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Research

Insects Compositions at Different Growing Phases of The Sarawak Indigenous Eggplant, Terung Asam (*Solanum lasiocarpum* Dunal.) with The First Report of A Ladybug Species, *Henosepilachna kaszabi* (Coleoptera: Coccinellidae) As Major Foliage Pest

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ABSTRACT

Solanum lasiocarpum (Solanaceae), commonly known as Terung Asam, is an indigenous crop in Sarawak, Borneo. The *S. lasiocarpum* is a renowned crop and is significant to the local and smallholder farmers for their household income. Study of insects associated with this crop is currently limited and lacking, despite their importance for Sarawak's agronomy. Hence, this study aimed to determine the associated insect species with *S. lasiocarpum* throughout the plant growth, namely, vegetative, flowering, and fruiting phases. *Henosepilachna kaszabi* (Coccinellidae) and mealybug Pseudococcidae were recorded as primary pests, while *Anoplolepis gracilipes* (Formicidae) and *Polyrhachis* sp. (Formicidae) as indirect pests for flowering and fruiting phases. Larvae and adults of *H. kaszabi* were sighted infesting leaves, stems, and roots, while Pseudococcidae congregated and infested the stems of *S. lasiocarpum*. Other visiting insects for *S. lasiocarpum* were also listed in this study. This study provides preliminary information regarding the insect pests of *S. lasiocarpum* for future effective pest management on this crop.

Key words: Beneficial insects, insect pests, Integrated Pest Management, Sarawak, *Solanum lasiocarpum*, visiting insect

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INTRODUCTION

Solanum lasiocarpum Dunal [synonym Solanum ferox var. lasiocarpum (Dunal) Miq.] known as Terung Asam, Terung Dayak (Dayak Brinjal), and Indian Nightshade is a species in the Solanaceae family. This species is known to originate from Southeast Asia and South Asia (Voon & Kueh, 1999) and was registered under Geographical Indications (GI) certification in 2011 as Terung Asam Sarawak (GI No. GI2010-00002). The registration was to ensure its authenticity and significant value protection. This crop is economically valuable for smallholder farmers as the yield is 16,000 fruits per harvest with a market value of Terung Asam is ranges depending on the grades from RM6.00 to RM10.00 per kg. This crop also has a high demand in Brunei (Umar, 2013).

The height of the plant ranges from 100-250 cm, and it can grow in a perpendicular direction (Voon & Kueh, 1999). The branches spread with hairy, thorny, and woody stems, sometimes with purple-tinged prickly stalks (Shariah *et al.*, 2013). The leaves are large and green, with alternate and broadly triangular lobes on each side (Lim *et al.*, 2013). It took 132-141 days to harvest Terung Asam from the transplanting phase, where the harvest period is about 26 - 44 days (Umar, 2013). A Terung Asam plant can produce fresh fruit of 2.6 kg/plant with a yield of 10.4 fruits/plant, and a hectare of Terung Asam can yield 16-26 mt/ha (Umar, 2013). The fruit has a uniform oval shape with reddish-yellow, and the flesh has a thickness of 14.8 mm. The pH value of the fruit is 4, and the acidity is 0.64%. It is commonly used in many delicacies and produced as sauce, juice, chips, jam, cake, and many more (Umar, 2013).

Most of the previous studies were on agronomy, phytochemicals, nutrient composition, downstream application, and postharvest management of the crops (Razili *et al*., 2013; Shariah *et al*., 2013; Rahman *et al*., 2019). To date, there are no records of insects associated with the *S. lasiocarpum* due to limited study for pests and beneficial insects for this indigenous species. A few pest species reported to be infesting *Solanum* sp. such as fruit and shoot borer *Leucinodes orbonalis* (Lepidoptera: Crambidae), fruit fly *Bactrocera latifr*ons (Diptera: Tephritidae) (McDougall *et al*., 2013), ladybug beetle *Epilachna indica* (Coleoptera: Coccinellidae) (Fauziah & Faizah, 2009) and whitefly *Bemisia tabaci* (Homoptera: Aleyrodidae) (Zaini *et al*., 2013). Previous studies have also recorded beneficial insects for Solanum sp. for instance, predator *Macrolophus caliginosus* (Heteroptera: Miridae) (Rasdi *et al*., 2012).

