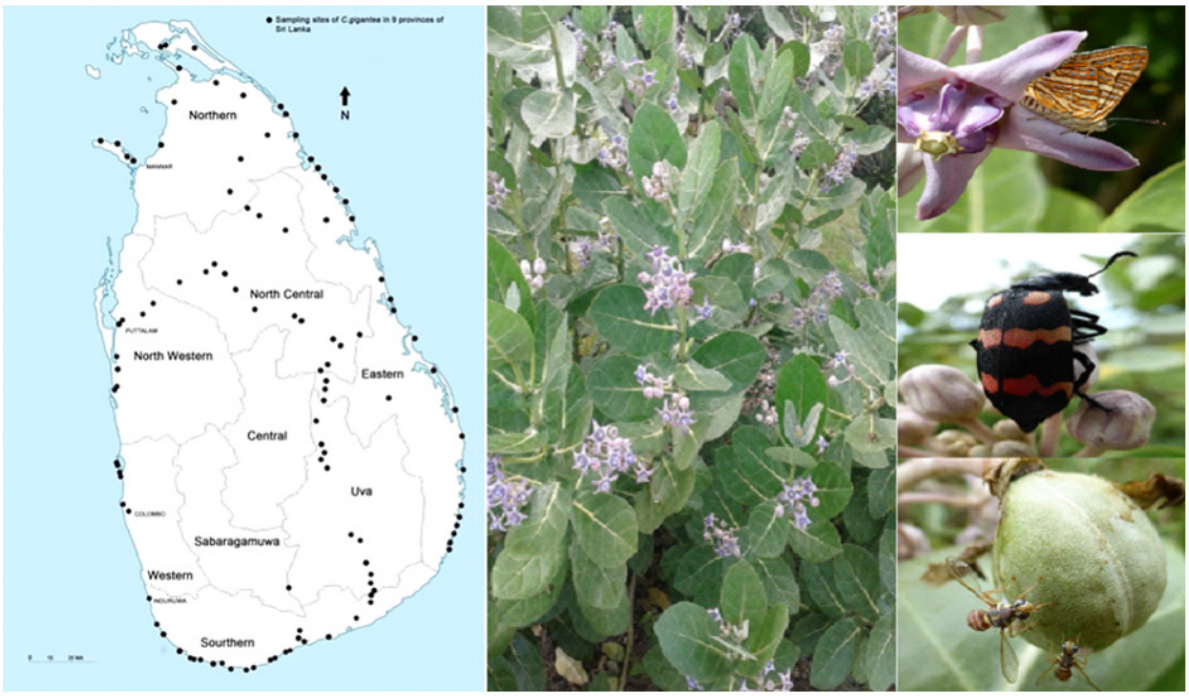

Highlights

- Insects found in *Calotropis gigantea* were pests, pollinators, and occasional visitors.
- 13 pests, 6 pollinators, and 14 occasional visitors were documented.
- *Dacus persicus* and *Paramecops farinosa* were destructive, monophagous pests.
- *Sphaeroderma* sp. was the most common pest.
- *Xylocopa* spp. were the most abundant insect pollinators.

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RESEARCH ARTICLE

Insect diversity on *Calotropis gigantea* (L.) in Sri Lanka

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Abstract: *Calotropis gigantea* is a drought-resistant and salt-tolerant medicinal plant native to Sri Lanka. Although *C. gigantea* is widely distributed in Sri Lanka, information on insects associated with the plant is less understood. The objective of the study is to identify the diversity of insect fauna associated with *C. gigantea*. Surveys were conducted in 120 sites covering all provinces of Sri Lanka to document the insect fauna associated with *C. gigantea* and their biotic associations. The insects found in *C. gigantea* were cataloged as pests, pollinators, and occasional visitors. A total of thirteen morphospecies of phytophagous pests, six species of pollinators, and fourteen species of occasional visitors were documented. *Dacus persicus* and *Paramecops farinosa* were the highly damaging pests while *Sphaeroderma* sp. was more widespread. *Xylocopa* spp. were the most abundant insect pollinators. *Dacus persicus* and *P. farinosa* were identified as monophagous species of *C. gigantea.* Occasional visitors belonged to five orders and their diversity was very high. As the initial record from Sri Lanka, the findings of the study provide information on the identification of the insect fauna associated with *Calotropis* and their association with *C. gigantea*.

