A PREDATORY ACTIVITY OF *Oecophylla smaragdina* (HYMENOPTERA: FORMICIDAE) ON CITRUS PESTS

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ABSTRACT

Oecophylla smaragdina (weaver ant) is an aggressive predator that is common throughout plantation areas. However, the predatory activity of this ant species on crop pests is not clearly analyzed and reported. Hence, this study was conducted to determine the predatory activity of the weaver ant on citrus plant (Calamansi) at Taman Pertanian Negeri Sekayu Terengganu, Malaysia was done. The weaver ant was found preyed on various species of insect pests on citrus plant during foraging. Our result showed that 90% of the prey items were pests to the Calamansi tree and only 10% are non-pest insects. The highest number of insect pests is under the order of Hemiptera, which dominates about 38% of pest insects, and 52% of the total insect pests are considered as the major pests to citrus plants. In this study, the potential of using *O. smaragdina* as a biocontrol agent on various crop pests is highlighted.

Key words: Weaver ants, natural enemies, predatory behaviour, citrus, and insect pest

ABSTRAK

Oecophylla smaragdina (kerengga) adalah pemangsa agresif yang sering wujud di kawasan ladang. Walau bagaimanapun, aktiviti semut spesies ini sebagai pemangsa pada perosak tanaman belum dianalisis dan dilaporkan dengan jelas. Oleh itu, kajian ini dijalankan untuk menentukan aktiviti pemangsaan kerengga terhadap pokok sitrus (Calamansi) di Taman Pertanian Negeri Sekayu Terengganu, Malaysia. Spesies kerengga didapati merupakan pemangsa bagi pelbagai jenis serangga perosak ke atas tanaman sitrus semasa mencari makanan. Hasil kajian menunjukkan bahawa 90% serangga yang menjadi mangsa adalah spesies perosak terhadap pokok Calamansi, manakala hanya 10% adalah bukan serangga perosak. Jumlah serangga perosak tertinggi didominasi oleh order Hemiptera sebanyak 38% dan 52% dari jumlah serangga perosak dianggap sebagai perosak utama kepada tanaman sitrus. Dalam kajian ini, potensi penggunaan *O. smaragdina* sebagai agen kawalan biologi pada pelbagai perosak tanaman turut dibincangkan.

Kata kunci: Kerengga, musuh semulajadi, tingkah laku pemangsa, sitrus, serangga perosak

INTRODUCTION

Oecophylla smaragdina commonly known as weaver ant has highly aggressive predatory behaviour and far-reaching foraging habits. This behaviour was very helpful as a biological control agent against all major pests of economically important crops (Mele et al. 2002). *Oecophylla smaragdina* has the potential to be a predator for the insect pests in domesticated fruits plantations such as mango, mangosteen, cocoa, langsat and water guava (Kenne et al. 2003). This was further supported by Peng and Christian (2004), who found that weaver ant also has the potential to control the population of mango leafhoppers, thrips, fruit flies, tip borers, scale bugs and mealy bugs. One of the Integrated Pest Management (IPM) methods is by using natural enemies as biocontrol agents such as the application of the weaver ant which is also partly triggered by emerging markets for organic food production (Mele 2008).

In agricultural sites, *O. smaragdina* preyed on various insect pests that caused damage to the fruit plant such as orange, tangerine, lemon, pomelo tree and other fruits (Bharti & Silla 2011). However, less than 70 publications on the use of this predator as a biological control agent in Asia were published (Bharti & Silla 2011). Weaver ants help to control a wide range of insect pests such as *Rhynchocoris humeralis* (Green stink bug), *Taxoptera* sp. (aphid species), *Papilio* sp. (Leaf beading caterpillar), coleopteran species (Inflorescence eaters) and several other pests (Mele et al. 2002) that are known as the main pest of citrus. The Vietnam citrus farmer spent on average half of their money on agrochemicals, compared to those farmers who did not use *Oecophylla* to protect their orchard (Mele & Cuc 2000). A previous study by Lim et al. (2008) proved that *O. smaragdina* was most effective to control or kill the larvae compared to using a chemical insecticide on preventing shoot damage and this weaver ant was effectively controlled *Bactocera jarvis* known as Jarvis's fruit fly in mango production in Australia. This research showed that fruit damage caused by fruit fly reduced to about 0.016% by using weaver ants with soft chemicals compared to insecticide usage (Peng & Christian 2006).