The lack of study on insects associated specifically with *S. lasiocarpum* carries a gap in the information on insect pests and beneficial insects for this crop. Not knowing the identity of the insect pests can bring wrong assessment in the pest management for *S. lasiocarpum*. Therefore, this study aimed to determine the associated insects with *S. lasiocarpum* or Terung Asam throughout the plant phases (vegetative, flowering, and fruiting).

MATERIALS AND METHODS

Cultivation of *Solanum lasiocarpum*

A total of 20 seeds of *Solanum lasiocarpum* were planted in a row with 1 m and 1.5 m spacing within and between rows, respectively. The seeds were germinated in the polybag with cocopeat before being transplanted on the raised beds. The cultivation site was at Field 2, Taman Pertanian Universiti, Universiti Putra Malaysia Bintulu Sarawak Campus (3° 12’ 26.244” N, 113° 4’ 56.604” E). The site is adjacent to the small plots of mustard, groundnuts, spinach, water spinach, and maize. There are fragmented secondary and rehabilitated forests near the areas.

The silvery shine layers were used for moisture retention and weed control. Watering was done twice daily, and fertilization was done once a month using 5 g of NPK fertilizer for each plant. NPK fertilizer with a ratio of 15:15:15 and 12:12:17:2+TE was used for vegetative flowering, and fruiting stages respectively by following the recommended dose. Manual weeding was conducted twice per week to clean the area between the rows and plant maintenance. The planting period was estimated at around 132-141 days from transplanting to harvesting (Umar, 2013).

Insect sampling and damages screening

Two methods of sampling were utilized, which were active and passive sampling. The active samplings were conducted using sweep nets and manually hand-picked the specimens at five randomly picked spots, with a 1m distance between each spot. Active samplings were done three times a week for one hour each in the morning (8.00-9.00 am) and late evening (5.00-6.00 pm). The sampling efforts were replicated three times, and the collected insect samples were stored in 70% ethanol before being brought to the laboratory for further analysis.

Passive sampling was conducted by using yellow pan traps and Malaise traps. The yellow pan traps were filled with a mixture of water and detergent at a ratio of 99:1. The set-up period for yellow pan traps was similar to active sampling. The function of the detergent is to reduce the water surface tension and prevent insects from escaping. The Malaise trap was set up for a month with the collection jar filled with 70% ethanol.

Damage screening was also conducted in between the active samplings. The infestations were monitored thoroughly from roots, branches, small branches, leaves, fruits, flowers, and shoots of the plants. The damages were surveyed, documented, and photographed for future reference.

Morphological identification

All collected insect samples were sorted into morphospecies before the identification process was carried out. The identification process was aided by Stereo Microscopes Leica EZ4 and Leica Zoom 2000. All of the sample identification was following Triplehorn and Johnson (2005), Thyssen (2009), and McDougall *et al*. (2013). The identified specimens were photographed by a digital camera and stored in Laboratory Entomology, Department of Crop Science, Universiti Putra Malaysia Bintulu Sarawak Campus for repository and future reference.

Diversity data analysis

Diversity indices such as the Shannon Diversity Index (H’), Margalef’s Index (R’), and Evenness Index (E’) of the collected samples were calculated using Paleontological Statistic Software (PAST) version 4.03.

RESULTS

Species abundance and composition

A total of 242 individual insect samples with 30 morphospecies and 22 families were collected in this study (Table 1). Seven insect orders collected are Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera, Mantodea, and Orthoptera (Figure 1). Diptera order has the highest number of individuals collected (76 individuals= 31.4%), while Hymenoptera has the highest number of morphospecies collected (10 morphospecies= 33.3%). *Henosepilachna kaszabi* Bielawski & Fürsch (1960) holds the highest number of individuals collected (60 individuals = 24.7%). The diversity indices of all the insect species were calculated using the Shannon Diversity Index (H'=2.62), Margalef's Index (R= 5.283), and Evenness Index (E= 0.4578).

