Jour. Trop. Coleop. 3(1), 1-9
JOURNAL OF TROPICAL COLEOPTEROLOGY
ISSN online 2718-9740 ; print 2719-1486

New records of *Exopholis hypoleuca* (Coleoptera: Scarabaeidae: Melolonthinae: Leucopholini) on *Corymbia citriodora* and *Eucalyptus* (Myrtaceae) with notes on its biology and population dynamics in North Sumatra, Indonesia

Heri Sunarko[1], Pulungan Sibuea[1], Jupiter Israel Muro Abad[1], Adventris Hutagaol[1], Srikumar Koda Kkadan[2], Nike Grace Hanjelina Br Sinulingga[2], Marthin Tarigan[2], Wagner de Souza Tavares[2], Alvaro Duran[2]
[1]PT. Toba Pulp Lestari (TPL), Porsea, 22384, Indonesia
[2]Asia Pacific Resources International Holdings Ltd. (APRIL), PT. Riau Andalan Pulp and Paper (RAPP), Pangkalan Kerinci, 28300, Indonesia
Corresponding author: Wagner de Souza Tavares, Wagner_Tavares@aprilasia.com
ORCID, https://orcid.org/0000-0002-8394-6808

Abstract

The white grub of *Exopholis hypoleuca* (Wiedemann, 1819) (Coleoptera: Scarabaeidae: Melolonthinae: Leucopholini) is a known pest of several crops on Pacific Islands. This insect was observed feeding on the roots and shoots of *Corymbia citriodora* (Hook.) K.D. Hill & L.A.S. Johnson and *Eucalyptus* L'Hér. (Myrtaceae) plants in Aek Nauli, North Sumatra, Indonesia, which triggered its study. Management strategies of white grub are necessary to be developed because *C. citriodora* and *Eucalyptus* are largely planted in Indonesia for production of paper, pulp and viscose materials. The objectives of this study were to identify a white grub species attacking *C. citriodora* and *Eucalyptus* in Aek Nauli and to study key attributes of its biology (in the laboratory) and population dynamics (in the field) for 19 consecutive months. We also recorded new plant hosts and expanded the known geographical distribution of this insect. White grub species was identified as *E. hypoleuca*. The complete life span is 363.5 days and number of eggs per female is 43. Larvae feed mostly on the roots of *C. citriodora* and *Eucalyptus* while its adults on the leaves of *Eucalyptus*. Larvae were collected from August 2019 to February 2021, except in March 2020. Species identification and key biological attributes of *E. hypoleuca* are important information to develop management strategies of this insect. The population dynamics show activity of *E. hypoleuca* year-round in the studied area. This indicates that management activities must be conducted regularly against *E. hypoleuca*.

Keywords: plant damage, geographical distribution, Melolonthinae, management, new plant host, population dynamic, Sumatra, white grub.

Introduction

Exopholis hypoleuca (Wiedemann, 1819) (Coleoptera: Scarabaeidae: Melolonthinae: Leucopholini) is a pest of annual and perennial crops in Indonesia, Malaysia and Myanmar (Abdullah et al., 2011; Chung, 1998; Chung et al., 2013; Shah, 1978; Winotai, 2014). Plants whose roots are damaged by larvae exhibit symptoms including the yellowing of leaves and top dieback,

DOI: https://doi.org./10.53716/jtc.3.1.1.2022
ZOOBANK: https://zoobank.org/References/04909A07-4DC2-403F-8D2C-DAC9FE68A921
Received: 29 November 2021
Published: 30 July 2022
www.jtcoleop.com

in most cases resulting in the death of the plant (Atmowidjojo et al., 1985; Chung et al., 2002; Intari, 2005; Jayasinghe, 1999; Samekto, 2008).
The objectives of this study were to identify a white grub species attacking *Corymbia citriodora* (Hook.) K.D. Hill & L.A.S. Johnson and *Eucalyptus* L'Hér. (Myrtaceae) plants in Aek Nauli, North Sumatra, Indonesia and to study key attributes of its biology (in the laboratory) and population dynamics (in the field) for 19 consecutive months. We also recorded new plant hosts and expanded the known geographical distribution of this insect.

