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Parasitoid of coffee berry borer, *Hypothenemus hampei* Ferrari (Coleoptera: Curculionidae) at Bogor District, West Java, Indonesia

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Abstract. *Saputra HM, Maryana N, Pudjianto. 2023. Parasitoid of coffee berry borer,* Hypothenemus hampei *Ferrari (Coleoptera: Curculionidae) at Bogor District, West Java, Indonesia. Biodiversitas 24: 6447-6453.* The coffee berry borer (CBB), *Hypothenemus hampei* Ferrari (Coleoptera: Curculionidae), is a pest that causes significant economic losses and decreases the quality of coffee berries. Parasitoids are natural enemies that can help control the presence of CBB in the ecosystem. This study aimed to identify and describe the parasitoid of CBB in Bogor District, West Java, Indonesia. The study was conducted from June 2022 to January 2023 on three coffee cultivation located in three sub-districts in Bogor District, i.e., Cijeruk, Dramaga, and Sukamakmur. This study collected attacked coffee berries by CBB from coffee cultivation and kept them until the parasitoids emerged. Ten species of Hymenopteran parasitoids belonging to five families were found. These parasitoids were Microgastrinae, Mendesellinae (Braconidae), *Trissolcus* sp. (Scelionidae), *Anagyrus* sp., *Marxella* sp., *Procheiloneurus* sp., *Pararhopella* sp., *Parablastothrix* sp. (Encyrtidae), *Pronotalia* sp. (Eulophidae), and *Pteromalus* sp. (Pteromalidae). The morphological characters and descriptions of parasitoids CBB were presented. Despite the diverse range of parasitoids found, their number was low.

Keywords: Bogor District, Coffee, Hymenopteran parasitoids, *Hypothenemus hampei*, natural enemies

INTRODUCTION

Coffee plants, of the genus *Coffea* are one of the commodities worldwide with high economic value (Cure et al. 2020). They originated in tropical Africa and were introduced to Indonesia in the late 16th century. Indonesia is an ideal place for coffee plants to develop, with robusta coffee (*C. canephora*) being more dominated rather than arabica coffee (*C. arabica*). Java, Sumatra, and Sulawesi are the three Primary regions in Indonesia known for their coffee production, with Java being the most prominent and best coffee producer. Bogor District, located in West Java, has several coffee plantations that produce high-quality coffee berries, reaching 4,632 tons in 2021 (BPS 2021). However, coffee production can be influenced by various factors, resulting in fluctuations in production. The primary pest that attacks coffee plants is the berry borer, *Hypothenemus hampei* Ferrari (Coleoptera: Curculionidae), commonly known as the coffee berry borer (CBB) (Vega et al. 2015). CBB is the most damaging insect pest worldwide. That affects coffee plants (Johnson et al 2019; Rasiska 2022). It causes low-quality coffee (Vijayalakshmi et al. 2014). Symptoms caused by CBB attacks are holes in the crackle marks at the end of the coffee berry (Efrata et al. 2023), blackish with seed damage, and even resulting in the fall of coffee berries. The CBB can cause economic losses due to decreased production and affect the quality of coffee berries produced. It attacks coffee berries ranging from green berries to post-harvest, with heavy attacks resulting in up to 100% yield loss (Aristizabel et al. 2023). The total losses caused by CBB attacks can exceed 500 million dollars each year (Perez et al. 2015).