Keywords: *Calotropis gigantea*; phytophagous insect; pollinator; Sri Lanka.

INTRODUCTION

Calotropis gigantea (L.) Dryand (Apocynaceae), commonly known as Arka (Singh *et al*., 2013) Madura, Yercum (Sethi, 2014), Crown flower, or Giant milk-weed (Kadiyala *et al*., 2013; Saikia *et al*., 2015), is native to India, China, Bangladesh, Burma, Indonesia, Malaysia, Pakistan, Thailand, Philippines, and Sri Lanka (Kumar and Kumar, 2015). In many countries in Asia, *C. gigantea* is used as a medicinal plant to cure various ailments, including bronchial asthma, cholera, convulsions, pneumonia, ringworm infection, smallpox infection, toothache, epilepsy, fever, leprosy, rheumatism, catarrh, cold, cough, inflammation, tumors, mental disorders, snakebite infection, and tuberculosis (Kumar *et al*., 2013; Kumar and Kumar, 2015; Abeysinghe, 2018). In Sri Lanka, *C. gigantea* is widely used in Ayurvedic medicine, for the treatment of pain and inflammation (Shukla *et al*., 2018). Furthermore, in Sri Lankan traditional medicine, *C. gigantea* is used to treat scorpion poisoning (Ediriweera *et al*., 2018) and snake bites (Herath, 2017). Similarly, the root is used to treat dysentery (Gunaratna *et al*., 2015). Also, Sri Lankan farmers used latex of the plant as a sticky material in sticky traps. Alpha and Beta calotropeol and Beta amyrin in latex act as excellent compounds for crop pest control (Widanapathirana and Dassanayake, 2013). Especially sugarcane farmers use latex of the plant to control termite attacks on their crop fields (Wanasinghe *et al*., 2018). Furthermore, under laboratory conditions, extractions of *C. gigantea* are effective in controlling the cotton mealybugs (Prishanthini and Vinobaba, 2014). Sri Lankan Buddhists offer *Calotropis* flowers to Load Buddha and in Thailand, flowers are used to decorate temple ceremonies (Gaur, *et al*., 2013).

Insects associated with *C. gigantea* utilize the plant as a feeding substrate, a shelter, a hunting ground (Salau and Nasiru, 2015) as well as a breeding place. Phytophagous insects associated with *C. gigantea* play an important ecological role while they act as pests, predators as well as parasites (Saikia *et al*., 2015). The diversity of insect fauna associated with *C. gigantea* varies in different regions of the World. Although latex of *C. procera* is considered toxic to insects (Al dhafer *et al*., 2011) large numbers of insect pests cause considerable damage to the plant. Dhileepan (2014) explains that there are sixty-five phytophagous insect species associated with *Calotropis* spp. (including *C. gigantea*) in their native range. Among them, more than 50% of insects feed on leaves while others feed on flowers, stems, seeds, and fruits. Most of the insects associated with *Calotropis* species were recorded from India.

Aphids, grasshoppers, and caterpillars of *Danaus* spp. are the common plant feeders associated with *C. procera* (Al dhafer *et al*., 2011). *Danaus* spp. is a pest of *Calotropis* species in Australia, Hawaii, Fiji, Brazil, Jamaica, and Puerto Rico (Dhileepan, 2014). The gregarious feeding nature of *Aphis nerii* Boyer leads to defoliation and dieback of shoots and immature fruits of *C. procera* (Dhileepan, 2014). Most of the insects associated with *C. procera* are polyphagous except for *Paramecops farinosa* Schoenherr and *Dacus persicus* Hendel. They are highly destructive, monophagous pests (Dhileepan, 2014). *Dacus persicus* is distributed in India, Sri Lanka, Pakistan,