Materials and methods

The field study was carried out in two commercial stands in Aek Nauli (approximately 2°6'N, 99°5'E, 1050 m), while that under controlled condition at the Entomology Laboratory of PT. Toba Pulp Lestari (TPL) in Porsea at 32 ± 8 ºC, 64 ± 24% RH and 12:12 h (L:D) photoperiod.
One stand planted with young *C. citriodora* and another with young *Eucalyptus*. *Corymbia citriodora* plants exhibiting pathological symptoms including leaf-yellowing and top dieback and *Eucalyptus* displaying signs of defoliation were selected.
The white grub collection was carried out every 30 days to the *C. citriodora* and *Eucalyptus* stands for a total period of 19 months (from August 2019 to February 2021). A 300 m^2 parcel with 50 *C. citriodora* plants spaced three meters between rows and two meters between plants was marked within the total area of 5.2 hectares. Five permanent sub-parcels each of 60 m^2 were marked within the parcel. All plants within the sub-parcels were assessed. The soil around the base of *C. citriodora* plants (around 1 m diameter) was excavated (up to 40 cm deep), all white grub eggs, larvae, pupae (found in the soil), and adults (found on the shoots and soil surface) were manually collected and placed in one-liter plastic containers (a total of 10 containers was used), with soil lined from the stand. Adult white grubs feeding on *Eucalyptus* shoots were also collected manually and placed in separate plastic containers to record a new plant host. The white grubs were collected from 10 *Eucalyptus* plants randomly selected whitin a 6.2 hectares stand (same plants were assessed every 30 days for a total period of 19 months, from August 2019 to February 2021).
Upon arrival in the laboratory white grubs from *C. citriodora* stand were transferred to new plastic containers (five individuals per container, separately per stage) filled with a mixture of cocopeat and soil (1:1) and with planted *C. citriodora* seedlings and wood debris placed on the media surface as food for the larvae and *C. citriodora* shoots for the adults. Clean water was sprayed daily on the media surface using a plastic hand sprayer. Eggs, larvae and pupae were reared until they became adults. The following life history data were recorded from daily assessments: egg incubation period (days), larval and pupal stages period (days), adult longevity (days), and complete lifespan (egg → larva → pupa → adult) (days). The number of eggs laid per female and adult body length (mm) were also evaluated.
Ten adult beetles from *C. citriodora* and another 10 from *Eucalyptus* stands were randomly selected from the laboratory rearing and identified through study of morphological characters employed in the dichotomous keys by Calcetas et al. (2020) and Kalshoven (1981).
White grub population dynamics were assessed from the same *C. citriodora* parcel marked to collect its individuals for studies on species identification and life-history for a total period of 19 months (from August 2019 to February 2021). All plants within the parcel were evaluated with excavations at a depth of 40 cm and one-meter diameter soil around it. The number of white grubs

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per plant and their stages were assessed. The normality of the white grub population dynamic data on *C. citriodora* plants was evaluated with the Kolmogorov-Smirnov test (Vrbik, 2018) using the software Social Science Statistics (Stangroom, 2022).

Results and Discussion

A single white grub species was recovered from both *C. citriodora* and *Eucalyptus* parcels. The species was identified as *E. hypoleuca* (Figures 1A-1B). The elytra have variable number of costae, sutural costa distinctly wide while the rest are narrow and less distinct. The apical margin of the pygidium is rounded. The clypeus is distinctly upturned laterally. The apical margin of the paramere of the male genitalia is triangulate and widely rounded apically while the basal paramere is inverted, lanceolate-shaped and with a lateral depression, as previously reported from a study carried out in the Philippines (Calcetas et al., 2020).

