INVESTIGATING ASIAN WEAVER ANTS (*Oecophylla smaragdina*) AS BIOLOGICAL CONTROL AGENTS OF BAGWORM OUTBREAKS IN OIL PALM PLANTATION

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INSTITUTE FOR TROPICAL BIOLOGY AND CONSERVATION
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DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, equations, summaries, and references, which have been duly acknowledged.

21 November 2022

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ABSTRACT

Oil palm plantation is susceptible to lepidopteran pests, particularly bagworm. To cope with bagworm outbreaks, integrated pest management programs, in which insecticide use is minimised, are widely implemented to support sustainable oil palm production. However, there remain opportunities for improvement and innovation. This study aims to investigate the role of the Asian Weaver Ant (*Oecophylla smaragdina*) as a predator of bagworm in oil palm plantations using monitoring censuses, experimental colony introductions in the field, and feeding trials of ant colonies in captivity. The study was conducted in plantations experiencing outbreaks of bagworm pests in Sumatra, Indonesia. Herbivory surveys in outbreak and non-outbreak areas indicated that the abundance of weaver ant workers was positively influenced by availability of brood nest, the presence of colonies, palm canopy cover, and the age of the palms. The proportion of palms that were colonized by the weaver ant colonies increased with palm age and were higher in the areas without insecticide intervention. In a colony introduction experiment, colonies in palms with insecticide had a 273% higher risk mortality (Cox proportional hazards model, hazard ratio=3.735, $p<0.001$) than untreated palms. Insecticide treatment significantly reduced weaver ant abundance (t-test, t- value=-1.990, $p=0.049$), although there was no difference in leaf damage between palms with and without ant colonies. In a mass-rearing experiment, weaver ant colonies were propagated using four commercial protein food sources: tuna, mackerel, cricket and mealworm. Colonies fed tuna had smaller colonies. Colonies fed with cricket showed higher levels of aggression that those fed with mackerel. This study shows that the occurrence of weaver ants in plantations is influenced by the characteristics of the ant colonies, some environmental parameters and the use of systemic insecticides. To maintain weaver ant colonies in captivity, mass rearing method can be successfully used. These results of this study are likely to drive future improvement and innovation of IPM programmes in oil palm plantations.

ABSTRAK

PENGAMATAN SEMUT KERENGGA (Oecophylla smaragdina) SEBAGAI AGEN KAWALAN BIOLOGI WABAK ULAT BUNGKUS DI LADANG KELAPA SAWIT

Ladang kelapa sawit adalah sensitif kepada serangga perosak, terutamanya larva Lepidoptera. Untuk menangani penyebaran wabak ini, program pengurusan serangga perosak bersepadu di mana penggunaan racun serangga adalah minimum dilaksanakan secara meluas untuk menyokong kelestarian produksi kelapa sawit yang mampan. Walaubagaimanapun, masih terdapat ruang untuk penambahbaikan dan inovasi dalam bidang ini. Kajian ini bertujuan untuk menyiasat peranan Oecophylla smaragdina *sebagai pemangsa ulat bungkus di ladang kelapa sawit menggunakan bancian pencerapan, eksperimen pengenalan koloni di ladang, dan eksperimen diet koloni semut dalam kurungan. Kajian ini dijalankan di ladang yang mempunyai masalah serius wabak ulat bungkus di Sumatera, Indonesia. Tinjauan herbivori di kawasan wabak dan bukan wabak menunjukkan bahawa adanya sarang ratu, kehadiran koloni, cakupan kanopi sawit, dan umur pokok sawit mempunyai pengaruh positif terhadap kelimpahan semut kerengga pekerja. Perkadaran pokok sawit yang diduduki oleh koloni semut kerengga meningkat dengan umur pokok sawit dan lebih tinggi di kawasan tanpa rawatan racun serangga. Dalam eksperimen pengenalan koloni, pokok sawit dengan rawatan racun serangga mempunyai risiko kadar kematian 273% lebih tinggi (nisbah risiko=3.735, p<0.001) berbanding pokok sawith yang tidak dirawat. Rawatan racun serangga mempunyai kesan negatif yang signifikan terhadap pengurangan kelimpahan semut kerengga (nilai-t=-1.990, p=0.049). Walaubagaimanapun, tidak terdapat perbezaan signifikan kerosakan daun antara pokok sawit yang mempunyai koloni semut dan tanpa koloni semut. Dalam eksperimen kesesuaian diet, koloni semut kerengga dibiakkan dengan empat protein komersial: ikan tuna, ikan tenggiri, cengkerik dan larva kumbang* (mealworm)*. Koloni yang diberikan tuna mempunyai saiz koloni yang lebih kecil. Kadar keagresifan semut berbeza dengan ketara antara koloni yang diberi makan cengkerik dan ikan tenggiri. Hasil kajian ini menunjukkan bahawa kehadiran semut kerengga di ladang dipengaruhi oleh beberapa ciri koloni semut, parameter persekitaran, dan penggunaan racun serangga sistemik. Untuk mengekalkan koloni semut kerengga dalam kurungan, kaedah penternakan boleh menjadi alternatif yang baik. Hasil kajian ini boleh dicadangkan sebagai peluang penambahbaikan dan inovasi untuk program pengurusan perosak bersepadu di ladang kelapa sawit.*

