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ASSESSMENT OF PARASITIC NEMATODES *Elaeolenchus parthenonema* POINAR, ON POLLINATING WEEVIL, *Elaeidobius kamerunicus* AT SELECTED OIL PALM PLANTATIONS IN PAHANG, MALAYSIA

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ABSTRACT

The introduction of the oil palm pollinating weevil, Elaeidobius kamerunicus *(Coleoptera: Curculionidae) from Africa in 1980s brought substantial benefit to the Malaysian economy. However, it was discovered that the weevil was parasitised by a nematode,* Elaeolenchus parthenonema *Poinar. This raising concern is addressed in this paper based on the assessment of the parasitic nematodes* E. parthenonema *on the weevil at selected oil palm plantations in Pahang, Malaysia. This study was conducted at Ladang Sungai Bebar Selatan Jerantut (peat soil), FELCRA Tembeling Tengah Jerantut (mineral soil) and MPOB Jerantut (mineral soil). The anthesis stage of oil palm male spikelets was sampled for weevil and nematode inspection. The weevils were inspected and showed a high number of nematodes from the larval, pupa, to adult stages. The nematode was not detected at the egg stage. The mean and percentage of total infected* E. kamerunicus *per spikelet by nematodes in March 2021 was highest at Ladang Sungai Bebar Selatan Jerantut (peat soil) with 19.19 ± 0.83, 91.03%, followed by September 2021 at 27.04 ± 1.95, 84.88% and October 2021 at 23.74 ± 2.24, 76.45% as compared to FELCRA Tembeling Tengah Jerantut (mineral soil) and MPOB Jerantut (mineral soil). Thus, the finding of high numbers of infected* E. kamerunicus *with nematodes raises significant concerns regarding the negative effects of nematode parasitism on weevils.*

Keywords: mineral soil, oil palm, parasitic nematode, peat soil, pollinator weevil.

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INTRODUCTION

Malaysia is one of the most well-known and significant exporters of palm oil in the world, holding a stake of 34.30% in the worldwide palm oil trade (Parveez *et al.*, 2021). As the second-largest palm oil producer in the world, Malaysia has the opportunity to play a significant role in the food and biofuel market due to its huge and expanding palm oil sector and strong global demand for oil palm (Gan and Li, 2014). In 2021, Malaysia reported 451 palm oil mills were in operation, with a total annual processing capacity of 115.87 million tonnes of fresh fruit bunches (FFB) (Parveez *et al.*, 2022). Moreover, 52.50% of the total processing capacity of 57.50 million tonnes were contributed from Peninsular Malaysia (Parveez *et al.*, 2022). The Arecaceae family includes the oil palm (*Elaeis guineensis* Jacq.), the main established industrial crop in Malaysia (Nurul Fatihah *et al.*, 2019). Malaysia earned RM108.52 billion in total revenue from exporting palm oil and palm oil products in

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2021 (MPOB, 2022). Apart from that, the Malaysian palm oil industry employs over 500 000 people and provides for the welfare of an estimated one million people (MPIC, 2018). The most valuable resource in Malaysia's agricultural sector is oil palm (Zulkefli *et al.*, 2020). In the year 2016, 5.74 million hectares were planted with oil palm (Kushairi *et al.*, 2018). The total area of the oil palm planted reached 5.74 million hectares in 2021 as compared to 5.87 million ha in 2020, indicating a 2.2% decline in total oil palm area due to the COVID-19 outbreak (Parveez *et al.*, 2022). The COVID-19 epidemic had halted replanting operations in oil palm plantations. A significant performance improvement was reported in the Malaysian oil palm sector in 2019 compared to 2018, with notable gains made in exports, palm oil stockpiles, and prices with export revenue of RM67.52 billion in 2018 and RM68.84 billion in 2019 (Parveez *et al.*, 2020). The export revenue climbed year after year as Malaysia generated RM108.52 billion in revenue from the export of palm oil and its products in 2021 compared to 2020 which earned RM73.33 billion (Parveez *et al.*, 2023). This happened due to the outbreak of the coronavirus disease (COVID-19) and the year 2020 faced an unusual challenge for nearly all of the worldwide revenue growth (Parveez *et al.*, 2021).