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Iran, and Iraq. Another fruit fly species, *Dacus longistylus* attacking *C. procera* fruits is widely distributed in Afro-tropical regions. *Paramecops farinosa* is distributed in India and Pakistan with a less dispersal range than *Dacus* spp. (Dhileepan, 2014). Also, a study from India reveals that several other species of pests of *C. gigantea* cause considerable damage to the plant (Tara and Madhu, 2011). As the initial record, *Platycorynus sp.* was recorded on *C. gigantea* plants in West Bengal. *Platycorynus sp.* feeds on leaves and flowers of *C. gigantea* plants (Sudip *et al*., 2004).

Calotropis flower is a good nectar source for pollinators. The majority of insect pollinators of the plant belonged to the order Hymenoptera (Salau and Nasiru, 2015). A study in Israel found two carpenter bees, *Xylocopa pubescens* Spinola and *X. sulcatipes* Maa as major pollinators of *C. procera.* Carpenter bees are widely distributed in Asia and Africa (Eisikowitch, 1986; Zafar *et al*., 2018). In India, *Apis dorsata* Fabricius, *Apis florae* Fabricius, and *Apis mellifera* Linnaeus are active diurnal flower visitors of *Calotropis* spp. (Sudan, 2013). Dipterans of Family Muscidae, Sarcophagidae, and Syrphidae also visit *C. procera* flowers. Butterflies of the family Nymphalidae, Noctuidae, and Lycaenidae are occasional pollinators of *C. procera* (Sudan, 2013).

Diversity of predators associated with *Calotropis* spp. varies according to the different regions of the World. In the Central region of Saudi Arabia, 22 species of insects are reported as predators associated with *C. procera* (Al dhafer *et al*., 2011). Occasional visitors display a "neutral" relationship with the *C. procera* plant. They do not feed on the plant or prey on associated insects (Al dhafer *et al*., 2011). Further, the study of Al dhafer et al. (2011) explains that occasional visitors may feed around the plant without having a direct association with *C. procera.*

Although *C. gigantea* is widely distributed in Sri Lanka, no systematic surveys have been conducted so far. Therefore, the information on insects associate with *C. gigantea* in Sri Lanka is lacking and only a few records are available related to insect fauna of *C. gigantea* in Sri Lanka. Few species of bees including *Amegilla comberi* Cockerell, *Amegilla fallax* Smith, *Amegilla violacea* Lepeletie, *Xylocopa fenestrata* Fabricius *and Xylocopa tenuiscapa* Westwood were identified as pollinators of *Calotropis* in Sri Lanka (Karunaratne, *et al*., 2005). Also, butterfly larvae of *Danaus chrysippus chrysippus* were recorded as feeders on *Calotropis* leaves and flowers (Jayasinghe *et al*., 2013; Perera and Wickramasinghe, 2014).

There is no information on insects associated with *C. gigantea* in Sri Lanka except in the above studies. Therefore, the present study was conducted to fill the important gaps in the survey, catalog, and identification of insect fauna of *C. gigantea* in Sri Lanka.

MATERIALS AND METHODS

Study sites

The study was conducted from December 2014 to June 2015, at a monthly interval, to identify the associated insect fauna of *C. gigantea* in Sri Lanka. Field visits were conducted covering 120 sites in nine provinces (Figure 1). Sampling was done only once for each site. Roadside sampling sites were selected randomly at thirty minutes intervals while traveling on a vehicle with a speed of fifty kilometers per hour. If a new site with *C. gigantea* plants was not observed after thirty minutes, traveling was continued until a site with *C. gigantea* was found (Wijeweera *et al*., 2021). In all sampling sites, the distribution of *C.* gigantea (GPS coordinates) was recorded. At each site, associated insect fauna of C. gigantea was observed for thirty minutes. During the survey, insects associated with the plant were observed and photographed. The insects were collected directly from various parts of the plant *i.e.* leaves, flowers, flower buds, stems, and fruits by hand-picking. Two or three individuals of the same species in each site were collected into small plastic vials for morphological identification.