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LIST OF SYMBOLS/ UNITS

am	- ante meridiem
CI	- confidence interval
cm	- centimetre
cm^2	- centimetre square
°C	- degree Celcius
d.f	- degree of freedom
H_0	- null hypothesis
H_1	- alternative hypothesis
mm	- millimetre
m^2	- meter square
nm	- nanometre
pm	- post meridiem
R^2	- R square
%	- percentage
>	- greater than
<	- less than
~	- tilde

LIST OF ABBREVIATIONS

AIC	-	Akaike Information Criterion
BEFTA	-	Biodiversity and Ecosystem Function in Tropical Agriculture
CPO	-	Crude Palm Oil
GAR	-	Golden Agri Resources
GDP	-	Gross Domestic Product
GLM	-	Generalizing Linear Model
GLMM	-	Generalizing Linear Mixed Model
GV	-	granulovirus
IOPRI	-	Indonesia Oil Palm Research Institute
IPM	-	Integrated Pest Management
LEC	-	Leaf-Eating Caterpillar
LMM	-	Linear Mixed Model
MPOB	-	Malaysia Palm Oil Board
NPV	-	nucleopolyhedrovirus
p	-	p-value
RNA	-	Ribonuclease Acid
RSPO	-	Roundtable for Sustainable Palm Oil
SEM	-	Structural Equation Modelling
SMARTRI	-	Sinar Mas Agro Resources and Technology Research Institute
SOP	-	Standard Operational Procedure
t	-	t-student value
UMS	-	University Malaysia Sabah

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CHAPTER 1

INTRODUCTION

1.1 Background

The total demand for food by the world's growing population has more than doubled since the 2000s, with demand for fats playing a significant role. The high demand for vegetable oils is likely to be primarily satisfied by palm oil rather than other vegetable oils, with global demand for vegetable oils expected to reach 307 metric tonnes in 2050 (Agri-Resources, 2018). Moreover, oil palm has the highest oil yields of all oil producing crops of 3.8 tonnes per hectare globally, with the lowest production cost (Rival & Levang, 2014). Oil palm produces 38% of all vegetable oil on less than 10% of the land allocated to growing oil crops. High yields and low-cost of production means that oil palm is a promising agribusiness in the future to meet world vegetable oil demand.

With large cultivated areas and intensive production, Indonesia and Malaysia are the two biggest palm oil producers in the world. The share of oil palm products in Malaysia is estimated at 2.7% of Malaysia's GDP in 2020 (Hirshmann, 2020). Moreover, in Indonesia, palm oil products contribute 3% to the country's GDP (Badan Pusat Statistik, 2020), while national crude palm oil (CPO) output comprises over 58% of total global palm oil production.

The expansion of oil palm in the future is likely to be limited by growing requirements (such as climate, soil, and topography (Pirker *et al.*, 2016)), palm oil prices, biofuel development policy (Rival & Levang, 2014), and increasingly importantly, environmental issues. The industry must adapt and answer environmental challenges with sustainability being a primary concern for consumers. Multiple organisations, both local and international, have provided a platform to endorse sustainability schemes for all oil palm stakeholders, giving greater transparency in the practice of sustainable management strategies. Consequently, it is hoped that oil palm production rates can remain high with reduced impact on the environment through use of sustainable production practices.

1.2 Problem Statement

As a monoculture ecosystem, oil palm plantations can be vulnerable to pests and catastrophic outbreaks because they have lower species diversity than forest ecosystems (Fitzherbert *et al.*, 2008). The complexity of the food web, especially in terms of prey-predator relationships in plantations, is also reduced; consequently, palms can be prone to pest attack.

Nettle caterpillar, slug caterpillar and bagworm are commonly found in oil palm as leaf defoliators. They can be found in immature and mature oil palms and sometimes cause severe damage across large planting areas. Consequently, they can cause leaf loss as high as 50%, causing the yield to be reduced by up to 40% in the second year after infestation on 8-year-old palms (Corley & Tinker, 2016). The effects of leaf-eating caterpillars on yield will depend on the extent of defoliation, unless management measures are taken.

Often insecticide is the ultimate strategy used to control caterpillar outbreaks. However, improper use of insecticide can cause other problems (Siti Ramlah *et al.*, 2011), like the resurgence of secondary pests, the disappearance of non-target organisms, and the long-term persistence of insecticide residue in the environment (Wood & Norman, 2019).

Bagworm outbreaks occur frequently. Instead of focusing on finding alternative insecticides to control bagworm, a better approach is to find another environmentally friendly control such as exploring biological control agents. This is in line with the Integrated Pest Management (IPM) strategies, which envisage various ecologically-friendly tactics for efficient pest control, with insecticides being used on when absolutely needed, if justified both economically and ecologically (Vetek *et al.*, 2017).