Oil palm is a monocotyledonous plant due to the prevalence of both male and female inflorescences on the same palm (Adam *et al.*, 2011). The female and male inflorescences bloom at various times and pollinate throughout the year (Gintoron *et al.*, 2023). The oil palm inflorescence is known to be self or cross-pollinated, wind-pollinated (anemophily) and insects-pollinated (entomophily) (Appiah and Dwarko, 2013). Until the late 1970s, oil palm was considered an anemophily instead of an entomophily (Swaray *et al.*, 2023). There are two native insect pollinators for oil palm in Malaysia, *Thrips hawaiiensis* and *Pyroderces* sp., but these pollinators proved to be inefficient (Teo, 2015). The pollination of oil palm is mostly entomophilous and attracts numerous insects mainly the genus *Elaeidobius* which are drawn to the inflorescences (Hala *et al.*, 2012).

During the anthesis stage, the oil palm pollinating weevil, *Elaeidobius kamerunicus* was drawn to the oil palm by the volatile organic compounds (VOCs) emitted from fully developed flowers with a strong anise smell known as estragole (Fahmi *et al.*, 2021; Aisagbonhi *et al.*, 2004). *Elaeidobius kamerunicus* is mostly lured to male inflorescences, but it is misled by a scent shared by both male and female inflorescences, which resulted in pollination and pollen unintentionally being carried from male to female inflorescences (Yousefi *et al.*, 2020; Sambathkumar and Ranjith, 2011). Estragole compounds are prominent for oil palm pollination activity and their capability to draw *E. kamerunicus* even without food source (Fahmi Halil *et al.*, 2021). In addition to depositing their eggs on the anthesising male flowers, adult weevils consume oil palm pollen. The larvae feed on pollen on the male flowers and become adult weevils within 10 days (Tuo *et al.*, 2011).

Elaeidobious kamerunicus is a small weevil that belongs to the order Coleoptera, family Curculionidae and it was found to reproduce and spread quickly in oil palm plantations across the country (Swaray *et al.*, 2023; Syed, 1982). The pollination assistance is primarily delivered by *E. kamerunicus*. Along with its high reproductive rate and ability to carry more pollen than other *Elaeidobius* species, *E. kamerunicus* was preferred for introduction into Malaysia (Yousefi *et al.*, 2020). *Elaeidobious kamerunicus* was brought into Malaysia in 1981 from Cameroon to Ladang Pamol in Sabah and Kluang, Johor (Nurul Fatihah *et al.*, 2019; Syed, 1979). It further improved pollination and increased oil palm yields (Tuo *et al.*, 2011). The pollinator *E. kamerunicus* effectively resolved the pollination problem in oil palm plantations throughout the period, ultimately resulting in improved oil production in most countries, including Malaysia, Indonesia, and India (Caudwell *et al.*, 2003).

In some areas in East Malaysia, low pollination has led to poor fruit sets, as documented by Yousefi *et al.* (2020). Recent findings point out that inadequate pollination due to the lack of weevils causes seasonal low fruit sets. Weevil numbers precipitously declined as a result of the wide nematode infection and unfavourable weather (Vaknin, 2012). The wet season is also one of the factors that influence the emergence of nematode parasitism in the *E. kamerunicus* population. *Elaeolenchus parthenonema* is a weevil parasite that belongs to the superfamily Sphaerularidea, and was first documented by Lubock in 1981 (Jackson and Bell, 2001). Since it survives and adapts well inside the weevil host, it is assumed that this nematode was associated with the introduced *E. kamerunicus* from Africa. Although every effort has been made to control all relevant organisms before importation into Malaysia, these internal parasites might have missed further inspection (Poinar *et al.*, 2002; Syed *et al.*, 1982). Caudwell *et al.* (2003) and Kang (1999) suggested that a low population of *E. kamerunicus* weevils can be associated with various problems. It may be due to direct or indirect effects of weather or nematode parasitism that can occur because of climate change. Further research by Mohamad *et al.* (2022) indicated that although both sexes of *E. kamerunicus* harbour nematodes, only extensively infected female weevils show the symptoms, which include a decrease in egg production, sterility, and reduction in size in response to a decrease in body fat. The weevil's ability to pollinate efficiently may be significantly affected by its interaction with this parasitic nematode. Thus, this study was conducted to inspect the percentage infection of parasitic nematode on *E. kamerunicus* in selected locations of study in Pahang.