The aggressive behaviour of the weaver ants helps to repel the pest away from flushing shoots which they catch nymphs of the pest for their meat supply, their pheromone can deter insect herbivores and fruit flies (Peng & Reilly 2012). Weaver ants were able to directly catch nymphs of the bug in order to prevent them from feeding on flushing shoots by aggressively chasing the bugs. Studies conducted by Peng and Christian (2005a,b), showed that weaver ants were effective in controlling the fruit-spotting bug on cashew and mango crops. This was further supported by Offenberg et al. (2004) and Adandonon et al. (2009), who found that weaver ant pheromone was effective to deter insect herbivores and fruit flies. A study by Sinzogan et al. (2008) found that the presence of *Oecophylla* on mango plantation area promoted 60% better mango quality in terms of appearance, shelf-life, sweetness and also protected mango from fruit flies. In tropical countries, with the emerging markets of organic food production, the successful application of the weaver ant slightly increased in crop plantation areas as an endemic natural enemy (Mele 2008). In northern Australia, the commercial cashew plantations used weaver ant as a biological control agent (Peng et al. 1997). In Vietnam, the ants *O. smaragdina* and *Dolichoderus thoracicus* (Cocoa black ant) help farmers control pests in citrus and sapodilla (Mele & Chien 2004). Other studies also show that pest damage and densities declined in trees in the presence of ants compared to those without ants across many other crops, including cacao, cashew, mango, and mahogany (Thurman et al. 2019).

In Malaysia, studies on the use of the weaver ants as a biological control on crops were quite rare. To date, only eight publications can be found (Abdullah & Hashim 2010; Exelis 2013; Heffernan 2004; Lim & Kirton 2001; Lim 2007; Lim et al. 2008; Pfeiffer et al. 2008; Pierre & Idris 2013) with the most recent publications focusing on the usage of the weaver ants to control pests of oil palm (Pierre & Idris 2013). Since the predatory activity of this ant on crop pests has not been well-published and explored in Malaysia, we conducted this study to investigate the predatory activity of *O. smaragdina* nesting on the citrus plants, *Citrus microcarpa*. These citrus plants were also known locally as "limau kasturi". In our study sites in Taman Pertanian Negeri Sekayu, Hulu Terengganu, Malaysia these plants' heights are around 1.5 to two metres. Many *O. smaragdina* colonies nest on these plants making it easier for us to study the predatory activity of these ants and record the prey items carried by worker ants as they return to their nests.

MATERIALS AND METHODS

Study Site

The sampling was done at Taman Pertanian Negeri Sekayu, Kuala Berang, Terengganu, Malaysia (4˚5'59" N 102˚55'46" E) (Figure 1). It is located about 70.2 km from Universiti Malaysia Terengganu (UMT). The citrus farm area is approximately 800 m² which consist of about 50 Calamansi lime trees. Taman Pertanian Hutan Negeri Sekayu was chosen as a sampling site because their agriculture site was not exposed to any chemical pesticide.

Figure 1. Sampling site at Taman Pertanian Negeri Sekayu, Terengganu. Inset: a colony of *O. smaragdina* on the Calamansi tree

Preys Collection Method

Calamansi trees that consist of weaver ant's nests (colonies) were tagged. Fifteen trees of Calamansi lime were observed. The foraging trails of the ants were observed from 1000 h until 1700 h. Any ants carrying food (prey items) back to the nest were collected. Both (the weaver ant and the prey item) were put into the killing jar with ethyl acetate used as the killing agent. After that, the samples were brought to the laboratory where the prey items were transferred into a plastic container that contained 70% ethanol for preservation and identification process.

Insect Identification

The prey samples were observed under a dissecting microscope and identified to the lowest taxonomic level according to Schowalter (2016), Gibb and Oseto (2019), and Capinera (2020).

Categorize of Pest and Non-Pest

Pest and non-pest insects of Calamansi were determined based on Schowalter (2016), Capinera (2020) and Badri et al. (2008). Each prey item that was harmful to the citrus tree was considered as a pest (main pest) to citrus while prey items found not to directly affect the citrus were considered as non-pest.