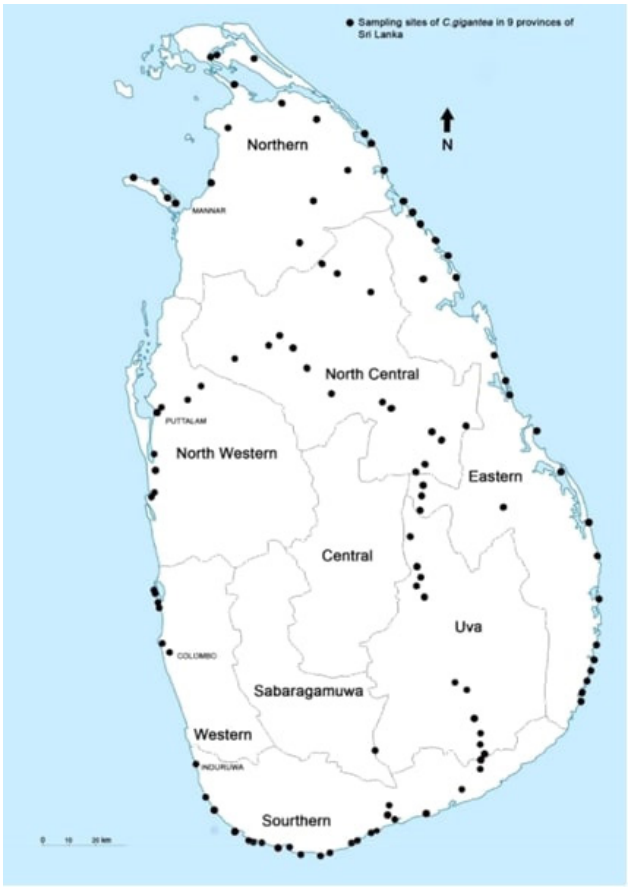

Figure 1: Insect sampling sites of *Calotropis gigantea* plant in Sri Lanka.

Identification of insects

The specimens were preserved, pinned, and lodged in the laboratory of the Department of Zoology at the University of Ruhuna, Sri Lanka. Specimens were identified up to genus/species level under the guidance of Entomologists of Entomology Division, National Plant Quarantine Service, Department of Agriculture, Gannoruwa. Unidentified specimens were sent to Mr. Justin Bartlett, Technical Officer (Taxonomy), Biosecurity Queensland, Department of Agriculture and Fisheries (DAF), Australia for identification.

RESULTS

Insect fauna of *C. gigantea* and their distribution in Sri Lanka

A total of 32 insect fauna (morphospecies) belonging to twenty-three families was observed on *C. gigantea* in Sri Lanka. Insects were categorized as phytophagous insects/ pests, pollinators/ flower visitors, and occasional visitors. High insect diversity was recorded in *C. gigantea* associated with the coastal belt of Sri Lanka. Also, well-established insect populations were observed in inland areas of the Southern, Northern, Eastern, and North-Central provinces of Sri Lanka.

Insect pests of *C. gigantea* in Sri Lanka

The majority of the insect fauna associated with *C. gigantea* in Sri Lanka were phytophagous species (Table 1).

The phytophagous insects associated with *C. gigantea* belonged to nine families, Chrysomelidae, Lygaeidae, Cercopidae, Membracidae, Tephritidae, Aphididae, Papilionidae, Curculionidae, and Cerambycidae, and feed on different plant parts including leaves, fruits, flowers, flower buds, fruits, seeds, and plant sap (Table 1). *Spilostethuspanduru* Militaris, S*phaeroderma* sp., *Graptostethus servus* Fabricius, *Spilostethus hospes* Scopoli, and *Aphis nerri* Boyer de Fonscolombe were observed as gregarious feeders. Field observations revealed that all the pests caused minor damage to *C. gigantea* plants, except *Phelipara moringae* Aurivillius, *Dacuspersicus* Hendel, and *Paramecops farinosa* Schoenherr which are the major pests. Even though *P. moringae* is a destructive pest, they were less abundant within the country with respect to *D. persicus* and *P. farinosa. Dacus persicus* and *P. farinosa* were highly destructive pests as they damage fruits and seeds of *C. gigantea* plants influencing the reproductive output of the plant (Figure 2).