MATERIALS AND METHODS

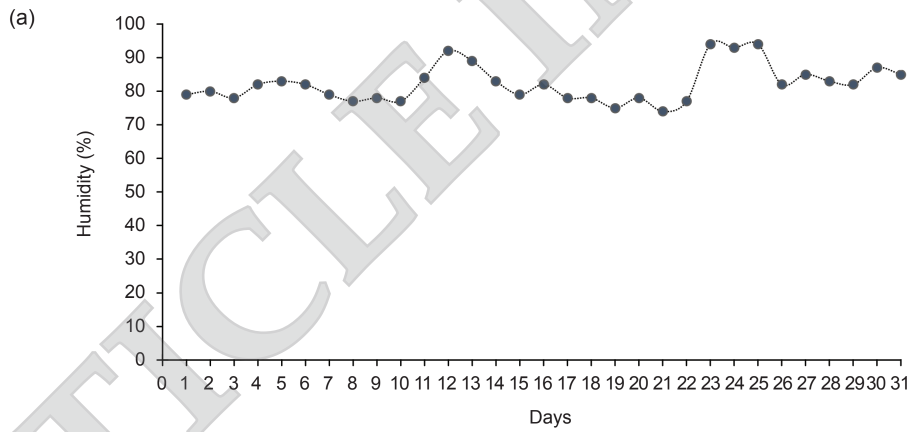
Location of the Study

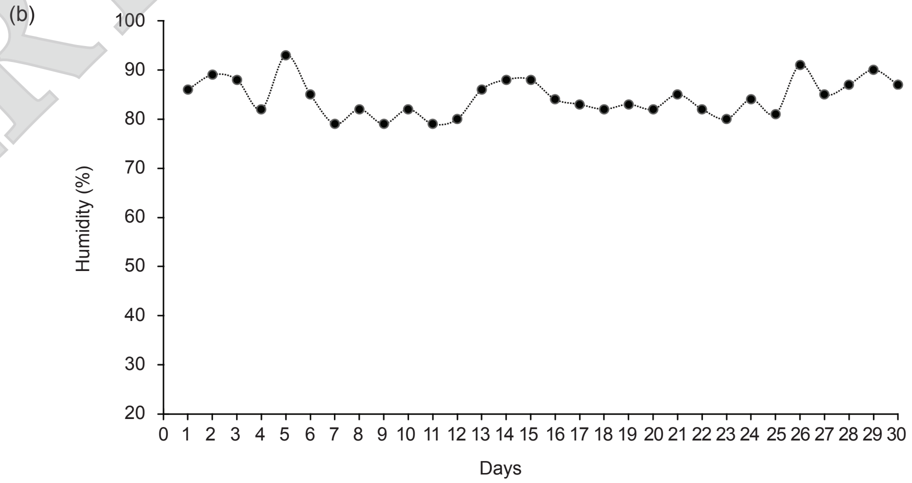
This study was carried out at Site I, Ladang Sungai Bebar Selatan, Jerantut (3°14′55″N 103°21′26″E) (Year Planted: 2010, Age: 13 years, Tree Type: DxP);Site II, FELCRA Tembeling Tengah, Jerantut (4°13′18.12430″N 102°23′13.63052″E) (Year planted: 2011, Age: 12 years, Tree Type: DxP); and Site III, MPOB Jerantut, Pahang (4°17′14.44776″N 102′24′44.12113″E) (Year planted: 2013, Age: 10 years, Tree Type: CLONE P456). Site I was picked to represent peat soil, and both Site II and Site III represented mineral soil. Every study location experienced rain in March, October, and September with Hourly Relative Humidity (%) of >70% (MET, 2021) (*Figures 1a-1c*). The collection of samples in this study involved field and fruit sampling at all three sites. The fruit samplings were randomly collected at each location.

Sampling Procedures for *Elaeidobius kamerunicus* and Parasitic *Elaeolenchus parthenonema*

Elaeidobius kamerunicus were collected in oil palm plantations through anthesising male flower cutting. Nine spikelets were randomly selected from each anthesising male flower and three were picked from the top, middle, and bottom (Jackson *et al*., 2003). Samples of anthesising male flowers were brought to the laboratory for examination. The weevils were collected from each spikelet for nematode identification (n = 27).

The weevils (larva, pupa, and adult) were crushed and examined under a compound microscope to identify the presence of nematodes in the weevils. The crushed *E. kamerunicus* were taken out, cleaned in sterile water, and put in White Traps in accordance with the nematode isolation protocol described by Orozco *et al*. (2014). The samples were inspected under a compound microscope Amscope to determine the presence of nematodes in the weevils. The characteristics of the parasitic nematode, *E. parthenonema* were observed using RaxVision 9.7-inch Touch Screen Tablet XPAD-97.





