BIODIVERSITAS
Volume 19, Number 5, September 2018
Pages: 1791-1797

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d190528

Diversity of ambrosia beetles (Coleoptera: Scolytidae) on teak forest in Malang District, East Java, Indonesia

YOGO SETIAWAN, RINA RACHMAWATI, HAGUS TARNO♥
Department Plant Pest and Disease, Faculty of Agriculture, Universitas Brawijaya. Jl. Veteran, Malang 65145, East Java, Indonesia. Tel.: +62-341-551665, 565845. Fax.: +62-341-560011, ♥email: h_gustarno@ub.ac.id, yogosinaga@gmail.com

Manuscript received: 17 June 2018. Revision accepted: 4 September 2018.

Abstract. *Setiawan Y, Rachmawati R, Tarno H. 2018. Diversity of* ambrosia beetles *(Coleoptera: Scolytidae) on teak forest in Malang District, East Java, Indonesia. Biodiversitas 19: 1791-1797.* Ambrosia beetle plays an important role in the temperate forest. Ambrosia beetle lives symbiotically with microorganism such as fungi, bacterium, and yeast that can cause plant wilt and death. In Java, ambrosia beetle has been reported to attack teak plantations in some regions. This research aimed to investigate the diversity of ambrosia beetles in the teak plant on monoculture and polyculture system in Malang District. This research was conducted in the teak forest in Dampit and Sumbermanjing Wetan, Malang District from March to May 2017. Ambrosia beetles were trapped by using baited bottle trap with 95% ethanol. The diversity of ambrosia beetles trapped was analyzed using Vegan package in R program to calculate the Shannon-Wiener diversity index (H), Species Evenness index (E), and Simpson's dominance index (D). The results showed that ambrosia beetles trapped in monoculture and polyculture teak plants system consist of nine species, i.e*.*, *Xylosandrus crassiusculus*, *X. morigerus*, *X. compactus*, *Xyleborus perforans*, *Euwallacea simillis*, *Xyleborinus andrewesi*, *Premnobius cavipennis*, *Coccotrypes distinctus,* and *Hypothenemus hampei*. The Shannon Wiener index of Ambrosia beetles in polyculture (H=1.40) was higher than in monoculture (H=1.30), and both locations were categorized in the medium diversity category. The Species Evenness index of ambrosia beetles in polyculture (E=0.67) and monoculture (E=0.66) were also categorized in medium category. The Simpson's dominance index in both locations was categorized in the middle dominance species. *X. crassiusculus* was the dominant species in polyculture and monoculture teak plant system.

Keywords: Ambrosia beetles, diversity, Scolytidae, teak forest

INTRODUCTION

Ambrosia beetles (Coleoptera: Scolytidae) play an important role in the temperate forest ecosystem and also cause substantial economic losses (Lindgren and Raffa 2013). Ambrosia beetles live symbiotically with microorganisms such as fungi, bacterium, and yeast and cause major plant diseases that can cause plant wilt and die (Tarno et al. 2016). They are abundant in the tropics region, and responsible for economic damage to the timber and wood industry (Bumrungsri et al. 2008). Worldwide, the ambrosia beetles contain 7400 species, and over 6000 species belong to Scolytidae (Kirkendall et al. 2015). Ambrosia beetles have been reported to attack many forest plants and teak plantation (Nair 2007).

Tectona grandis L. is native in Indonesia especially in Java and Muna, but teak forest mostly found in Java (Pratiwi and Lust 1994). Teak is one of the most important tropical hardwood tree in the international market as the high-quality timber. This plant has aesthetic values that make it the precious wood for forestry plantation (Bermejo et al. 2004). In Malang District, the plantation teak forests grow in monoculture and polyculture system and carry out by Perum Perhutani.

In several countries, teak plants have been attacked by Scolytidae. In India, teak plants were attacked by five species of ambrosia beetles, i.e. *Trachipholis hisida, Cryphalus tectonae, Xyleborus velatus, Xy. naxius and Xy. hagedorni* (Patil et al. 2016). *Xylosandrus* sp. and *Hypothenemus* sp. were also reported attack teak plant in Ghana and Mexico (Nair 2007). *Xy. Destruens* was reported in the occurrence of the borer of teak plantations growing in South Malang and some regions in Java and now is widely distributed (Kalshoven 1981). They are attacking living teak plant and making branching tunnels that extend into the heartwood (Nair 2007).