Data Analysis

A Mann-Whitney U-test was used to determine the difference in the number of prey items collected between two categories (pest insects & non-pest insects) using Paleontological statistics software (PAST) version 4.01.

RESULTS

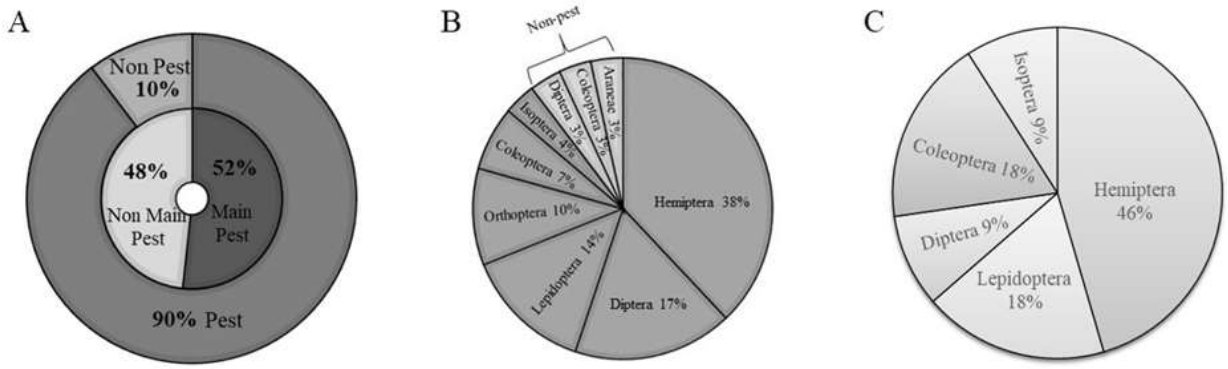
In total, prey items from 29 species of prey items from 21 families and seven insect orders were collected from the foraging workers (Table 1). It was found that most of the prey insects collected by the weaver ants were from the order Hemiptera. A total of 11, six, four, three and one individuals from order Hemiptera, Diptera, Lepidoptera, Coleoptera, Orthoptera, Isoptera and Araneae, respectively. Most of the prey items collected by the ants are considered pests to citrus and other types of crops.

The result of the prey items collected by *O. smaragdina* was further divided into two categories which were either pest and non-pest of citrus (Calamansi). Overall, out of 79 individuals from the 29 species of prey items, 26 species of them were known as pest to citrus while three species where non-pest of citrus. Mann-Whitney test shows that there was a significant difference in the number of pest and non-pest insects preyed by the weaver ants ($U=6.5$, $p=< 0.05$; Figure 2).

Table 1. List of prey items collected by *O. smaragdina*. Some of the prey insects cannot be identified due to incomplete morphology, not enough information of identification key and some of the insects were in the juvenile stage

Order	Family	Species	Common Name	Category of Pest
Hemiptera	Pentatomidae	*Rhynchocoris humeralis*	Green stink bug/lime shield bug	Pest of citrus
		sp. 1	Stink bug/ Shield bug	Pest of citrus
	Aphididae	*Toxoptera aurantii*	Brown citrus aphid	Pest of citrus
		Aphis spiraecola	Green citrus aphid	Pest of citrus
	Coccidae	*Pulvinaria psidii*	Guava scale/ green shield scale	Pest of citrus, guava
	Pseudococcidae	*Rastrococcus iceryoides*	Mango meal bug	Pest of mango, citrus and cotton
	Coreidae	sp. 2	Spiky leaf-footed bug	Pest of citrus, potatoes, pomegranates and vegetables
		Dasynus sp.	True bug	Pest of pepper, coconut and vegetables
		Zicca sp.	True bug	Pest of vegetables and fruit
	Cicadellidae	sp. 3	Leafhopper	Pest of vegetables
	Membracidae	*Gargara* sp.	Treehopper	Pest of cocoa