Source: MET (2021).

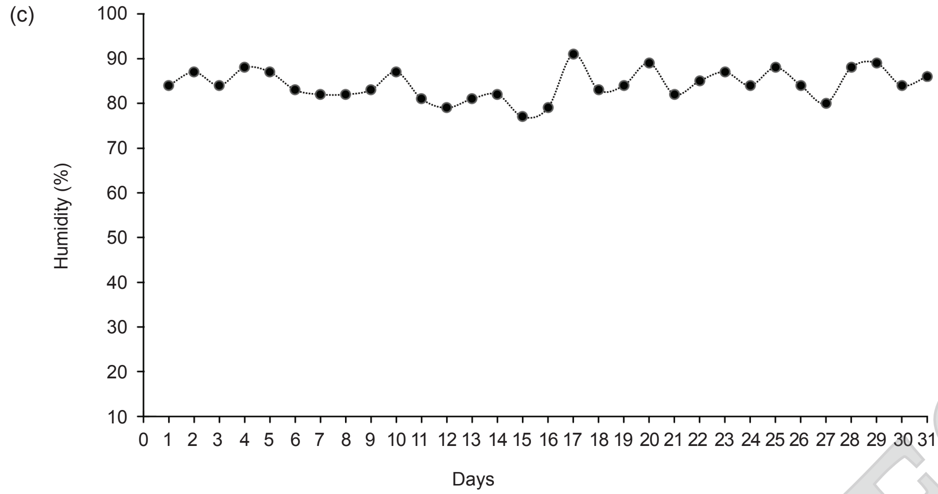


Figure 1. The percentage of humidity on (a) March 2021, (b) September 2021 and (c) October 2021 in Pahang.

Then, the morphological features of the nematode were referred to Caudwell *et al.* (2003), Zulkefli *et al.* (2011) and Poinar *et al.* (2002). The emergence of parasitic nematodes inside the haemocoel of *E. kamerunicus* was evaluated to classify the severity of the infections.

Data Analysis

The total number of parasitic nematodes was recorded, and the percentages of infections were evaluated to measure the infestations and their impact on weevil populations. The following formula by Zulkefli *et al.* (2011) was used to determine the percentages of infected pollinating weevil *E. kamerunicus* by *E. parthenonema*:

$$\frac{\text{Number of infected } E.\ kamerunicus \text{ by nematode } E.\ parthenonema}{\text{Total number of } E.\ kamerunicus} \times 100$$

The ANOVA test was performed to analyse the infected *E. kamerunicus* (larvae, pupae, adult) per spikelet by using R studio version 3.1.3.

RESULTS AND DISCUSSION

The Characteristics of Parasitic Nematodes *E. parthenonema* Isolated from *E. kamerunicus*

During the study, parasitic nematodes were found in the weevil population at all locations of the study. All life stages of *E. kamerunicus* were found with the nematodes, except for the egg. *Elaelenchus parthenonema* that infected the *E. kamerunicus* was identified as an internal parasite to the weevil and belonged to the superfamily Sphaerularioidea Lubbock 1861 (Poinar *et al.*, 2002; Jackson and Bell, 2001). *Figure 2* shows an adult stage of *E. parthenonema*. The mature female nematode was mostly found in the haemocoel of late larval instars, pupae and adult stage of *E. kamerunicus* weevil. Capinera (2008) revealed that obligate parasites belonging to the Sphaerulariidae are commonly discovered in the body cavity of their insect host. The shape of a mature female nematode is sausage-shaped (*Figure 2*).

The entire body of a mature female nematode is filled up with genital system. It has a stylet and an elongated ovary. Adult *E. parthenonema* body is loaded with eggs and has developed stylet (*Figure 2*). Poinar *et al.* (1993) stated that the foremost features of fertilised female nematode in the Sphaerulariidae family had an elongated uterus and bulb-shaped pharyngeal glands. They also added that the glands lengthened over the intestine and formed a short lobe. The identification of adult nematode is based on the coiled body (*Figure 2*). Zulkefli *et al.* (2011) indicated that the coiled body of the parasitic female nematode aided in the identification. In this study, it can be found at a minimum number of one to 20 nematodes per weevil. Poinar *et al.* (2002) found one weevil could host up to 30 mature female and juveniles. Besides, no male nematodes were found in this study, similar to the previous study reported by Poinar *et al.* (2002).