Outbreaks of ambrosia beetle population are difficult to detect or forecast, and application of insecticidal treatments perform poorly (Werle et al. 2011). Baited traps with chemical attractants commonly are as an effective control used to capture ambrosia beetles for monitoring, studying population dynamics, predicting outbreaks, and mass trapping to reduce damage (Burbano et al*.,* 2012). Some studies have shown that an ethanol-baited trap can collect a variety of ambrosia beetle species thus it can be facilitated the monitoring of beetle populations (Reding et al. 2011; Werle et al. 2011; Galko 2014).

There is no recent report about ambrosia beetle that attacks teak plant grown in monoculture and polyculture in Malang District. Studies on the diversity of ambrosia beetles in forestry plants especially in the teak plantation are needed because ambrosia beetle is a pest that can damage and increase the economic losses of wood. This research aimed to investigate the diversity of ambrosia beetles in monoculture and polyculture teak plant system in Malang District, East Java, Indonesia.

MATERIALS AND METHODS

Study site

This research was conducted in the teak forests in two Subdistricts in Malang District, East Java, Indonesia (Dampit and Sumbermanjing Wetan) from March to May 2017. The identification of specimens was done in the Laboratory of Plant Pest, Faculty of Agriculture, Brawijaya University. Dampit Subdistrict was monoculture teak plant system, while Sumbermanjing Wetan Subdistrict was polyculture teak plant system with coffee (*Coffea arabica* L.) and mahogany (*Swietenia mahogany* L.). Locations of observations were described in Figure 1 and Table 1.

Procedures: Ambrosia beetles collection and identification

Ambrosia beetles were trapped by using baited bottle trap with 95% ethanol that tied up in teak plants approximately 1 m above the ground (Figure 2) (Oliver et al. 2004; Steininger 2015). At each site, 20 ethanol-bait bottle traps were deployed, and each site was divided into two plots. Each plot was set up as about 10 traps with the distance between the trap was approximately 20 m. Samples were taken eight times with three days interval a month. The trapped ambrosia beetles in bottle trap were collected and fixed on 70% ethanol in small tubes. Identification of ambrosia beetle was based on morphological character, i.e. body size, elytra, and color of the body using the identification keys of Ambrosia beetles (Rabaglia et al. 2006; Wood 2007; Hulcr and Smith 2010).

Table 1. Details of ambrosia beetles sampling in monoculture and polyculture teak plant system, Malang District, East Java, Indonesia

Sites	Plots	Altitude (m asl.)	GPS coordinates
Monoculture	M1	396	06° 87’79.0” S, 90° 90’92.8” W
	M2	392	06° 87’55.3” S, 90° 91’10.6” W
Polyculture	P1	401	06° 85’80.1” S, 90° 89’46.9” W
	P2	403	06° 85’70.6” S, 90° 89’36.1” W

Note: M1: Monoculture plot 1, M2: Monoculture plot 2, P1: Polyculture plot 1, P2: Polyculture plot 2 and Masl: Meters above sea level