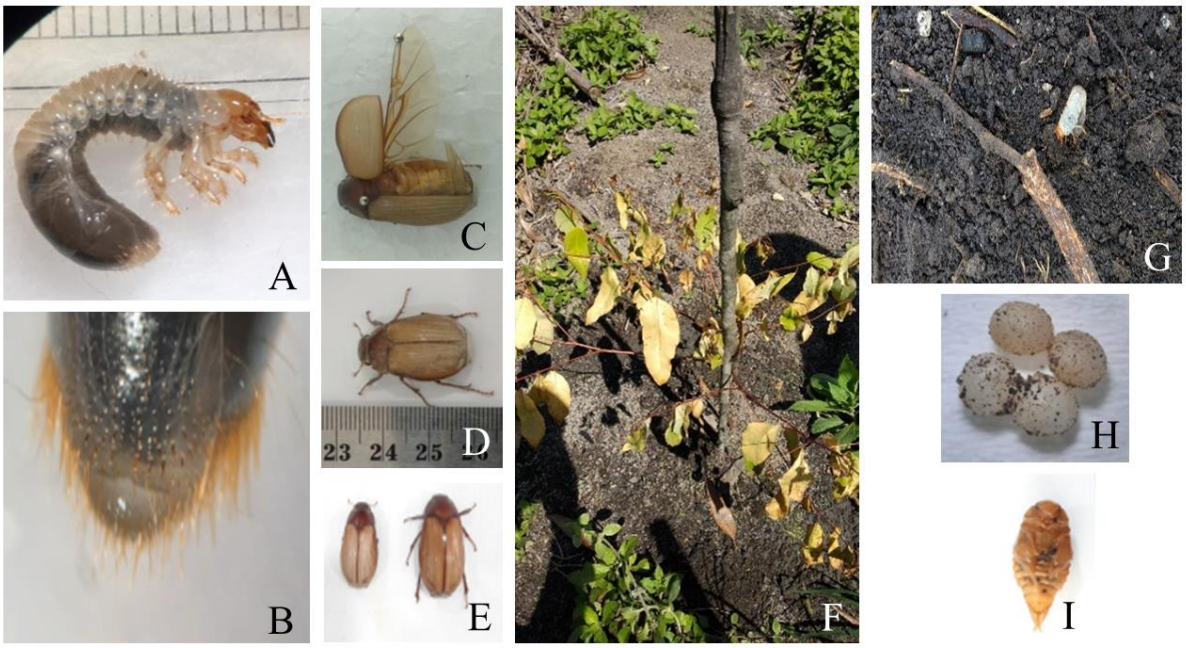

Figure 1. *Exopholis hypoleuca* (Coleoptera: Scarabaeidae: Melolonthinae: Leucopholini) larva (A), rastral spines (B), wing (C), adult (D), male-left and female-right side (E), dying *Eucalyptus* (Myrtaceae) plant from white grub infestation (F), damaged *Eucalyptus* roots from white grub infestation (G), eggs (H), and pupa (I).

Exopholis hypoleuca, collected from the *C. citriodora* and *Eucalyptus* stands in Aek Nauli, differs from other *Exopholis* Motschulsky, 1859 species distributed in Asia; e.g., *E. borneensis* Brenske, 1894 with four costae (different from each other); *E. lacordairei* Waterhouse, 1867 with five costae; *E. philippinica* Brenske, 1896 with four costae; and *E. pinguis* Lansberge, 1879 with seven costae (Calcetas et al., 2020).

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Exopholis hypoleuca adults have a shiny-light brown elytra with dark brown spots near their margin; the ventral side of the abdomen is white, with few fine, short and white hairs in the ventral side of the abdomen (Figure 1C-1D), as previously reported from a study carried out in the Philippines (Calcetas et al., 2020). Color variability was observed in *E. hypoleuca* populations from Ambon Island (Maluku), Nias (North Sumatra) and Sumatra, Indonesia and from Borneo (Indonesia and Malaysia) with elytra light brown to dark chestnut-brown while some individuals from Sumatra were entirely black with brown pygidium (Brenske, 1894).