The juvenile stage four (J4) is a pre-adult nematode stage (*Figures 3a-3b*). This nematode moults to a female adult. The body of juvenile stage four nematode has a nearly curved form and rounded body in contrast to juvenile stage three which has a slim body (*Figure 3b*). Furthermore, it possesses a circled head and short stylet as compared to juvenile stage 3, which has a pointy stylet. The infective stage (J3) has a similar stylet as the mature female nematode (Poinar *et al.*, 2002). It has a slender formed body and is swift in swimming (*Figure 3c*). This nematode stage is extended and thin. The tail is pointed and 70% of the nematode body is filled with granular material.

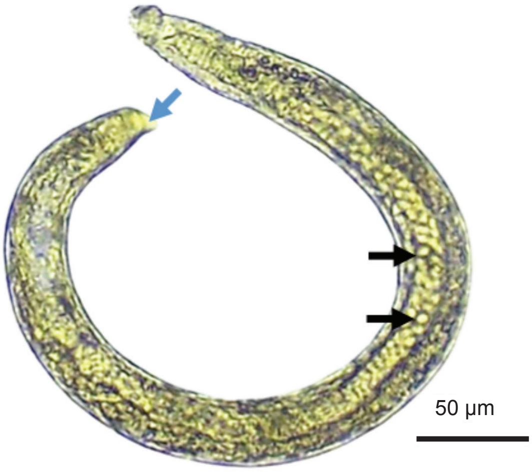


Figure 2. Adult Elaeolenchus parthenonema *with a developed stylet (blue arrow) and eggs (black arrows).*

They are highly active and can swim in the water by undulating their bodies like snakes or S shape movements. The infective stage (J3) nematodes can be found mostly in the digestive system of the weevil or within the weevil haemocoel. It can be observed in larvae, pupae, live weevils, and dead weevils. These nematodes are isolated by squashing the insects and maintained in White Trap for a certain period only. These nematodes can only be maintained for a certain period of time, because they are highly adapted to the insect host, *E. kamerunicus* weevil. Furthermore, juvenile stage three can be found to clump together (*Figure 3c*), with juvenile stage four (*Figure 3b*), and other stages of nematodes. Aisagbonhi *et al.* (2004) found that the abdomen of a single adult weevil has 20 to 30 nematodes that fit the *E. parthenonema* infective stage (J3) description. Juvenile stage two (J2) nematodes are small and slender with very poor locomotion (*Figure 3d*). It is difficult to distinguish the nematodes' features. Juvenile stage two (J2) nematodes are found in the White Traps that keep adult female nematodes. They are mostly found in ruptured adult female nematodes haemocoel. Aisagbonhi *et al.* (2004) found juvenile stage two (J2) nematodes in the haemocoel of one weevil.

Severity of Infections Parasitic Nematodes, *E. parthenonema* on *E. kamerunicus*

The occurrence of parasitic nematodes indicates the severity of infection in *E. kamerunicus*. Camino *et al.* (2016) and Poinar (1975) stated that the insect's body cavities can host nematodes from the superfamilies Sphaerulariidae and the consequence of these nematode infection to insects has resulted to infertility and mortality. The uninfected weevil showed no nematode infection in *E. kamerunicus* (*Figure 4a*). Meanwhile, mild nematode infection on weevil can indicate a low infection of nematodes. There were only a few nematodes found inside the weevil (*Figure 4b*). Nematodes can take up half of the haemocoel and elytra space and are classified as moderate nematode infections. The infection is considered high when nematodes from various stages fully occupy the weevil. (*Figure 4c*). In heavily infected *E. kamerunicus*, nematodes can critically impact the weevil as they parasitised all space in the haemocoel (*Figure 4d*). It is a severe nematode infection on the weevil. Nematode parasitism can be worse as they develop fast and multiply in the host.