Insect species with various growth phases in *Solanum lasiocarpum* cultivation

The growing phases of *S. lasiocarpum* can be divided into vegetative, flowering, and fruiting (Figure 2). The insects collected from each growth phase are different species, which may imply the ecological function of each insect species. Table 1 shows the insect morphospecies collected during all three growth phases of the *S. lasiocarpum*. Twenty-six (87%) and 17 morphospecies (57%) were recorded during flowering and fruiting periods of *S. lasiocarpum*, respectively. *Amblypsilopus* sp. 1 and *Amblypsilopus* sp. 2 were recorded in all *S. lasiocarpum* growth phases.

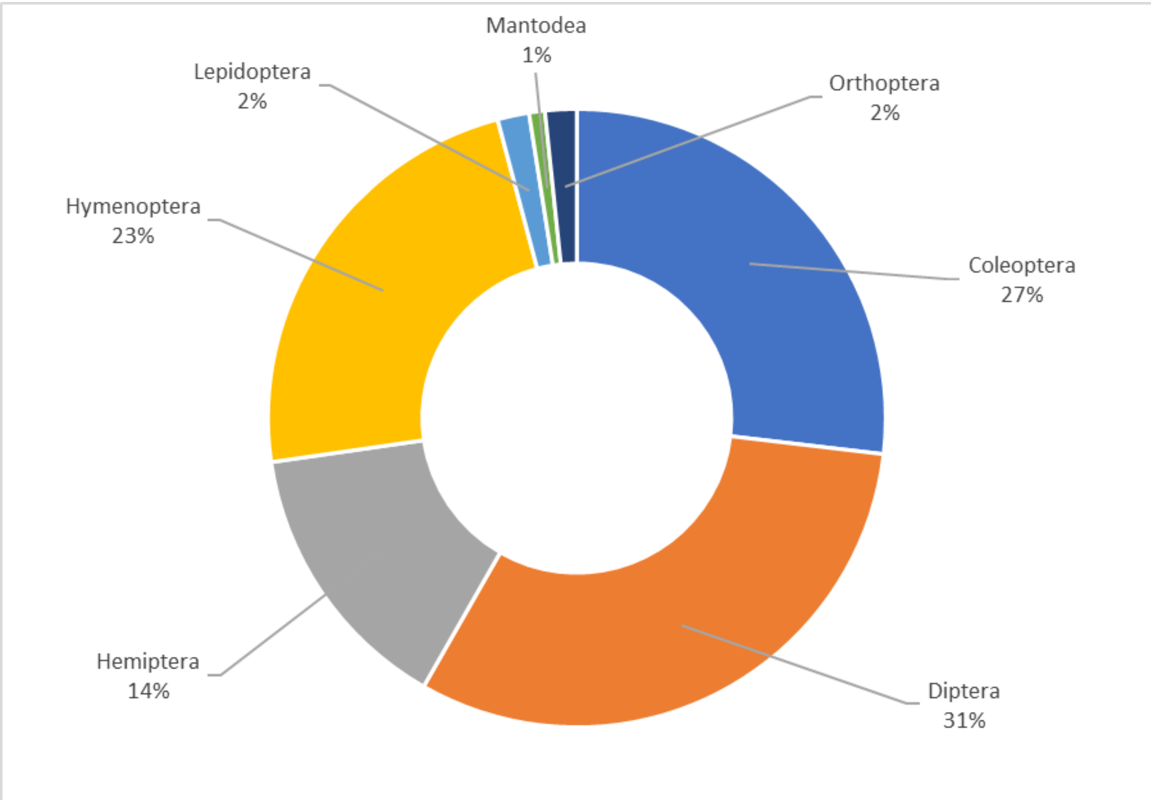

Fig. 1. Composition of insect orders collected during *Solanum lasiocarpum* cultivation.