Exopholis and its closely related genera *Leucopholis* Dejean, 1833 and *Lepidiota* Kirby, 1837 share same morphological attributes, such as an antennal club with three antenommeres. These attributes differ to *Engertia* Dalla Torre, 1912 with three. The clypeus is inclined backward when viewed laterally and the pronotum is without a mediam carina in *Exopholis*, *Leucopholis* and *Lepidiota*, differing to *Stephanopholis* Brenske, 1896 with clypeus inclined forward when viewed laterally and the pronotum with a distinct medium carina. However, the labrum is not bilobed in *Exopholis* while it is bilobed in both *Leucopholis* and *Lepidiota*. Also, the posterior margin of the maxillary palpi are medially acute and the terminal palpomere is lacking an indistinct flattened area, shallow groove or depression in *Exopholis* while the posterior margin of the maxillary palpi are not acute and the terminal palpomere has a flattened area, shallow groove or depression in both *Leucopholis* and *Lepidiota*. The prosternal and metaventral processes of *Exopholis* and *Lepidiota* are similar. The prosternal processes of *Exopholis* and *Lepidiota* are both lanceolate dorsally, round when viewed laterally and with a rounded apex. They are also covered with long, yellowish-white hairs and acicular scales. The metaventral process of both *Exopholis* and *Lepidiota* are triangulate and rounded apically. Also, the metaventral process of *Exopholis* and *Lepidiota* is not extending in front of the mesocoxae while it is extending in front of the mesocoxae in *Leucopholis* (Calcetas and Adorada, 2017; Calcetas et al., 2020).

The mean duration and number of key life cycle attributes are presented (Table 1). The egg incubation and pupal stage period and adult longevity of *E. hypoleuca* individuals are longer and larval stage period shorter than those from Bogor, West Java, Indonesia (Leefmans, 1929), possibly because of different plant species utilized as food source and environmental conditions to rear this insect.

Table 1. Life history of *Exopholis hypoleuca* (Coleoptera: Scarabaeidae: Melolonthinae: Leucopholini) under laboratory conditions in North Sumatra, Indonesia

Parameters	Mean duration	Range	N
Egg incubation period	18.5 days	17–20	200
Larval stage period	255 days	240–270	100
Pupal stage period	30 days	28–32	80
Adult longevity	60 days	55–65	50
Complete lifespan (egg → larva → pupa → adult)	363.5 days	360–367	50
Number of eggs per female	43 units	40–45	25

The average body length of *E. hypoleuca* adults is 25 mm (N= 25). The body length of adult females is higher than in males (Figure 1E). The average body length of *E. hypoleuca* adults is within the range from individuals collected in Ambon Island, Borneo, Nias, and Sumatra (21–25 mm) (Brenske, 1894) and in Sepilok, Malaysia (22–25 mm) (Chung et al., 2013).

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Exopholis hypoleuca larvae feed on roots (Figures 1F-1G) while its adults cause defoliation on both plant species, *C. citriodora* and *Eucalyptus*. This is the first record of *E. hypoleuca* on *C. citriodora* and *Eucalyptus* (Table 2), and the second of this insect in North Sumatra (Table 3). Adults feed mostly on tender leaves, and their eggs are laid in the soil under both field and laboratory conditions (Figures 1H-1I). Our study increases the number of known plant hosts of *E. hypoleuca* from 17 to 19. Nias, North Sumatra was the location of the first record of *E. hypoleuca* in this province (Brenske, 1894).

Table 2. Major crops attacked by *Exopholis hypoleuca* (Coleoptera: Scarabaeidae: Melolonthinae: Leucopholini) in Indonesia, Malaysia and Myanmar