Pollinators and occasional visitors associated with *Calotropis gigantea* in Sri Lanka

The most common pollinators were *Xylocopa fenestrate* Fabricius, *Xylocopa caerulea* Fabricius and *Apis cerana* Fabricius. They consumed nectar as well as pollen of *C. gigantea* flowers while *Spindasis lohita* Horsfield, *Danaus chrysippus* Linnaeus, and *Xylocopa* spp. only feed on nectar (Figure 3).

Occasional visitors utilized *C. gigantea* plants as a shelter and hiding place. *Coccinella* sp. fed on aphids on *C. gigantea* plants. Different insect pollinators/ flower visitors and occasional visitors associated with *C. gigantea* are given in Table 2.

DISCUSSION

The insects collected from *C. gigantea* during this study in Sri Lanka are very similar to the insects reported on *C. procera* and *C. gigantea* from India (Pugalenthi and Livingstone, 1997; Chandra *et al*., 2011; Jana *et al*., 2012; Dhileepan 2014). A similar study had been conducted in Saudi Arabia related to *C. procera* and 99 insect species belonging to 43 families were identified (Al dhafer *et al*., 2011). According to a study in the Jabalpur district in India,

Table 1: The occurrence of different species of insect pests associated with *Calotropis gigantea* and their damage as per the survey from December 2014 to June 2015.

Family	Common name	Scientific name	No. of recorded sites	Feeding substrate
Chrysomelidae	Chrysomelid beetle	*Sphaeroderma* sp.	81 (67.50%)	Leaf
Lygaeidae	Lygaeid bug	*Graptostethus servus* Fabricius *Spilostethus hospes* (Scopoli) *Spilostethus pandurus* Militaris	80 (66.67%)	Seed, Leaf
Cercopidae	Spittle bug	*Abidma refula*	62 (51.67%)	Leaf
Membracidae	Cow bug	*Oxyrachis* sp.	57 (47.50%)	Leaf, Stem
Tephritidae	Aak Fruit fly larvae	*Dacus persicus* Hendel	26 (21.67%)	Fruit, Seed
Aphididae	Aphid	*Aphis nerri* Boyer de Fonscolombe	20 (16.67%)	Leaf, Fruit Flower
Papilionidae	Plain Tiger larvae	*Danaus chrysippus* L.	20 (16.67%)	Leaf
Curculionidae	Aak weevil	*Paramecops farinosa* Schoenherr	20 (16.67%)	Leaf, Flower
	Aak weevil larvae	*Paramecops farinosa* Schoenherr	20 (16.67%)	Fruit, Seed
Cerambycidae	Long-horned beetle	*Phelipara moringae* Aurivillius *Sybra praeusta* Pascoe	08 (6.67%)	Stem
	Long-horned beetle larvae	*Ropica* sp. *Phelipara moringae* Aurivillius	06 (5.00%)	Stem

Figure 2: Phytophagous insects/ insect pests associated with *Calotropis gigantea* in Sri Lanka.
A.*Sphaeroderma* sp. B. *Abidma refula* C. *Graptostethus servus* D. *Aphis nerri* E. *Phelipara moringa,* F. *Paramecops farinosa* G. *Danaus chrysippus* H. *Dacus persicus* I. *Oxyrachis* sp.