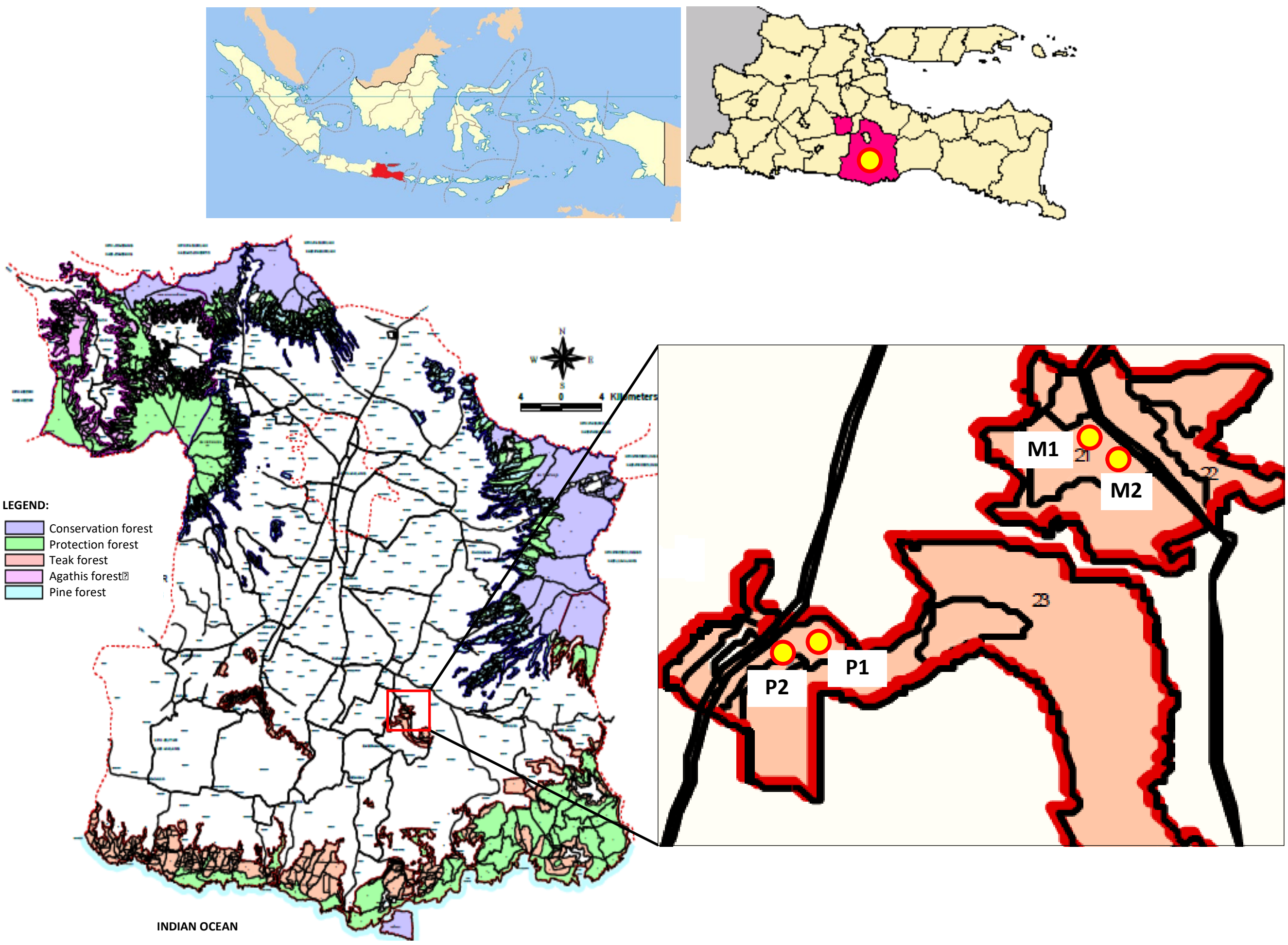

Figure 1. Sampling site in Dampit and Sumbermanjing Wetan Sub-district, Malang District, East Java, Indonesia. M1: Monoculture plot 1, M2: Monoculture plot 2, P1: Polyculture plot 1 and P2: Polyculture plot 2 (Source: Perum Perhutani KPH Malang 2002)

Figure 2. Ethanol bait bottle trap was used to collect ambrosia beetles

Data analysis

Diversity of ambrosia beetles were analyzed using R program with Vegan package to calculate the value of Shannon Wiener diversity index (H), Species Evenness index (E) and Simpson's dominance index (D) (Oksanen 2015; R Core Team 2017).

RESULTS AND DISCUSSION

Diversity and abundance of ambrosia beetles in monoculture and polyculture teak plant system

Species abundance of ambrosia beetles found in the monoculture and polyculture teak plant system was different. Polyculture teak plantations system had higher number of species and individual than monoculture system. The most abundant species in both locations was *X. crassiusculus* (Table 2).

The polyculture teak plantation system had higher Shannon Wiener diversity index than monoculture (Table 3). Both of them were categorized in the medium diversity category because the individual distribution for each species was in the middle level. This showed that the ecosystem of both locations was unstable. According to Tarno et al. (2016), the value of diversity index between 1 and 3 is categorized in the middle level of diversity and middle level of individual distribution for each species. Teak forest in Indonesia is an industrial plantation, and there are human activities such as the cultivation of coffee and seasonal crops so the ecosystem of teak forests is unstable. The Species Evenness index of ambrosia beetles in both locations was also categorized in medium category. Tarno et al. (2016) stated that the value of Evenness index between 0.50 and 0.75, is categorized in the medium level. It means that the community is unstable. The Simpson's dominance index in both locations was categorized in middle dominance of species (Table 3). It showed that there were still dominant species in both locations, although even in the medium category. Dominance species in both locations caused by the ecosystem in teak forests unstable, those the species has not been distributed evenly.