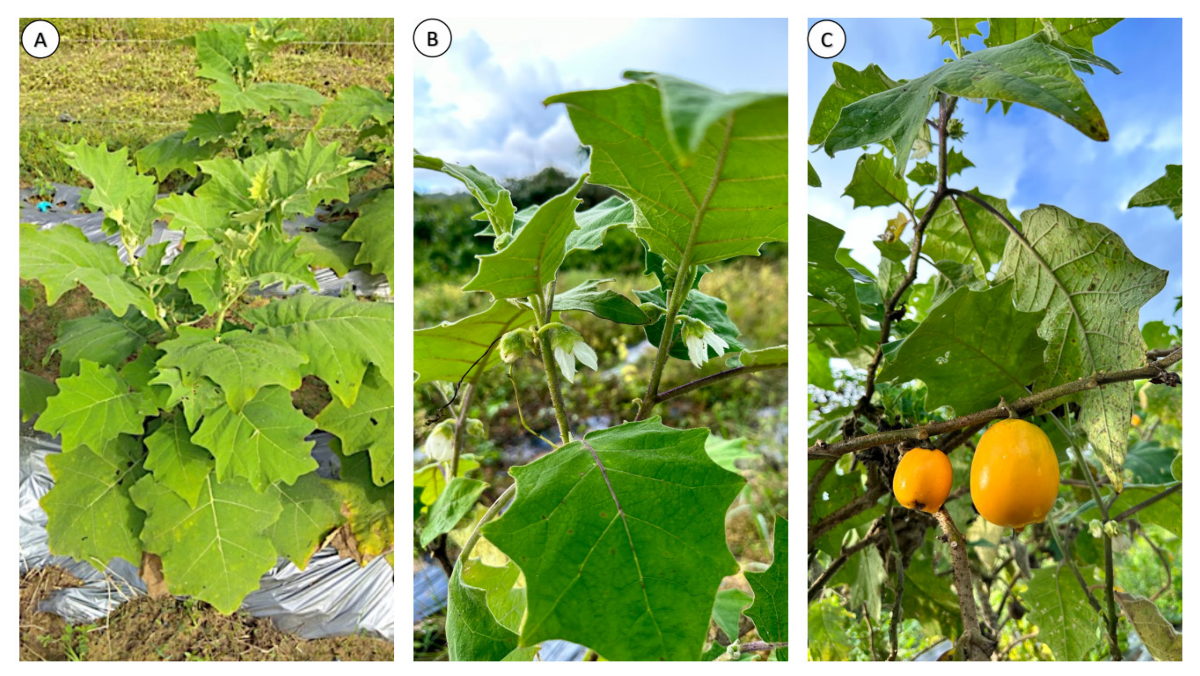

Fig. 2. (A) Vegetative, (B) Flowering, and (C) Fruiting phases of *Solanum lasiocarpum*.

Table 1. List of insects associated with three growing phases of *Solanum lasiocarpum*

Insect Orders and Species	*S. lasiocarpum* Growing Phase			No. of individuals
	V	Fl	Fr	
Coleoptera				
Henosepilachna kaszabi		√	√	60
Cheilomenes sexmaculata		√	√	4
Chrysomelidae		√		1
Diptera				
Calliphoridae	√			1
Conopidae		√		1
Amblypsilopus sp. 1	√	√	√	16
Amblypsilopus sp. 2	√	√	√	30
Musca domestica		√	√	15
Eristalinus sp.		√	√	10
Syrphidae		√		3
Hemiptera				
Alydidae			√	3
Cercopidae		√		1
Pseudococcidae		√	√	30
Reduviidae			√	1
Hymenoptera				
Apidae		√		1
Braunsapis sp.		√		9
Polyrhachis sp.	√	√		8
Anoplolepis gracilipes	√	√	√	19
Formicidae	√	√		4
Ichneumoninae		√		1
Rogadinae		√		1

continued...

Table 1 continued...

Vespa affinis		√	√	6
Vespidae 1		√	√	4
Vespidae 2		√	√	3
Lepidoptera				
Psychidae		√		4
Mantodea				
Mantidae 1		√	√	1
Mantidae 2		√	√	1
Orthoptera				
Acrididae		√	√	2
Tettigonidae		√	√	1
Tetrigidae	√			1

*V= vegetative phase, Fl= flowering phase, Fr= fruiting phase

Insect monitoring and damage screening

Two primary pests monitored in this study were *Henosepilachna kaszabi* and mealybug Pseudococcidae. Both insects were sighted infesting *S. lasiocarpum* from flowering to fruiting phases at the field. The larvae and adults of *H. kaszabi* infest on *S. lasiocarpum* leaves from the softer part into the midrib (Figure 3). Larvae of *H. kaszabi* were also found boring and causing holes at the root and stem of the plant. Pseudococcidae mealybugs were found infesting and congregating in the stalk of the *S. lasiocarpum* (Figure 4).