Plant species	Family	References
Allium tuberosum Rottler ex Spreng. not Roxb.	Amaryllidaceae	Luther (2006)
Arachis hypogaea L.	Fabaceae	Chung et al. (2013), Tung (1983)
Cocos nucifera L.	Arecaceae	Benigno and Soewarno (1985), Chung et al. (2013), Kalshoven (1981)
Coffea arabica L.	Rubiaceae	Chung et al. (2013), Tung (1983)
Corymbia citriodora (Hook.) K.D. Hill & L.A.S. Johnson	Myrtaceae	Current study
Dipterocarpus applanatus Slooten	Dipterocarpaceae	Chung (1998), Chung et al. (2013)
Dryobalanops lanceolata Burck	Dipterocarpaceae	Chung et al. (2013)
Durio zibethinus L.	Malvaceae	Chung et al. (2013), Kalshoven (1981)
Elaeis guineensis Jacq.	Arecaceae	Chung et al. (2013), Kalshoven (1981)
Eucalyptus L'Hér.	Myrtaceae	Current study
Musa acuminata Colla	Musaceae	Chung et al. (2013), Kalshoven (1981)
Nephelium lappaceum L.	Sapindaceae	Chung et al. (2013), Kalshoven (1981)
Oryza L.	Poaceae	van der Gott (1930)
Pogostemon cablin (Blanco) Benth.	Lamiaceae	Darwis (2005)
Psophocarpus tetragonolobus (L.) D.C.	Fabaceae	Anna and Adisoemarto (1984)
Shorea Roxb. ex C.F. Gaertn.	Dipterocarpaceae	Intari (2005)
Vigna unguiculata (L.) Walp.	Fabaceae	Rahayuningsih et al. (1984)
Zea mays L.	Poaceae	Chung et al. (2013), Tung (1983)
Zingiber officinale Roscoe	Zingiberaceae	Hartatik and Yasa (2015)

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Table 3. Geographical distribution of *Exopholis hypoleuca* (Coleoptera: Scarabaeidae: Melolonthinae: Leucopholini)

Country	Locality	References
Indonesia	Aek Nauli, North Sumatra	Current study
	Ambon Island, Maluku	Brenske (1894)
	Bogor, West Java	Hanna and Adisoemarto (1984), Leefmans (1929), Rahayuningsih et al. (1984)
	Borneo	Brenske (1894)
	Java	Brenske (1894)
	Nanggung, West Java	Luther (2006)
	Nias, North Sumatra	Brenske (1894)
	Sukamulya, Sukabumi, Java	Darwis (2005)
	Sumatra	Brenske (1894)
	-	Kalshoven (1981)
Malaysia	Borneo	Brenske (1894)
	Cameron Highlands, Pahang	Abdullah et al. (2011)
	Sepilok, Sandakan, Sabah, Borneo	Chung et al. (2013)
Myanmar	-	Dalla Torre (1912)

-= Unknown.

The data of *E. hypoleuca* population dynamics in *C. citrodora* did not follow normal distribution (Kolmogorov-Smirnov test; D= 0.20489; *p*-value= 0.00056; standard deviation= 7.397118; skewness= 2.364093; kurtosis= 8.4091). *Exopholis hypoleuca* was recovered at every collection date, except in March 2020 (Figure 2, Table 4). The collection of *E. hypoleuca* from August 2019 to February 2021 in the current study agrees with reports of this insect throughout the year in several localities in Indonesia (Kalshoven, 1981). *Exopholis hypoleuca* adults were collected during the dry season (from April to May) in Sepilok (Chung, 1998) and at the end of the dry season (September and October) in Bogor (Hanna and Adisoemarto, 1984; Rahayuningsih et al., 1984), indicating year-round activity of this insect in North Sumatra.