Assessment of *E. kamerunicus* Infected by Parasitic Nematodes per Spikelets

Parasitic nematode infections were positively identified at all three locations of the study. Based on the statistical analysis, it was observed that the mean of larvae that were infected by nematodes at Sungai Bebar Selatan (peat soil) was significantly greater than other locations, which was 24.74 ± 0.96 followed by MPOB Jerantut (mineral soil) 23.33 ± 1.63 and FELCRA Tembeling Tengah Jerantut (mineral soil) 11.26 ± 0.96 (p<0.05, p=0.001) (*Table 1*). There was a significant difference between the mean number of pupae infected by the nematodes during the study period on samples collected in peat soil and mineral soil in March (p<0.05, p=0.0216). The mean number of infected pupae in Sungai Bebar Selatan (peat soil) was higher at 15.48 ± 1.37 as compared to infected pupae in FELCRA Tembeling Tengah Jerantut (mineral soil) at 12.74 ± 1.03 and the mean number of infected pupae in MPOB Jerantut (mineral soil) was 10.59 ± 1.03. Meanwhile, samples collected in March showed no significant differences detected in all locations of the study in terms of the mean number of infected adult weevils (p>0.05, p=0.4691). FELCRA Tembeling Tengah Jerantut (mineral soil) was 34.07 ± 1.47, followed by Sungai Bebar Selatan (peat soil) was 17.33 ± 1.32 and MPOB Jerantut (mineral soil) with 12.37 ± 0.91.

It was observed that the mean of the larvae infected by the nematodes at Sungai Bebar Selatan (peat soil) was significantly greater than other locations, which was 44.07 ± 3.55, followed by FELCRA Tembeling Tengah Jerantut (mineral soil) with 38.00 ± 4.25 and MPOB Jerantut (mineral soil) with 37.56 ± 3.05 (p<0.05, p=0.000) (*Table 2*). Meanwhile, the mean number of pupae infected by the nematodes showed no significant differences in all the study locations. The mean number of infected pupae in MPOB Jerantut (mineral soil) was 21.41 ± 1.23, FELCRA Tembeling Tengah Jerantut (mineral soil) was 20.93 ± 1.59, and Sungai Bebar Selatan (peat soil) was 17.41 ± 1.61 (p>0.05, p=0.122). Generally, there was a significant difference between the mean number of adult weevils that were infected by nematodes in all three locations, within FELCRA

Figure 3. Elaeolenchus parthenonema*, (a) juvenile stage 4, (b) juvenile stage 3 (infective stage) together with juvenile stage 4, (c) juvenile stage 3 (infective stage) and (d) juvenile stage 2.*

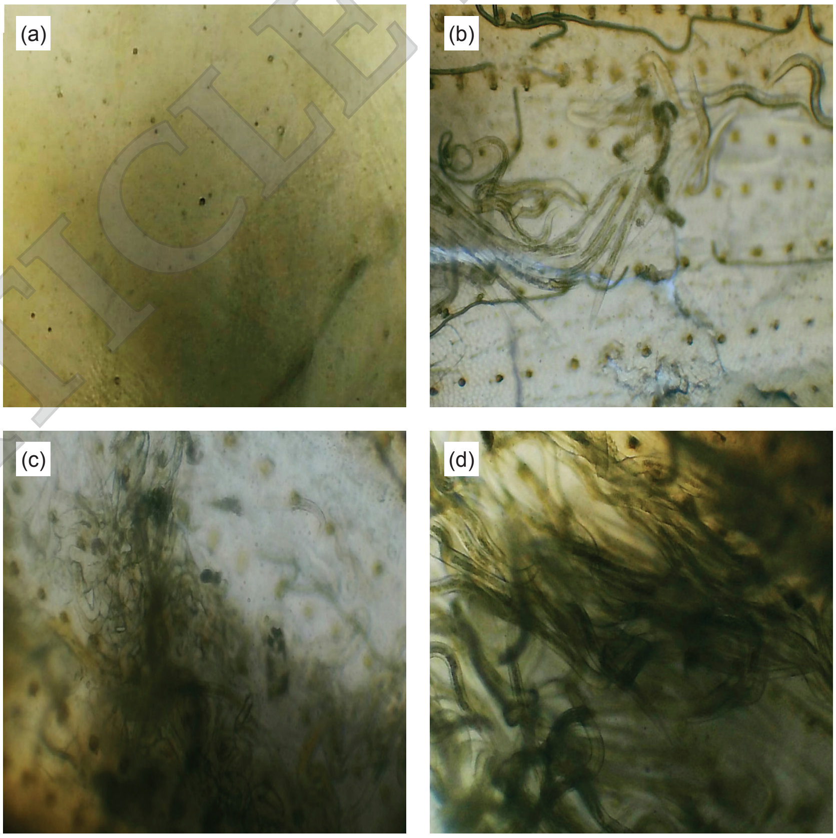


Figure 4. Classification of infection severity in haemocoel E. kamerunicus*. (a) no nematode infection in* E. kamerunicus*, (b) mild nematode infection in* E. kamerunicus*, (c) moderate nematode infection in* E. kamerunicus *and (d) severe nematode infection in* E. kamerunicus*.*