Several control techniques can be applied to suppress the pest population, specifically for CBB i.e., cultural, physical, mechanical, chemical, and biological control. One of the most commonly used methods is biological control, which involves using natural enemies such as parasitoids to control the attack of CBB (Calatayud et al. 2020). Parasitoids are insects that parasitize other insects during the larval phase and are an important component of integrated pest management (IPM) systems (Calatayud et al. 2020). Taxonomically, 80% of parasitoids belong to the order Hymenoptera, which is one of the largest insect orders worldwide, with over 300,000 species estimated (Goulet and Huber 1993). Using parasitoids as biological control agents can reduce CBB infestation, as these insects can live outside or inside the host's body by sucking the host's body fluids. Parasitoids, such as *Cephalonomia stephanoderis* Betr., *Prorops nasuta* (Hymenoptera: Bethylidae), *Heterospilus coffeicola* (Hymenoptera: Braconidae), *Phymasticus coffea* La Salle and *Tetrastichus* sp. (Hymenoptera: Eulophidae) (Portilla and Grodowitz 2018), have been reported to attack CBB. Based on the studies that have been conducted, each parasitoid has a distinct level of effectiveness when attacking CBB; parasitoid *P. coffea* has the highest level, followed by parasitoid *C. stephanoderis*, while parasitoid *C. hyalinipennis* and *P. nasuta* have the lowest levels of effectiveness (Rodriguez et al. 2017). Information related to parasitoids on CBB in Bogor District is not yet available.

Therefore, the present study aimed to determine the species of parasitoids that can control CBB in the Bogor District, West Java, Indonesia.

MATERIALS AND METHODS

The study was conducted from June 2022 to January 2023. Samples of coffee berries attacked by CBB were obtained from three coffee cultivation (Tabel 1) located in 3 sub-districts in Bogor District, i.e., Cijeruk (6°42'34.10''S, 106°46'47.50''E), Dramaga (6°33'09.4''S, 106°43'02.5''E) and Sukamakmur (6°38'0.20''S, 106°59'22.20'' E). Maintenance of coffee berries attacked by CBB was carried out in the Insect Biosystematics Laboratory, Department of Plant Protection, IPB University.

Collection of infested berries

Coffee that was attacked by berry borers was picked from plants and put into aerated plastic. The attacked coffee berries can be recognized by the perforated symptoms at the end of the coffee berry (Figure 1). The number of infested coffee berries taken at each location was 350. The collected berries were maintained in the laboratory to determine the parasitoid species.

Maintenance of the collected berries in the laboratory

The coffee berries attacked by CBB collected from the coffee cultivation were kept in the laboratory. The attacked coffee berry was aerated and wrapped by tissue to remove excessive moisture content, and tissue was used to clean the berries' surface to prevent the infestation of other insects. Next, the berry was put in a handling bottle (Figure 2) coated with paper towels. Maintenance lasted 2-3 weeks until parasitoids emerged. Handling bottles were stored in racks with an inclined position, and light was given to attract parasitoids out. The emerging parasitoid was stored in a 1.5 ml vial tube containing 70% alcohol.

Identification of parasitoids

To identify the parasitoid, a book by Goulet and Huber (1993) was used up to the family level. For identification up to the subfamily level to the genus level was carried out based on observations of parasitoid body morphological characters using identification by Masner (1976), Noyes and Hayat (1984), Boucek (1988), and Wharton (1997). Identification and photo-taking were done using the Olympus SZ51 camera and Leica M205C stereo microscopes with Leica DFC450 and LAS V.4.4.0 digital camera applications connected to a computer.

Data analysis

The identified parasitoids were tabulated using Microsoft Excel 365 to determine their number and visualized into a table form.

Figure 1. Coffee berry attacked by CBB

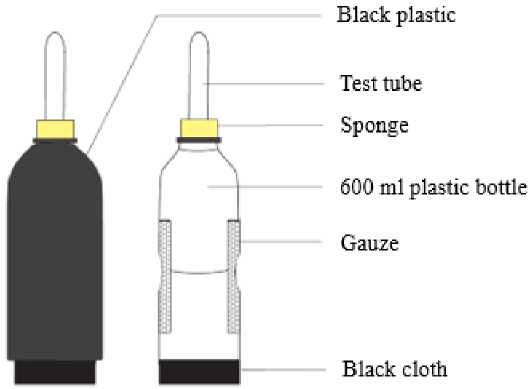

Figure 2. Handling bootle for coffee berries attacked by CBB

Table 1. General conditions in coffee cultivation

Location	Altitude (m asl.)	Age (year)	Distance (m x m)	Cropping pattern	Types	Berry color	Shade plants
Dramaga	173	5-8	2.50 x 2.50	Monoculture	Robusta	Red	Durian
Cijeruk	779	6-10	3.00 x 3.00	Monoculture	Robusta	Red	No shade
Sukamakmur	1,168	4-6	3.00 x 3.00	Monoculture	Arabica	Red	Baros, fir, cipore, jackfruit, cinnamon