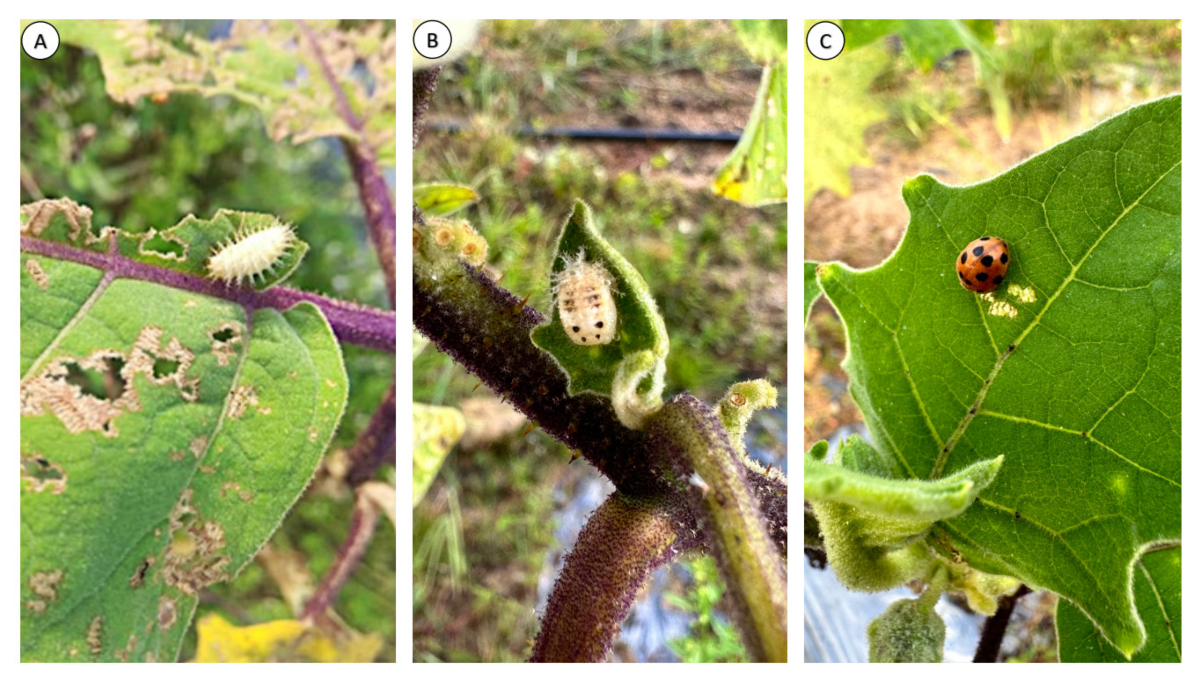

Fig. 3. (A) Larva, (B) Pupa, and (C) Adult stages of *Henosepilachna kaszabi* infesting the leaves of *Solanum lasiocarpum*.

Fig. 4. Pseudococcidae mealybug infesting and congregating inside the holes of the *Solanum lasiocarpum* stem, and its mutualist Formicidae ant.

DISCUSSION

Abundance and composition of insect orders

In this study, we found seven insect orders associated with the *Solanum lasiocarpum*. Diptera order holds the highest abundance at 31.4%, Coleoptera at 26.9%, and Hymenoptera at 23.1%. Previous studies also reported the occurrence of Diptera, Hymenoptera, and Coleoptera associated with *Solanum* species (Latif *et al*., 2009; Bodlah & Waqar, 2013). In Bodlah and Waqar (2013), nine hymenopteran species and three dipteran species were identified as pollinators for *S. melongena*. Ladybug *Epilachna* sp. was reported as a significant pest *for S. melongena* with a frequency of 25.8% in Bangladesh (Latif *et al*., 2009). The remaining insect orders collected in the field were Hemiptera with an abundance of 14.5%, Lepidoptera (1.7%), Orthoptera (1.7%), and Mantodea (0.8%).

The composition of insects recorded at the *S. lasiocarpum* cultivation site was influenced by the sampling method. In this study, four types of sampling methods were utilized, were Malaise trap, sweep net, yellow pan trap, and hand-picked. It resulted in collecting flying and crop-dwelling insects. Compared to a study by Dar *et al.* (2015), a total of ten insect orders were collected at the brinjal crop in Kashmir when using visual, sweep net, pitfall, and pheromone traps that can entrap flying, crop-dwelling, and soil-dwelling insects.