Flight activity of three dominant species of ambrosia beetles (*X. crassiusculus, E. similis,* and *X. morigerus*) in monoculture and polyculture teak plant system

During the collection of ambrosia beetle, flight activity of *X. crassiusculus, E. similis,* and *X. morigeru*s fluctuated. Flight activity of *X. crassiusculus* had different pattern with *E. similis* and *X. morigerus*. In both locations, *X. crassiusculus* had the high flight activity on 11 March 2017 (Figure 3), while the highest flight activity of *E. similis* and *X. morigerus* was on 22 March 2017.

Morphological character of ambrosia beetles

Identification of ambrosia beetles was based on morphological character which featured i.e. body size, elytra, and color of the body.

Xylosandrus crassiusculus. Body length was 2.8 mm. Body color was reddish brown. Obsolete was on declivity. Declivity surface was dull, surface with dense, confused small tubercles uniformly distributed from base to apex. Body was less stout. Elytra were longer than pronotum. Declivity was more sloping, and uniformly distributed granules (Figure 4.A).

Table 2. Species diversity and abundance of ambrosia beetles in monoculture and polyculture teak plant system of Malang District, East Java, Indonesia

Species	Abundance	
	Monoculture	Polyculture
Xylosandrus crassiusculus	82	138
Xylosandrus morigerus	18	25
Xylosandrus compactus	4	9
Xyleborinus andrewesi	5	0
Euwallacea similis	22	32
Xyleborus perforans	8	18
Premnobius cavipennis	0	5
Coccotrypes distinctus	0	1
Hypothenemus hampei	2	12
Total	141	240

Table 3. Diversity of ambrosia beetles in monoculture and polyculture teak plant system of Malang District, East Java, Indonesia

Sites	Number of species	Index value		
		H	E	D
Monoculture	7	1.31	0.67	0.61
Polyculture	8	1.40	0.66	0.63

Note: H: Shannon Wiener diversity index, E: Species Evenness index and D: Simpson's dominance index

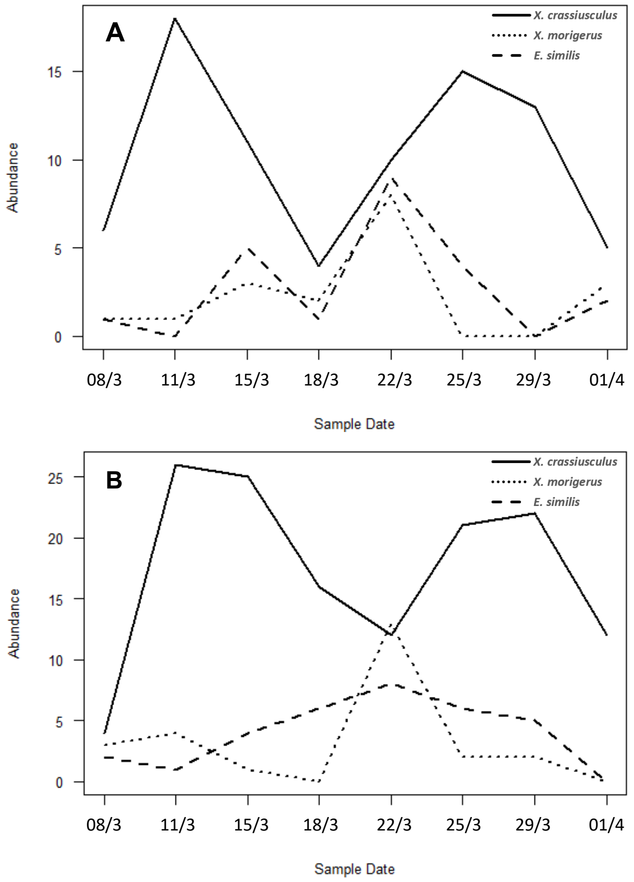

Figure 3. Flight activity of *X. crassiusculus, E. similis,* and *X. morigerus* from March to April 2017in Malang District, East Java, Indonesia; A. Monoculture, B. Polyculture

According to Wood (2007), Rabaglia et al. (2006), and Hulcr and Smith (2010), ambrosia beetle with these morphological characters is *X. crassiusculus.* The present distribution of *X. crassiusculus* is in southern Asia, Africa, Indonesia, Australia, Islands of the Pacific, Europe, and the U.S (Horn and Horn 2006; Gomes et al. 2018).