Note: m asl.: meters above sea levels

RESULTS AND DISCUSSION

Based on observation, as much ten species of Hymenoptera parasitoids were found consisting of five families, namely Microgastrinae gen. sp., Mendesellinae gen. sp. (Braconidae), *Trissolcus* sp. (Scelionidae), *Anagyrus* sp., *Marxella* sp., *Procheiloneurus* sp., *Pararhopella* sp., *Parablastothrix* sp. (Encyrtidae), *Pronotalia* sp. (Eulophidae) and *Pteromalus* sp. (Pteromalidae).

The identification of parasitoids

During this study, we collected the parasitoid Microgastrinae gen. sp., Mendesellinae gen. sp., *Trissolcus* sp., *Anagyrus* sp., *Marxella* sp., *Procheiloneurus* sp., *Pararhopella* sp., *Parablastothrix* sp., *Pronotalia* sp. and *Pteromalus* sp. One individual female of Microgastrinae gen. sp. has a black body (Figure 3A). The body length was 2.30 mm. The antenna was dark, consisting of a scape, pedicel, and sixteen segments of flagellum. It had no occipital carina. The forewing had complex veins; m-cu was tubular; RS did not reach the wing margin as tubular (Wharton et al. 1997). The mesosoma and metasoma were black. The legs were dark brown. The mandibles were endodon.

The female adult of Mendesellinae gen. sp. had a blackish-brown and metallic body (Figure 3B). The body length was 1.82 mm. The antenna was dark, consisting of a scape, pedicel, and eighteen flagellum segments; the first was 1.5 times longer than the second. It had no occipital carina. The forewing had complex veins; m-cu was unpigmented tubular; RS did not reach the wing margin as tubular; RS was straight and not curved (Wharton et al. 1997). The mesosoma and metasoma were black. The legs were light brown, brighter than the rest of the body. The mandibles were endodon overlapped when the position was closed. A total of one individual was collected.

The female adult of *Trissolcus* sp. had a black and metallic body. The compound eyes were black and glabrous, not hairy (Masner 1976) (Figure 3C). The body length was 0.75 mm. The antenna was light to dark brown, consisting of a scape, pedicel, five funicle segments, and three clava segments, darker than the rest. The forewing was metallic hyaline with setae on the surface; there were only marginal and stigmal veins. The legs were yellow. The tarsi were five segments. The mesosoma and metasoma were black (Masner 1976). A total of three individuals were collected.

The female adults of *Anagyrus* sp. had a black and non-metallic body. The compound eyes were black (Figure 3D). The body length was 1.44 mm. The antenna consists of an enlarged black scape, a pedicel, six pieces of black and white funicle, and two white clavas. The mesosoma was black; the mesoscutum had visible notaular lines; the scutellum had two submarginal lines divided into three parts accompanied by two pairs of setae. The metasoma was black; one-third part of it contained cerci. The forewing was metallic hyaline without pattern; it had *linea calva* on the posterior marginal vein; the post marginal vein was no longer than the stigmas (Noyes and Hayat 1984); it had setae on the submarginal vein. The legs were brownish yellow; the femur was brownish black; the spines were on the tip of the tibia; the tarsi were five segments. A total of two individuals were collected.

The female adult of *Marxella* sp. had a light-to-dark yellow body, not metallic. The compound eyes were dark brown (Figure 3E). The body length was 1.04 mm. The antenna consists of a scape, a pedicel, and three segments of the funicle; three segments of the Clava were shorter than the combination of the pedicel and funicle (Noyes and Hayat 1984). The forewing hyaline on the surface had spine-like setae in the submarginal vein. The legs were brownish yellow; the femur was brownish black; the spines were on the tip of the tibia. The metasoma had a brighter yellow color than the rest of the body; there were cerci on one-third of the posterior part of the metasoma. A total of one individual was collected.