TABLE 1. MEAN AND PERCENTAGE OF INFECTED *Elaeidobius kamerunicus* WITH NEMATODES PER SPIKELET (MARCH 2021)

Location	Larvae		Pupae		Adult		Total	
	Mean	Nematode infection (%)	Mean	Nematode infection (%)	Mean	Nematode infection (%)	Mean	Nematode infection (%)
Sungai Bebar Selatan (peat soil)	24.74 ± 0.96 ^{a} n = 27 spikelets total larvae = 732	91.26	15.48 ± 1.37 ^{a} n = 27 spikelets total pupae = 455	91.87	17.33 ± 1.32 ^{ab} n = 27 spikelets total adult = 520	90.00	19.19 ± 0.83	91.03
FELCRA Tembeling Tengah Jerantut (mineral soil)	11.26 ± 0.96 ^{b} n = 27 spikelets total larvae = 476	63.87	12.74 ± 1.03 ^{b} n = 27 spikelets total pupae = 516	66.67	34.07 ± 1.47 ^{ab} n = 27 spikelets total adult = 1 252	73.96	19.35 ± 1.34	69.86
MPOB Jerantut (mineral soil)	23.33 ±1.63 ^{b} n = 27 spikelets total larvae = 963	65.42	10.59 ± 1.03 ^{b} n = 27 spikelets total pupae = 511	55.97	12.37 ± 0.91 ^{ab} n = 27 spikelets total adult = 498	67.07	15.34 ± 0.94	63.39

TABLE 2. MEAN AND PERCENTAGE OF INFECTED *Elaeidobius kamerunicus* WITH NEMATODES PER SPIKELET (SEPTEMBER 2021)

Location	Larvae		Pupae		Adult		Total	
	Mean	Nematode infection (%)	Mean	Nematode infection (%)	Mean	Nematode infection (%)	Mean	Nematode infection (%)
Sungai Bebar Selatan (peat soil)	44.07 ± 3.55 ^{a} n = 27 spikelets total larvae = 1 399	85.06	17.41 ± 1.61 ^{ab} n = 27 spikelets total pupae = 587	80.07	19.63 ± 1.76 ^{a} n = 27 spikelets total adulte = 594	89.23	27.04 ± 1.95	84.88
FELCRA Tembeling Tengah Jerantut (mineral soil)	38.00 ± 4.25 ^{b} n = 27 spikelets total larvae = 1 449	70.81	20.93 ± 1.59 ^{ab} n = 27 spikelets total pupae = 744	75.94	33.93 ± 2.90 ^{b} n = 27 spikelets total adult = 1 194	76.72	30.95 ± 1.95	74.02
MPOB Jerantut (mineral soil)	37.56 ± 3.05 ^{b} n = 27 spikelets total larvae = 1 526	66.45	21.41 ± 1.23 ^{ab} n = 27 spikelets total pupae = 818	70.66	18.81 ±1.18 ^{b} n = 27 spikelets total adult = 901	56.38	25.93 ± 1.48	64.71

Tembeling Tengah Jerantut (mineral soil) at 34.63 ± 3.00, Sungai Bebar Selatan (peat soil) 19.63 ± 1.76 and MPOB Jerantut (mineral soil) 18.81 ± 1.80 (p<0.05, p=0.000).

A comparison between the mean number of *E. kamerunicus* infected with nematodes per spikelet in October is presented in *Table 3*. The data based on October sampling showed that the study location in Sungai Bebar Selatan (peat soil) had higher infection of the nematodes compared to other locations. The statistical analysis showed that there were no significant differences (p>0.05, p=0.082) between the mean of larvae in all the study locations. The mean of the larvae that were infected by the nematodes at Sungai Bebar Selatan (peat soil) was 43.72 ± 2.59, followed by FELCRA Tembeling Tengah Jerantut (mineral soil) 36.00 ± 4.96 and MPOB Jerantut (mineral soil) 32.89 ± 2.07. Meanwhile, there was a significant difference (p<0.05, p=0.000) between the mean number of pupae infected by the nematodes in all three locations. The number of pupae that were infected in mineral soil was greater than in peat soil. FELCRA Tembeling Tengah Jerantut (mineral soil) was 23.78 ± 2.31, MPOB Jerantut (mineral soil) was 18.00 ± 1.48, and Sungai Bebar Selatan (peat soil) was 10.22 ± 1.22. The number of infected adults *E. kamerunicus* in FELCRA Tembeling Tengah