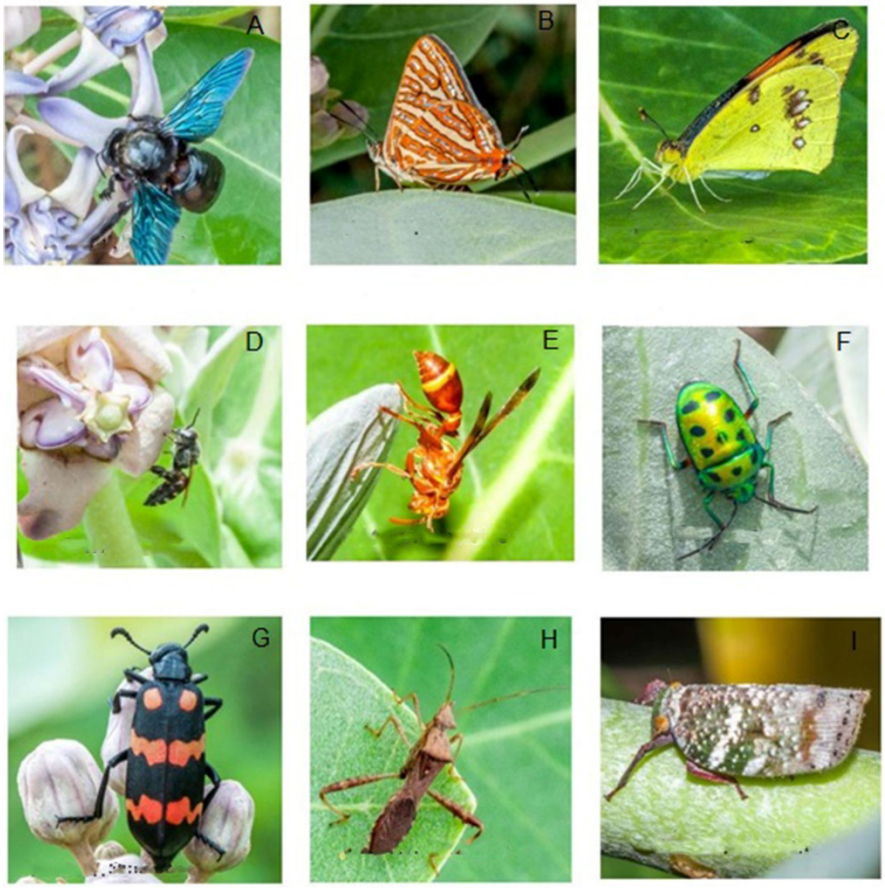

Figure 3: Pollinators and occasional visitors associated with *Calotropis gigantea* in Sri Lanka; A. *Xylocopa fenestrata* B. *Spindasis lohita* C. *Ixias pyrene* D. *Apis cerana* E. *Ropalidia marginata* F. *Chrysocoris stollii* G. *Hycleus biundulatus* H. *Riptortus* sp. I. *Eurybrachis* sp.

Table 2: The occurrence of different insect pollinators/ flower visitors and occasional visitors associated with *Calotropis gigantea* as per the survey from December 2014 to June 2015.

Order	Family	Common name	Scientific name	No. of recorded sites
Pollinators				
Hymenoptera	Anthophoridae	Carpenter bee	*Xylocopa caerulea* Fabricius *Xylocopa fenestrata* Fabricius	17 (14.17%)
Lepidoptera	Papilionidae	The plain tiger	*Danaus chrysippus* Linnaeus	04 (03.33%)
	Lycaenidae	Long-banded Silverline	*Spindasis lohita* Horsfield	01 (0.83%)
	Pieridae	Yellow-orange tip	*Ixias pyrene* (Pieridae)	01 (0.83%)
Hymenoptera	Apidae	Honeybee	*Apis cerana* Fabricius	Not estimated
Occasional visitors				
Diptera	Drosophillidae	Drosophila	*Drosophila* sp.	33 (27.5%)
Coleoptera	Coccinellidae	Lady bird beetle	*Coccinella* sp.	15 (12.5%)
	Meloidae	Blister beetle	*Hycleus biundulatus* (Pallas)	01 (0.83%)
	Chrysomelidae	Leaf beetle	*Platycorynus peregrinus* Herbst	03 (2.79%)
Lepidoptera	Erebidae	Tiger moth	*Amata* sp.	10 (8.33%)
	Erebidae	Tussock moth	*Olene* sp.	01 (0.83%)
Hemiptera	Coreoidae	Coreid bugs	*Leptocorisa* sp. *Cletus* sp. *Homoeocerus* sp.	08 (6.67%)
	Cicadellidae	Leafhopper	*Calodia* sp.	06 (5.0%)
	Eurybrachidae	Planthopper	*Eurybrachis* sp.	01 (0.83%)
	Scutelleridae	Jewel bug	*Chrysocoris stollii* Wolff	01 (0.83%)
	Alydidae	Broad-headed bug	*Riptortus* sp.	01 (0.83%)
Hymenoptera	Vespidae	Paper wasp	*Ropalidia marginata* le Peletier	02 (1.16%)