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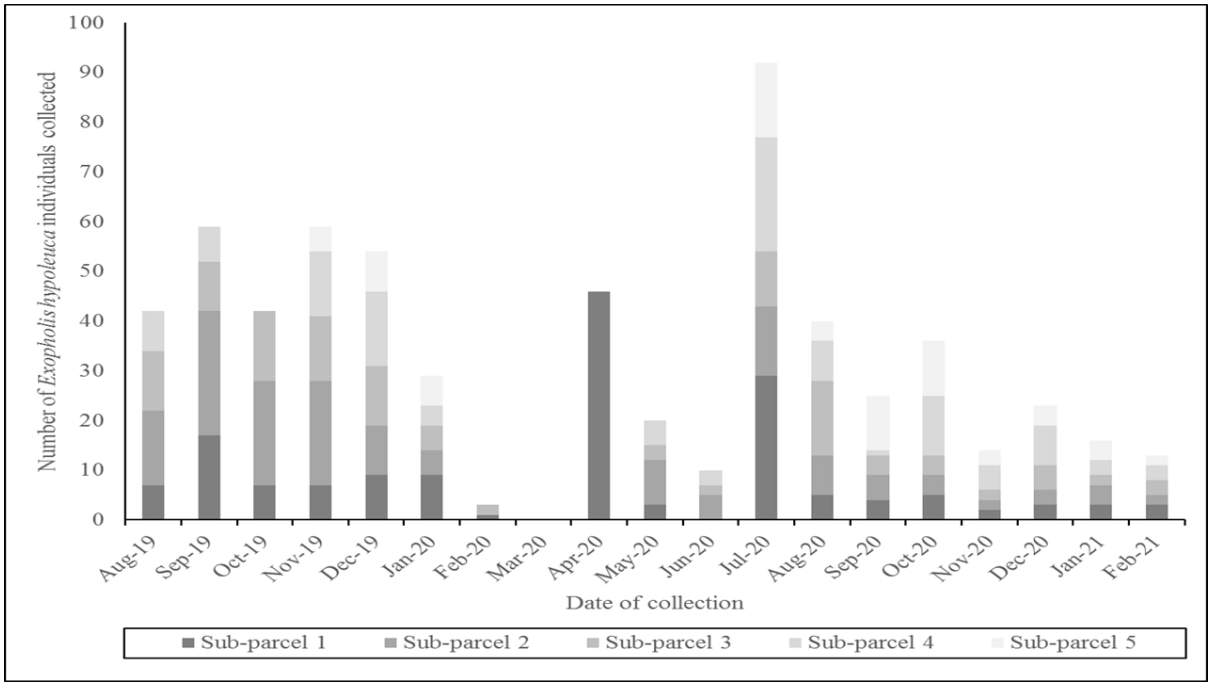

Figure 2. Population dynamic of *Exopholis hypoleuca* (Coleoptera: Scarabaeidae: Melolonthinae: Leucopholini) per *Corymbia citriodora* (Myrtaceae) sub-parcel with monthly collections for 19 consecutive months in Aek Nauli, North Sumatra, Indonesia. Aug= August, Sep= September, Oct= October, Dec= December, Jan= January, Feb= February, Mar= March, Apr= April, Jun= June, Jul= July, 19= 2019, 20= 2020, 21= 2021. Kolmogorov-Smirnov test; D= 0.20489; *p*-value= 0.00056; standard deviation= 7.397118; skewness= 2.364093; kurtosis= 8.4091.

Table 4. *Exopholis hypoleuca* (Coleoptera: Scarabaeidae: Melolonthinae: Leucopholini) stages from individuals collected in a *Corymbia citriodora* (Myrtaceae) parcel in Aek Nauli, North Sumatra, Indonesia

Insect stages	Date of collection
Egg	Apr-20, May-20, Jun-20
Larva*	Jan-20
First instar	Aug-19, May-20, Jun-20, Jul-20, Aug-20, Jan-21, Feb-21
Second instar	Aug-19, Sep-19, Oct-19, Nov-19, Aug-20, Sep-20, Oct-20
Third instar	Nov-19, Dec-19, Nov-20, Dec-20
Pupa	Dec-19, Jan-20, Feb-20, Jan-21
Adult	Jan-20, May-20, Jun-20

*Larval instar was not identified. Aug= August, Sep= September, Oct= October, Dec= December, Jan= January, Feb= February, Mar= March, Apr= April, Jun= June, Jul= July, 19= 2019, 20= 2020, 21= 2021. Insects were collected in all months, except in March 2020.

Conclusion and Recommendation

Identification of white grub species as *E. hypoleuca* and notes on its biology are information that support the management of this insect. Year-round population dynamics of *E. hypoleuca* in North

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Sumatra indicate that management activities must be regularly employed against white grubs on *C. citriodora* and *Eucalyptus* plantations in North Sumatra.

Funding
This work received financial support from the following Indonesian companies: PT. Toba Pulp Lestari (TPL), PT. Riau Andalan Pulp and Paper (RAPP) and Asia Pacific Resources International Holdings Ltd. (APRIL).

Competing interests
The authors declared that no competing interests exist in the preparation of the manuscript.

Acknowledgements
Thanks to Ervan S. Purba, Jeremia A. Hasugian and Riyanti L. Pasaribu for their assistance in field and laboratory activities. The English of the final version was revised by Adam Batten from Get It Right in Jakarta, Indonesia.

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