Lepidoptera	Pyralidae	*Citiripestis sagittiferella*	Citrus fruit borer/ snout moth	Pest of citrus
	Choreutidae	sp. 4	Metalmark moth/ choreuitid moth	Pest of sunflower family, flowering plants
	Erebidae	*Orygia* spp	Tussock moth	Pest of cherry and oak
		Lyclene sp.	Lichen moth	Pest of paddy
Diptera	Dolichopodidae	*Condylostylus* sp.	Asian long legged fly	Non Pest
	Phoridae	sp. 5	Phorid fly	Pest of vegetables and fruit
		Diplonevra sp.	Scuttle flies	Pest of vegetables and fruit
	Muscidae	*Musca domestica*	House flies/ stable flies	Pest of vegetables and fruit
	Tephritidae	sp. 6	Common fruit fly/ peacock flies	Pest of vegetables and fruit
	Ulidiidae	sp. 7	Picture-winged fly	Pest of agriculture
Coleoptera	Curculionidae	sp. 8	Weevils	Pest of agriculture
		sp. 9	True weevil/ snout beetles	Pest of agriculture
	Coccinellidae	*Cryptogomus* sp.	Ladybug	Non Pest
Orthoptera	Gryllidae	*Nisitrus vittatuss*	Common bush cricket	Pest of agriculture
		Acheta domestica	House cricket	Pest of agriculture
	Tetrigidae	sp. 10	Pygmy grasshopper/ groundhopper	Pest of agriculture
Isoptera	Rhinotermitidae	*Coptotermes* sp.	Wood feeding termites	Pest of wood
Araneae	Ctenidae	*Ctenus* sp.	Wandering spider	Non Pest



Figures 2A-C. Percentage of the total number of insect pests of citrus collected in Taman Pertanian Negeri Sekayu

Ninety percent from the species collected were pest of citrus, while 10% were non-pest of citrus. About 52% of the pest were classified as the main pest, and the rest were minor pest (Figure 2A). Detail percentage of prey items by order that is considered as pest of citrus collected by the weaver ants. The 3% of non-pest insects were from Order of Diptera, Coleoptera and Araneae, respectively (Figure 2B). The percentage by order of all prey items

(juvenile and adult forms) including pest and non-pests of citrus that were caught by *O. smaragdina* workers during foraging activity and were brought back to their nest.

This study discovers that 90% of the prey items collected by the weaver ants were pests of citrus, while 10% of the prey items were non-pest of citrus. Moreover, 52% of the overall citrus pests were considered as the main pest (major pests) of citrus plants and 48% were considered as minor pests to citrus (Figure 2A). Most of the prey items collected by the weaver ants were pests of citrus indicating that the presence of these ants on the citrus plants give huge benefit to controlling pests of this crop. Further analysis revealed that there were 3% of prey items collected by the ants which are under the order of Diptera, Coleoptera and Araneae were not considered as pests of citrus, whereas the highest number of preys under order Hemiptera (38%) were considered as a pest of citrus (Figure 2B). The main pest of citrus can be categorized as a pest that brings more harm and damage to citrus than the minor pest, which does not play a role as the leading cause of damage to the citrus crop. From our observation, the main pests were easy to spot and identify when they are frequently found on host plants, and their presence leaves a detrimental effect on host plants.

Most of the prey items collected by weaver ants were hemipteran species which is 46% (*Rhynchocoris humeralis*: Nymph & adults, *Pulvinaria psidii*: Adult, *Dasynus* sp.: Adult, Spiky leaf-footed bug: Nymph). The number of this species individuals were higher compared to the other order of insects (Figure 2C). Most of the insects in this order preyed by the weaver ants were also known as the main pest of citrus. There were three types of pests' species that were considered as the main pests of citrus plants caught by the weaver ants namely *R. humeralis* (Green stink bug), *T. aurantii* (Brown citrus aphid) and *A. spiraecola* (Green citrus aphid) (Table 1).

Weaver ant also preyed on the larvae and nymphs of Lepidoptera and Coleoptera (18%, respectively). Nine percent of insect pests under Diptera (nymph & adult) and Isoptera (adult) were also caught by the weaver ants during their foraging activity (Figure 2C). However, none of the orthopterans was caught by weaver ants although these insects were also spotted on calamansi trees during the 35 hours of observation period (1000 to 1700 hours for 5 days).