Primary and indirect pests of *Solanum lasiocarpum*

Two monitored insect species were deduced to be the primary pests for *S. lasiocarpum Henosepilachna kaszabi* and mealybug Pseudococcidae. Both insect species were found to be infesting *S. lasiocarpum* during the flowering and fruiting phases of the crop. The feeding of *H. kaszabi* causes consequential damage to the leaves and affects the productivity of the crop. The larvae and adults of *H. kaszabi* were found infesting the leaves, boring and causing holes at the root and stem of the plant. According to Halim *et al.* (2017), *H. kaszabi* was found infesting Solanaceae crops such as eggplants and sponge gourds.

In this study, Pseudococcidae was found infesting the stem of the *S. lasiocarpum* to ingest the sap, phloem, and secondary compound from the crop (Figure 4). These phenomena will cause problems to the plant, such as tissue damage and water loss, disturb translocation, and excrete honeydew, hence vulnerability to fungal infection (Jahn *et al*., 2003). Mealybugs are also a vector disease that carries various pathogens like bacteria and viruses (Jahn *et al*., 2003; Cooper *et al*., 2018). Furthermore, honeydew excreted from mealybugs contain neonicotinoids that can kill beneficial insects such as parasitoid and pollinating syrphid flies (Calvo-Agudo *et al*., 2019). The previous study reports mealybugs as the pest for *Solanum* crops such as *Pseudococcus viburni* to be infesting *Solanum tuberosum* and *Phenococcus solenopsis* to be infesting *S. lycopersicum* (Culik & Gullan, 2005). In addition, we also found that mealybugs can cause further damage to the *S. lasiocarpum* tree by sucking the plant sap through the wounds and holes at the stem created by the burrowing *H. kaszabi* larvae.

The holes then become the reservoir for the mealybugs to reproduce and multiply their numbers inside the tree. According to Tanwar *et al*. 2007, the hiding habit of the mealybugs in crevices of crop plants is among the limitations of plant protection efforts.

The association of the Pseudococcidae and its mutualist, Formicidae, was also recorded in this study. Two Formicidae species, i.e., *Anoplolepis gracilipes* and *Polyrhachis* sp., were considered indirect pests and found in tri-trophic relationships with the Pseudococcidae and *S. lasiocarpum*. The mutual relationship was recorded in a previous study between the ant *Tetramorium bicarinatum* and mealybug *Phenacoccus solenopsis*. The ant obtains their food from the mealybug and, at the same time, protects the mealybug from parasitoid *Aenasius bambawalei* (Hymenoptera: Encyrtidae) (Huang *et al*., 2017).

In another study, *Anoplolepis gracilipes* poses threats to the honeybees that pollinate the crop (Sinu *et al*., 2017). It was recorded to predate 17% of honeybees pollinating pumpkins in India (Sinu *et al*., 2017). Other than having a mutual relationship with the mealybug by having its food requirement through the honeydew (Zhou *et al*., 2015). Genus *Polyrhachis* has been recorded as the predator of small insects such as termites (Latifian *et al*., 2018). The species *Polyrhachis simplex* was reported to be the predator of small insects at the chili *Capsicum annuum* farm (Kaur & Sangha, 2016).

Visiting insect at *Solanum lasiocarpum*

Twenty-six insect species were gathered and assumed as visiting insects at *Solanum lasiocarpum* crops. Of the twenty-six species, eight were hymenopterans, and seven were dipterans, while the rest were coleopterans, hemipterans, lepidopterans, mantodeans, and orthopterans. Hymenopterans and dipterans visiting insects at *Solanum* crops were associated with higher crop yield, despite *Solanum* being self-pollinating crops (Srinivas *et al*., 2016). The biology of *Solanum's* flower promotes self-pollinating; however, cross-pollination could often occur (Reddy *et al*., 2021). The presence of the hymenopterans and dipterans aids in pollinating the crops through the acting of sound waves or buzz waves of their flying (Nayak *et al*., 2020).