The female adult of *Procheiloneurus* sp. had a black and non-metallic body (Figure 3F). The compound eyes were black. The body length was 0.97 mm. The antenna consists of a scape that did not enlarge, 3 times longer than width; pedicel; six segments of cylindrical funicle with the first and second segments longer than width; three rounded segments of clava. The forewing was metallic hyaline, with a black and white setae pattern adjacent to the *linea calva*. The pronotum has a pair of white spots, the scutellum with thin tufts (Noyes and Hayat 1984). The legs were white; spines were on the tip of the tibia. The mesosoma was black. The metasoma was black; hypopygium did not reach two-thirds of the metasoma. A total of one individual was collected.

The female adult of *Pararhopella* sp. had a combined color of the dark brown and black body, non-metallic (Figure 3G). The compound eyes were black. The body length was 0.74 mm. The antenna comprises a scape, pedicel, five cylindrical funicle segments, and three clava segments. The forewing was membraneus hyaline with setae on the surface and had a short postmarginal vein, not longer than the stigmal vein (Noyes and Hayat 1984). The mesosoma was dark with a dark brown layer; mesoscutum without clear notaular lines. The legs were light brown; spines were on the tip of the tibia. The metasoma had a dark base color and dark brown, yellow to green color patterns. A total of one individual was collected.

The female adult of *Parablastothrix* sp. had a black body with a solid metallic green sheen (Figure 3H). The compound eyes were black and located near part of the mandibles. The body length was 1.12 mm. It had a short malar space, no more than one-fifth of the length of compound eyes (Noyes and Hayat 1984). The antenna had a light brown color consisting of a scape three times longer than its width, a pedicel, six pieces of funicle, and three segments of clava. The forewing had setae on the surface and *a linea calva*. The legs were greyish white; spines were on the tip of the tibia. The mesosoma was black. The metasoma was black with a metallic green sheen; one-third contained cerci. A total of one individual was collected.