TABLE 3. MEAN AND PERCENTAGE OF INFECTED *Elaeidobius kamerunicus* WITH NEMATODES PER SPIKELET (OCTOBER 2021)

Locations	Larvae		Pupae		Adult		Total	
	Mean	Nematode infection (%)	Mean	Nematode infection (%)	Mean	Nematode infection (%)	Mean	Nematode infection (%)
Sungai Bebar Selatan (peat soil)	43.72 ± 2.59 [ab] n = 27 spikelets total larvae = 1 005	78.31	10.22 ± 1.22 [a] n = 27 spikelets total pupae = 247	74.49	17.29 ± 1.40 [a] n = 27 spikelets total adult = 425	73.18	23.74 ± 2.24	76.45
FELCRA Tembeling Tengah Jerantut (mineral soil)	36.00 ± 4.96 [ab] n = 27 spikelets total larvae = 1 040	62.31	23.78 ± 2.31 [b] n = 27 spikelets total pupae = 649	64.56	31.28 ± 2.93 [b] n = 27 spikelets total adult = 841	66.94	30.19 ± 2.15	64.43
MPOB Jerantut (mineral soil)	32.89 ± 2.07 [ab] n = 27 spikelets total larvae = 1 044	56.71	18.00 ± 1.48 [b] n = 27 spikelets total pupae = 579	55.99	24.05 ± 2.22 [b] n = 27 spikelets total adult = 673	64.34	24.98 ± 1.40	58.75

Jerantut (mineral soil) was significantly greater (31.28 ± 2.93) than the number of infected adults in MPOB Jerantut (mineral soil), which was 24.98 ± 1.40 followed by Sungai Bebar Selatan (peat soil) with 23.74 ± 2.24.

Rainfall with hourly relative humidity percentage of greater than 70% were reported in every study location in Pahang on March, October, and September 2021 (MET, 2021) (*Figures 1a-1c*). The results showed the weather patterns correlated to the parasitic nematode infection because the higher the moisture contents on the spikelets, the higher the infection by the parasitic nematodes. The moisture content of the spikelets might be influenced by the rainy season. Jackson *et al.* (2003) stated that the spikelets with the highest percentage of nematode infection on the larvae and pupae were three-hourly sprayed with water and had the tip of the spikelet soaked in water. They also suggested in comparison to spikelets that were sprayed water hourly, the daily water sprayers showed greater nematode infection on the larvae and pupae. This indicated that as the moisture level of the spikelet increased, the infection by the nematodes increased. Nonetheless, as the moisture increased, most nematodes would have been rinsed off from the spikelets and decreased the infections on the weevils. Furthermore, Zulkefli *et al.* (2011) stated that moderate rainfall showed higher infection of female nematodes on adult weevils compared to low and high rainfall in Pamol Sandakan Plantation in Sabah and MPOB Lahad Datu. They also added that excessive rainfall is associated with low fruit set as it inhibits weevil pollination efficiency. Low weevil populations had been identified as the root cause of occasionally observed poor pollination in Riau, Sumatra. The dramatic drop in the population numbers has been attributed to two factors, namely fewer male inflorescences (weevil breeding sites) during the rainy season and greater nematode parasitism (which reduces both weevil fecundity and longevity) before the conclusion of the rainy season (Donough and Law 1988; Jackson *et al.*, 2003; Zulkefli *et al.*, 2011).

CONCLUSION

In conclusion, parasitic nematode infection was detected in all three study locations. The parasitic nematode infection was influenced by the weather. The higher the humidity, the higher the moisture content on spikelets. This indicates that when the moisture is increased, the parasitic nematode infection on *E. kamerunicus* is increased. There is also insufficient research on entomoparasitic nematode related to the type of oil palm soil and fruit set production in Peninsular Malaysia. It is vital to conduct extensive research on the ecology, biology, and distribution of the entomoparasitic nematode *E. parthenonema* to examine the parasite's actual and potential effects on the host, as well as the cascading effect on pollination and, ultimately the palm oil output. The fruit set in all of the experimental locations was excellent for the time being. However, it is still unclear whether the nematodes can significantly influence the main pollinator of oil palm, *E. kamerunicus*'s longevity over a long period. Indeed, this matter has to be reinforced as reported in various published studies that this entomoparasitic nematode, *E. parthenonema* could give a detrimental effect on insects.

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