(Chandra *et al*., 2011), 8 species of insects from 6 families have been documented on *C. procera*. Similarly, a study in West Bengal in India reported 19 insect species from ten families of *C. procera* (Jana *et al*., 2012).

Thirteen phytophagous pest species belonging to nine families were recorded in Sri Lanka. In the study of Saudi Arabia (Al dhafer *et al*., 2011), three species; the carpenter moth, *Semitocossus Johannes* (Staudinger), scale insect *Contigaspis zilla* (Hall), and milkweed aphid *Aphis nerii* (Boyer de Fons–colombe) were pests of *C. procera*. Similarly, a study in India revealed eight species of pests associated with *C. procera* including *A. chrysippus*, *S. pandurus*, *S. hospes*, *L. acuta*, *A. nerii*, *A. foveicollis*, *C. peregrinus*, and *C. sexmaculata* (Chandra *et al*., 2011). Concerning both studies, the highest pest species richness was recorded in *Calotropis* in Sri Lanka.

Most pest species recorded in the present study were polyphagous feeders. Only *P. farinosa* (Aak weevil) and *D. persicus* (Aak fruit fly) were monophagous feeders (Dhileepan, 2014; Wijeweera *et al*., 2021). A similar observation was recorded in India (Dhileepan, 2014) and Pakistan (Sudan, 2013; Shabbir *et al*, 2019; Ali *et al* 2020; Ali *et al*; 2021) as well. *Dacus persicus* was found in 26 sites including coastal and inland regions of the country. Gravid females lay eggs inside *C. gigantea* fruits by penetrating the skin of the fruit with its ovipositor (Kumar and Kumar, 2015). The larval stage of *D. persicus* is a major destructive seed predator in *Calotropis* species (Sharma and Amriphale, 2008). Nourishment and development of larval stages of *D. persicus* are taken place within the fruit. Infected fruits rot and often drop prematurely. Pupation of this species occurs in the soil after the detachment of the fruit from the tree (Dhileepan, 2014). The damage is directly focused on the reproductive output of the plant which severely reduces the propagation and dispersal of the *Calotropis* species.

Parameceps farinosa naturally occurs in India,

Pakistan (Sudan, 2013), and Sri Lanka. The slow-moving nature of *P. farinosa* might limit their distribution into twenty inland sites and their relative frequency of occurrences was recorded as 16.67% (Table 1). Larval stages of *P. farinosa* feed and destroy fruits, and seeds while the adult weevil depends on the *C. procera* plant for feeding, sheltering, and oviposition. *Paramecops farinosa* feeds on leaves, flowers, and fruits (Sharma and Amriphale, 2007; Dhileepan, 2014). Field observations revealed that the adults prefer to feed on flower buds and tender leaves.