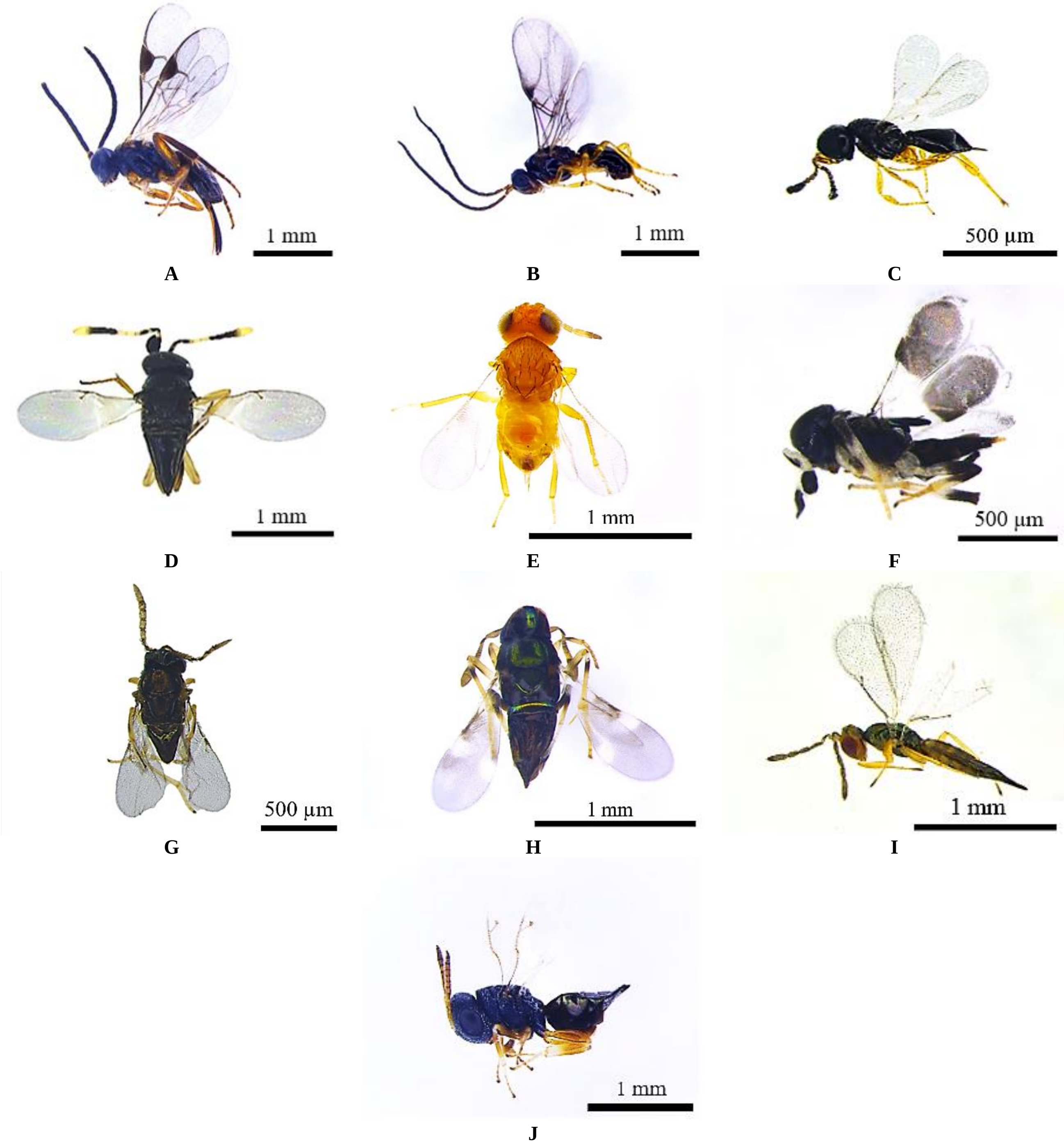

Figure 3. Parasitoid on coffee berry borer: A) Microgastrinae gen. sp. (female); B) Mendesellinae gen. sp. (female); C) *Trissolcus* sp. (female); D) *Anagyrus* sp. (female); E) *Marxella* sp. (female); F) *Procheiloneurus* sp. (female); G) *Pararhopella* sp. (female); H) *Parablastothrix* sp. (female); I) *Pronotalia* sp. (female); J) *Pteromalus* sp. (female)

The female adult of *Pronotalia* sp. had a body with a combined color of green, black, and metallic yellow (Figure 3I). The compound eyes were red. The body length was 1.39 mm. The antenna had a light to dark brown consisting of a scape, pedicel, three segments of funicle, and three segments of clava. The forewing was hyaline with smooth setae on the surface; there was a longer setae around the margin. The legs were light yellow. The mesosoma was black with a yellowish-green sheen; the scutellum had two pairs of setae; there were notaular lines on the mesoscutum (Gibson et al. 1997). A total of one individual was collected.

The female adult of *Pteromalus* sp. had a black and non-metallic head and mesosoma but metallic on metasoma (Figure 3J). The body length was 2.51 mm. The antenna had a dark brown color consisting of a scape, pedicel, two segments of anelli, five segments of funicle that extend in size than width, and three segments of the clava. The forewing had setae on the surface and had a long postmarginal vein (Boucek 1988). The legs were brownish yellow; spines were on the tip of the tibia. The metasoma was black with a metallic green sheen. A total of three individuals were collected.

Discussion

It has been reported that various species of parasitoids can control CBB in ecosystems in Indonesia and the world. These parasitoids include *Cephalonomia hyalinipennis*, *Cephalonomia stephanoderis*, *Prorops nasuta*, (Rodriguez et al. 2017), *Phymastichus coffea* (Yousuf et al. 2021), *Heterospilus coffeicola* (Jaramillo et al. 2009), *Elachertus* sp., *Anagyrus* sp., *Copidosoma* sp., and *Erythmelus* sp. (Jannah 2017). However, only a few of these parasitoids were known to have enough potential to control CBB. The study result of Rodriguez et al. (2017) in Colombia found that a single release of Eulophid *P. coffea* can reduce up to 47.38% in CBB infested berries on the plant, *C. stephanoderis* reduce 1.3%, *C. hyalinipennis* reaches 16.93% reduction, while *P. nasuta* reaches 16.83%.