DISCUSSION

Oecophylla smaragdina has been used as a successful predator on several agricultural plants such as oil palm (Pierre & Azarae 2012), mango orchard, and timber (Lim et al. 2008). Our study on the predatory activity of the weaver ants on calamansi trees found that the most dominant species caught by weaver ants was from order Hemiptera. A similar finding was also reported by Kamel (2010) in which they found that the hemipteran species was the insect pests that were abundant on citrus plants. The hemipteran species (true bugs) generally have their own distinctive character which has piercing-sucking mouthparts and is mostly known as a plant feeder or predacious (McGavin 1997) . There were only two types of species which were *R. humeralis* (family Pentatomidae), *Taxoptera citricida* (Black citrus aphid) and *A. spiraecola* (nymph & adult: family Aphididae) known as the main pest insects on the citrus plant that were caught by *O. smaragdina* during their foraging activity while the insects present on the citrus plants. However, weaver ants have a special mutualism relationship with aphids where aphids produce honeydew to the weaver ant, and this ant can be functional to protect plant species that host or provide food resources (trophobiont honeydew and plant nectar) to the ant (Lim 2007). This relationship helps to reduce other species of pests but does not help weaver ants to control aphid populations and prevent these species from damaging citrus crops.

Three species of insects from family Coccidae, Aphididae and Pseudococcidae have possibly been a host plant (trophobiont insect) for *O. smaragdina* (Lim et al. 2008). Trophobiont insect is the type of insect that can give a benefit to the ants, which creates a mutual interaction (both sides get a benefit) (de Freitas & Rossi 2015). All of the trophobiont insects are from order Hemiptera and frequently recorded in this experiment such as *Coccus* sp. (family Coccidae), *T. citricida* (family Aphididae) and *R. iceryoides* (Mango mealybug; family Pseudococcidae) were known as the pest insect on the citrus plant (Badri et al. 2008). All of the hemipteran trophobionts were classified as a pest on citrus because they have a high tendency to bring or transmit pathogens and diseases for the host plant, but they really give benefit for the ant because they produced honeydew used by ants as a food source (Davidson et al. 2003). The typical visual symptoms for the infected trees by insect pests can be confusing, and these symptoms might attribute to nutrient deficiency or other physiological disorders of the plant (Leong et al. 2020).

This study figures out that certain prey items collected by the weaver ants were not pest insects to citrus, but are pollinator agents for the citrus plants. According to Tsuji et al. (2004), the *Oecophylla* was related to the decreasing number of pollinator visitors due to being attacked by the weaver ants and resulting in a low number of fruit production. The main pollinator for citrus plants in Southeast Asia was *Apis mellifera* (Honey bee; Hymenoptera: Apidae) (Bhatia 1995).

The results from this study also found that *O. smaragdina* collects tussock moths (*Orygia* spp., Lepidoptera: Erebidae) which were minor pest of citrus but known as insect pest on jackfruits, fig, mango and banyan, there were most abundant during the rainy season (Muniappan 2012). The ants also preyed on *Coccus* sp. (Hemiptera: Coccidae) which is mostly distributed in Southeast Asia and is known as the main pest of *Manilkara achras* (Sapodilla) and also a pest of jackfruits, durian, guava and orange (Badri et al. 2008). Thus, this shows that the weaver ants also forage on occasional pests of citrus plants other than the main pest. This is not quite surprising because the citrus plantation area in Sekayu was surrounded by various crops. Hence, many pests can be found around the area and their foraging sites may overlap. Overall, our study showed that based on the number of insect pests that were preyed upon by the weaver ants, this species has a high possibility to be used as a biological control agent in various types of crops.

CONCLUSION

Based on the number of insect pests that were preyed upon the weaver ants has a high potential to be used as a biological control agent in various types of crops. Thus, this study is important to understand the predatory behaviour of weaver ants during their foraging activity. Besides that, this study will help to understand the predatory behaviour of the weaver ant to control pest insects on crops and enhance knowledge especially on the specific predatory activity of the weaver ants as a biocontrol agent or natural enemy. However, because this ant could also attack pollinators, hence an efficient method should be developed to introduce this ant in crop plantations as biological control agents and at the same time protect the pollinator agents from being attacked by this ant.

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