Sphaeroderma sp. mostly occurred (67.5%) in many of the sampling sites (Table 1). It is considered a polyphagous pest feeding on leaves (Dhileepan, 2014). According to observations of the present study, it tends to aggregate as groups to feed on tender leaves. Damaged leaves appeared as a perforated mesh with emerging whitish latex. Later on, damaged leaves become brownish in color and dried out. According to a study in India (Saikia *et al*., 2015) both adult and larvae of *Corynodes* sp. are pests of *C. gigantea* plants. *Corynodes* beetles appear metallic-blue in color and they feed on leaves while larval stages act as stem borers.

Lygaeid bugs *S. hospes*, *S. pandurus*, and *G. servus* were the second most common (66.67%) polyphagous insect pests associated with *C. gigantea* plants (Table 1). *Graptostethus servus* Fabricius feeds on the seeds of *Calotropis* sp. Also, it is recorded in India, China, Pakistan, Indonesia, Turkey, Syria, and Australia (Hussain *et al*., 2014). The three species are seed predators of *Calotropis* plants (Dhileepan, 2014). Additionally, adult and nymphal stages of *S. hospes* feed on leaf sap of *Calotropis* sp. Nymphal stages inflict severe damage to the tender leaves by actively sucking leaf sap. Attacked leaves appear yellowish in color and dried (Saikia *et al*., 2015). These damages were observed in the present study too. *Spilostethus hospes* has also been recorded in Australia, China, Malaysia Archipelago, Pakistan, India, and New Caledonia while *S. pandurus* has been reported from Australia, India, and Pakistan (Chandra *et al*., 2015).

Abidma refula (Spittlebug) was recorded as the third most common insect pest of *C. gigantea*. It fed on plant sap and was recorded in 62 sites (51%) in Sri Lanka (Table 1). One species of the same genus was recorded in India which feeds on *C. gigantea* as well as *C. procera* (Dhileepan, 2014). *Oxyrachis* sp. (cow bug) was observed as a pest of *C. gigantea* in 57 sites. *Oxyrachis* sp. is widely distributed in South Asia, including in India, Sri Lanka, and Nepal. They occasionally feed on *C. procera*. Both nymphs and adults feed gregariously on the sap of immature stems, leaves, and flower buds (Sudan, 2013). The gregarious feeding nature of *Oxyrachis* sp. leads to the weakening of plants. They produce honeydew which leads to the attraction of ants to *C. procera* plants (Sudan, 2013) and a similar observation was recorded in the present study also.

Xylocopa spp. (Carpenter bee), *A. cerana* Fabricius (Honeybee), and *D. chrysippus* (Plain Tiger) were commonly recorded as pollinators of *C. gigantea. Spindasis lohita* Horsfield (Long-banded Silverline) and *I. pyrene* (Pieridae) (Yellow-orange tip) rarely visit *Calotropis* flowers. *Xylocopa* spp. visit *Calotropis* plants to collect nectar, not pollen (Willmer, 1988; Aluri and Rao, 2006). The recorded butterflies in the present study are attracted to *Calotropis* flowers for nectar and might act as pollinators of the plant.

Apart from pests and pollinators in *C. gigantea*, there was a great species richness in occasional visitors. *Drosophil*a sp. was commonly observed under the shade of *C. gigantea* leaves in 33 sampling sites. *Coccinella* sp. visits *C. gigantea* plants to hunt small insects. They are predators of aphids and other small insects. Similarly, *Brumoides suturalis* Fabricius is a predatory beetle recorded in Pakistan, Bangladesh, China, Taiwan, and India that feeds on aphids and mealybugs associated with *C. gigantea* (Sudan, 2013).

CONCLUSIONS

The findings of the present study provide detailed records of insect fauna associated with the *C. gigantea* plant in Sri Lanka. Insects associated with *Calotropis* were cataloged as pests, pollinators, and occasional visitors. A total of thirty-two morphospecies of insects belonging to twenty-three families were identified. Thirteen pests associated with *C. gigantea* were identified up to the genus/species level. Six species of pollinators and high diversity of occasional visitors belonged to five orders also documented.

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DECLARATION OF CONFLICT OF INTEREST

The authors have no conflict of interest or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in the manuscript**.**

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