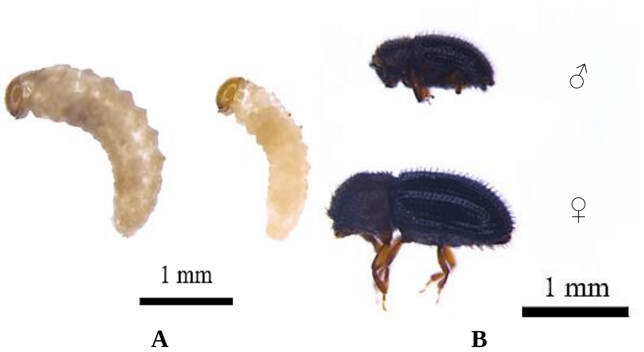

Figure 4. The coffee berry borer. A. Larvae; B. Adult

Table 2. The individual number of parasitoids attacked CBB

Parasitoid	Location		
	Dramaga	Cijeruk	Sukamakmur
Braconidae			
Mendesellinae gen. sp.	-	1	-
Microgastrinae gen. sp.	-	1	-
Scelionidae			
Trissolcus sp.	3	-	-
Encyrtidae			
Anagyrus sp.	1	1	-
Marxella sp.	-	-	1
Procheiloneurus sp.	1	-	-
Pararhopella sp.	1	-	-
Parablastothrix sp.	-	1	-
Eulophidae			
Pronotalia sp.	1	-	-
Pteromalidae			
Pteromalus sp.	-	3	-

Ten species of Hymenopteran parasitoids were found during this study. These parasitoids were identified morphologically to the subfamily and genus level. The identification results are acceptable because of the limited identification key for the family Braconidae in Indonesia. Parasitoids in each location differ in the number of individuals (Table 2). For instance, five taxa of parasitoids found in Cijeruk, namely Mendesellinae gen. sp., Microgastrinae gen. sp., *Anagyrus* sp., *Parablastothrix* sp., and *Pteromalus* sp. (Table 2). There were five species of parasitoids found in Dramaga, namely *Trissolcus* sp., *Anagyrus* sp., *Procheiloneurus* sp., *Pararhopella* sp., and *Pronotalia* sp. Meanwhile, only one parasitoid species was found in Sukamakmur, namely *Marxella* sp. Based on this, only the parasitoid *Anagyrus* sp. was found in two different locations, namely Cijeruk and Dramaga. At the same time, there were only two types of parasitoids with more than one individual found in this study, namely *Pteromalus* sp. (Pteromalidae) and *Trissolcus* sp. (Scelionidae).

In this study, all parasitoids came from families within the same order, Hymenoptera. Microgastrinae and Mendesellinae belonging to the family Braconidae were discovered during this study. Microgastrinae, on the other hand, is a known parasitoid that attacks Lepidoptera (Wharton et al. 1997; Gupta and Fernandez-Triana 2014). Mendesellinae is a small group of family Braconidae (Bortoni et al. 2017), which has limited information related to biology and the host attacked range because this subfamily is rarely found (Wharton et al. 1997).

Trissolcus sp. belongs to the subfamily Telenominae in the family Scelionidae and was discovered during this study. This subfamily was known as a primary egg parasitoid of Hemiptera (Sabbatini-Peverieri et al. 2020), Lepidoptera, and rarely of Diptera and Neuroptera (Masner 1976).