1.3 Justification

There are some insects or insect communities in oil palm plantations that are potentially useful as biological control agents for bagworm pest. These act either as predators or parasitoids.

Several species of Hymenoptera are commonly found as parasitoids of bagworm pest species, with parasitism rates in the range 18-70% (Sankaran & Syed, 1972). Hemiptera and Coleoptera can act as predators of bagworm. The use of parasitoids and predators for biological control of bagworm appears to require additional cost and great efforts (Wood & Norman, 2019). The parasitoid community is vulnerable to disturbance from hyperparasitoids and other external factors. In addition, predators such as *Sycanus dichotomus*, will only increase in numbers once an outbreak has already occurred. These biological control agents are often encouraged by conserving beneficial plants as nectar sources inside plantations.

The most interesting function of predatory ants in agroecosystems is their role as predators of caterpillar pests. As a generalist predator, the weaver ant *Oecophylla* has been reported as an effective biocontrol agent against several pests at field and landscape scale (Furlong & Zalucki, 2010) in cacao, cashew, mango, coconut, and mahogany trees (Thurman *et al*., 2019). In addition, Asian weaver ants have positively impacted agroecosystems, particularly in terms of replacing insecticide use (Peng *et al*., 2014) and compatibility with bioinsecticide use (Coulibaly *et al*., 2019) which can potentially minimise use of conventional insecticides.

The study of the potential of weaver ants as biological control agents in oil palm plantations is still limited. In a recent study by Pierre and Idris (2013), this ant has been directly considered as a biocontrol agent in oil palm, with *O. smaragdina* predating bagworm pests and no reporting of any negative effects of weaver ants on palm weevil pollinators in oil palm flowers. Furthermore, co-occurrence with other ant species, *Oecophylla* ant can protect palm with leaf-miner beetle attack (Dejean *et al*., 1997).

The role of the Asian weaver ant (*Oecophylla smaragdina*) as a biological control agent for bagworm pests in oil palm plantations has not been fully considered in terms of IPM strategies. Research on oil palm pest control is needed to continue in order to find, propose, and implement alternative strategies for biological control agents. The Asian weaver ant *O. smaragdina* should be investigated as a potential biocontrol agent in IPM programmes, as this species has already achieved many other successes in controlling pests in orchards and other agricultural systems.

The possibility of using weaver ants as part of IPM strategies should be investigated because of increasing interest in sustainable management in the oil palm industry, especially in terms of using biological control agent and reducing insecticide intervention to control bagworm.

1.4 Significance of the Study

Variation in the abundance of weaver ants spatially and temporally is likely to be driven by both biotic and abiotic factors (M. J Way, 1954; Vanderplank, 1960). These can affect the ability of the weaver ant population to control bagworm outbreaks.

First, this study will use an observational census approach to assess the density of weaver ant populations in areas with and without bagworm infestations. This will provide information on the correlation between weaver ant abundance, bagworm population, insecticide intervention effects, and palm-intrinsic factors.

It is possible to increase weaver ant populations in agricultural systems such as mango and cashew through additional colony transplants (Peng, 2015; Peng *et al.*, 2014), and this is investigated here in oil palm. The study will use weaver ant colony introduction as an experimental treatment. This is a novel proposed method for augmenting weaver ant populations and provides a potential path to integrate them into IPM programs in oil palm plantations. In addition, it is being investigated whether systemic insecticide and weaver ants can be used simultaneously to control bagworm outbreaks. This is important to know because there is currently no information on how sensitive weaver ants are to systemic insecticide delivered by trunk injection.

In an outbreak situation, a generalist predator such as a weaver ant is likely to increase both in terms of colony density and abundance of workers as they continue to find prey. Consequently, there is a possibility of reducing the bagworm population by boosting the predator population through mass-rearing (Wood & Norman, 2019). In addition, increasing weaver ant colony densities through mass-rearing also increases the availability of weaver ant colonies when they are scarce in the field. The mass-rearing of weaver ants is common practice, for example, in Indonesia for bird feed purposes (Prayoga, 2015) and similarly in Thailand, where the ants are eaten as a delicacy, used as bird feed and taken as traditional medicine (Offenberg & Wiwatwitaya, 2010). This study also investigates whether *O. smaragdina* is suitable for propagation for biological control in terms of its growth ability and aggressive behaviour.

With these activities taken together, this research will be an integrated study to investigate the predatory role of Asian weaver ant against bagworm pest in oil palm plantations. In addition, this work can serve as a stimulus to oil palm industry and its stakeholders to promote and conserve the occurrence of Asian weaver ant in oil palm landscapes.

1.5 Research Objectives

The objectives of this study are

1. To explore the potential of Asian-weaver ants (*Oecophylla smaragdina)* as a biological control agent for bagworm pests in oil palm plantations and the factors influencing their abundance.

2. To test the method of introducing colonies of Asian weaver ant for bagworm control as a complementary strategy in the programme IPM.

3. To investigate the effects of multiple commercial protein feeds on colony size and aggressiveness of *O. smaragdina* in mass rearing scale.