A total of four insect species from Diptera and Hymenoptera orders were assumed to be the pollinator or flower-visiting insects of *S. lasiocarpum*. Species *Eristalinus* sp. (N=10), *Musca domestica* (N=15), *Braunsapis* sp. (N=9), and *Vespa affinis* (N=6) are from family Syrphidae, Muscidae, Apidae and Vespidae, respectively. Previous studies found that *Eristalinus* sp. was the most abundant forage on ridge gourd (Bodlah & Waqar, 2013), while *E. aeneus* and *E. laetus* are the most foliage insect visitors from 59 plant species in Pakistan (Sajjad *et al*., 2010). Adult of *M. domestica* consumes human food, rotting carrion, fruits, and vegetables (Dahlem, 2009). The presence of *M. domestica* was assumed to be attracted by the flower or fruits of *S. lasiocarpum*. A study reported that *M. domestica* acts as a pollinator for okra, *Abelmoschus esculentus* (Nadine *et al*., 2020). Another study recorded *M. domestica* might be the pollinator in tomato field, *Solanum lycopersicum* (Rana *et al*., 2017). Bees from the genus *Braunsapis* are known to be generalist pollinators for flowering plants (Hayes *et al*., 2019). Examples of the plants are mango, *Solanum melongena*, *Muntingia calabura*, *Ageratum* sp., *Cleome viscosa*, *Hedyotis corymbosa*, *Mitracarpus hirtus*, *Sesamum radiatum*, *Vernonia cinerea, Mimosa pudica*, *Sida rhombifolia*, *Trichospermum calyculata, Spermacoce assurgens*, *Sphagneticola trilobata*, *Elephantopus mollis* and *Triumfetta rhomboidea* (Inoka *et al*., 2006; Das *et al*., 2018; Hayes *et al*., 2019). The function of *V. affinis* in *S. lasiocarpum* cultivation could be categorized into either pollinator or predator. A study from Tangmitcharoen *et al*. (2006) shows *V. affinis* pollinating 100% of visited flower *Tectona grandis*. However, *V. affinis* also is known to be a generalist scavenger that feeds on tree sap, nectar, carrion, and insects like bees (Smith-Parda *et al*., 2020).

Another two dipterans species gathered at the *S. lasiocarpum* crops are *Amblypsilopus* sp. 1 and sp. 2 from family the Dolichopodidae. Most Dolichopodidae species are known to be predators of small invertebrates and have the potential to be natural enemies for pests in forests and agricultural sites (Runyon, 2020). Among documented prey for dolichopodids are Chironomidae, Culicidae, Aphididae, Collembola, mites, thrips, whiteflies, and larvae of bark beetles (Runyon, 2020).

Three parasitoid insects collected at the Terung Asam cultivation are Conopidae, Ichneumoninae, and Rogadinae. The presence of these parasitoids at the cultivation should be studied more in the future because the number of individuals collected is only one for each taxon. The status of these parasitoid insects in this study is disregarded and remarked as visiting insects in Terung Asam cultivation. Conopidae species are the parasitoid for Apidae, for example, the genus *Physocephala* parasitizes *Euglossa intersecta*, *E. anodorhynchi,* and *Centris analis* (Melo *et al*., 2008; Moure-Oliveira *et al*., 2019), and *Pediobius williamsoni* parasitizes *Xylocopa augusti* (Lucia *et al*., 2010). Ichneumoninae and Rogadinae are parasitoids for Lepidoptera (Zaldivar-Riveron *et al*., 2008; Laquinta *et al*., 2015).

CONCLUSION

Despite *S. lasiocarpum* or Terung Asam as a renowned crop in Sarawak, studies on this indigenous crop are still limited and lacking. Through this study, we can conclude that *Henosepilachna kaszabi* and mealybugs Pseudococcidae are the primary pests, while *Anoplolepis gracilipes* and *Polyrhachis* sp. are the indirect pests for *S. lasiocarpum*. Both *H. kaszabi* and Pseudococcidae were found during the flowering and fruiting phases of *S. lasiocarpum*. Other insect species collected can be classified as visiting insects at the cultivations. In the future, more studies should be conducted to confirm the insect's function, and the frequency of insect visiting, and provide data on the insect pests and beneficial insects towards the crop for efficiently controlling the insect pests of *S. lasiocarpum*.

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ETHICAL STATEMENT

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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