The subfamily of Encyrtinae (Encyrtidae) that were identified in this study were *Marxella* sp., *Procheiloneurus* sp., *Pararhopella* sp., and *Parablastothrix* sp. Information on *Marxella* sp., *Procheiloneurus* sp., and *Pararhopella* sp. was limited and unknown specifically, so information related to biology and its host range was not widely known (Noyes and Hayat 1984). *Parablastothrix* sp. was known as a larval parasitoid of the families Lyonetiidae and Nepticulidae in the order Lepidoptera (Noyes and Hayat 1984). Another parasitoid *Anagyrus* sp. belongs to the subfamily Tetracneminaeare known to parasitize on Pseudococcidae (Hemiptera) and Coccinellidae (Coleoptera) (Noyes and Hayat 1984). Information on *Anagyrus* attacking CBB had been reported from Banyuwangi District, East Java, Indonesia (Jannah 2017).

Pronotalia sp. (Eulophidae: Tetrastichinae) was discovered in this study. Subfamily Tetrastichinae was known as a primary parasitoid in Lepidoptera (Boucek 1988), while the genus *Pronotali* was known as a gregarious parasitoid in Diptera, family Tephritidae and Agromyzidae (Gibson et al. 1997).

Pteromalus sp. belongs to the subfamily Pteromalinae (Pteromalidae) and was found to attack CBB in this study. Pteromalidae is the largest family of Hymenopteran Chalcidoidea, found in all regions worldwide and showcasing a wide range of biology and morphology (Boucek and Heydon 1997). The classification of Pteromalidae coincides with that of its host. The biology of Pteromalidae is diverse. The majority of Pteromalidae species are parasitoids, primary or secondary parasitoids of a wide range of insect orders, including Coleoptera, Diptera, Hemiptera, Hymenoptera, and Lepidoptera (Baur 2015). Some Pteromalidae is phytophagous, developing inside seeds that consume certain grasses or soft parts of the plant. Many Pteromalidae species attack concealed hosts i.e., wood borers, stem miners, leaf miners, and gall formers (Baur 2015). Pteromalidae plays an essential role in nature. Meanwhile, the subfamily Pteromalinae lacks characters that define other families and is difficult to diagnose. Lepidoptera, Diptera, and Coleoptera are the primary hosts of most species in this subfamily (Ko et al. 2018).

The information on parasitoids, especially in Bogor District, is not yet known, specifically as parasitoids of CBB. Furthermore, it added new information about the parasitoid of CBB. The number of parasitoid CBB was low. It was not the natural enemies of CBB, but the local parasitoids on coffee cultivation. The local parasitoids try to form associations with CBB due to adaptation to the environment. However, based on the handling methods (Figure 2), the collected berries attacked by CBB were cleaned to prevent the other insects from contaminating in the handling bottle. This meant that only CBB (Figure 4) was present in the collected berries in the handling bottle. Thus, the parasitoids found in this study were identified as parasitoids of CBB.Ecological studies often focus on the interactions between parasitoids, their hosts, and populations. Therefore, parasitoids are necessary to control pests biologically. The parasitoid taxa of Hymenoptera are an interesting study, with numerous species that need to be identified, and their biology is unknown (Forbes et al. 2018; Haas et al. 2021). Numerous studies have been conducted on how parasitoids affect their hosts and can cause host populations to deteriorate (Abdala-Roberts et al. 2019). As the populations of parasitoids and their hosts are inversely correlated, the number of hosts increases as the parasitoid population does as well. This is influenced by various other factors, including the vegetation's diversity and abundance (Maqalina et al. 2021). According to the conditions of the coffee cultivation in the three research areas, Cijeruk and Dramaga were sizable open spaces with various surrounding vegetation, including grass, flowering plants, and fruit trees. Sukamakmur had lower species of parasitoid than others related to its altitude. Sukamakmur sub-district is the highest altitude (1,168 m asl) in this research area, it was related to the presence of CBB. Higher altitudes, such as those above 1,000 m asl, result in a lower infestation of CBB (Erfandari et al. 2019). This low infestation is linked to a smaller number of CBB, leading to a lower diversity of parasitoids.

This study has identified ten parasitoids that were found during the maintenance of coffee berries that were attackedCBB in the laboratory. In addition, to the previously recognized parasitoids, these newly discovered ones need to be identified down to the species level. The prevalence of parasitoids was rated as low in Bogor District

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