Xylosandrus morigerus. Body length was 1.6 mm. Declivity was commencing one-third elytra length from base. Body color was yellowish (Figure 4.B).

According to Wood (2007) and Hulcr and Smith (2010), ambrosia beetle with these morphological characters is *X. morigerus.* The present distribution of *X. morigerus* is in Tropical Africa, SE Asia to Micronesia, Hawaii, Mexico to Venezuela, Brazil, Madagascar, Indomalaysian Region, Pacific and South America (Beaver and Browne 1978; Wood 2007).

Xylosandrus compactus. Body length was 1.6 mm. Body color was black. Elytra was more slender, evenly arched from middle of disc to apex. Posterior portion of pronotum was shining (Figure 4.C).

According to Wood (2007), Rabaglia et al. (2006), and Hulcr and Smith (2010), ambrosia beetle with these morphological characters was *X. compactus.* The present distribution of *X. compactus* in tropical Africa, Indomalaysian region, Fiji, Samoa, United States (introduced). Its pantropical distribution includes Brazil, Cuba, Indonesia, Japan, and Sri Lanka (Ceylon) and the occurrence of this species in Java was reported by Beaver and Browne (1978), Dixon et al. (2003), Kalshoven (1981), Wood (2007), and Gomes et al. (2018).

Euwallacea similis. The body length was 2.3 mm. Body color was dark brown. Most of postolateral declivital margin were rounded. Declivity face basically was convex and have two pairs of tubercle. Pronotum was commonly subquadrate (Figure 4.D).

According to Wood (2007), Rabaglia et al. (2006), and Hulcr and Smith (2010), ambrosia beetle with these morphological characters was *E. similis.* The present distribution of *E. similis* in Africa; tropical Asia; North America (introduced): Texas; Oceania; South America (introduced): Brazil and North Australia to Micronesia (Wood 2007; Gomes et al. 2018).

Xyleborus perforans. Body length was 2.2 mm. Body was more slender and yellowish brown. Declivity was rather steep and dull, broadly convex. Surface was rarely shining and opaque (not shiny) when dry, with small tubercle in elytra declivity (Figure 4.E).

According to Wood (2007), Hulcr and Smith (2010), and Bateman and Hulcr (2014), ambrosia beetle with these morphological characters is *Xy. perforans.* The present distribution of *Xy. Perforans* is in circum tropical areas such as Southeast Asia and widespread throughout in Java, Indonesia (Beaver and Browne 1975; Beaver and Browne 1978; Kalshoven 1981).

Premnobius cavipennis. Body length was 2.8 mm. Body color was reddish brown.; Frons were broadly convex. Elytra declivity was broadly, rather deeply, concavely excavated on posterior third of elytra length. Antennal club was strongly fattened (Figure 4.F).

According to Rabaglia et al. (2006), Wood (2007), and Hulcr and Smith (2010), ambrosia beetle with these morphological characters is *P. cavipennis.* The distribution of *P. cavipennis* is in Tropical Africa, introduced to South America (Colombia and Venezuela to Bolivia and Brazil). It is possible the species is also introduced to Asia (Wood 2007).

Xyleborinus andrewesi. Body length was 1.9 mm. Body was dark brown, and elongate-cylindrical. Small knob was surrounded by hair between pronotum and abdomen. Scutellum was depressed below the level of the elytra surface (Figure 4.G).

According to Wood (2007), Hulcr and Smith (2010), and Bateman and Hulcr (2014)**,** ambrosia beetle with these morphological characters is *Xyl. andrewesi. Xyl. andrewesi* previously has been recorded in Andaman Islands, Bangladesh, Burma, China, India, Indonesia, Japan, Malaya, Micronesia, Nepal, New Guinea, Philippine Islands, Ryukyu Islands, Seychelles Islands, Sri Lanka, Thailand, Vietnam and New Zealand (Okins and Thomas 2009; Gomes et al. 2018).

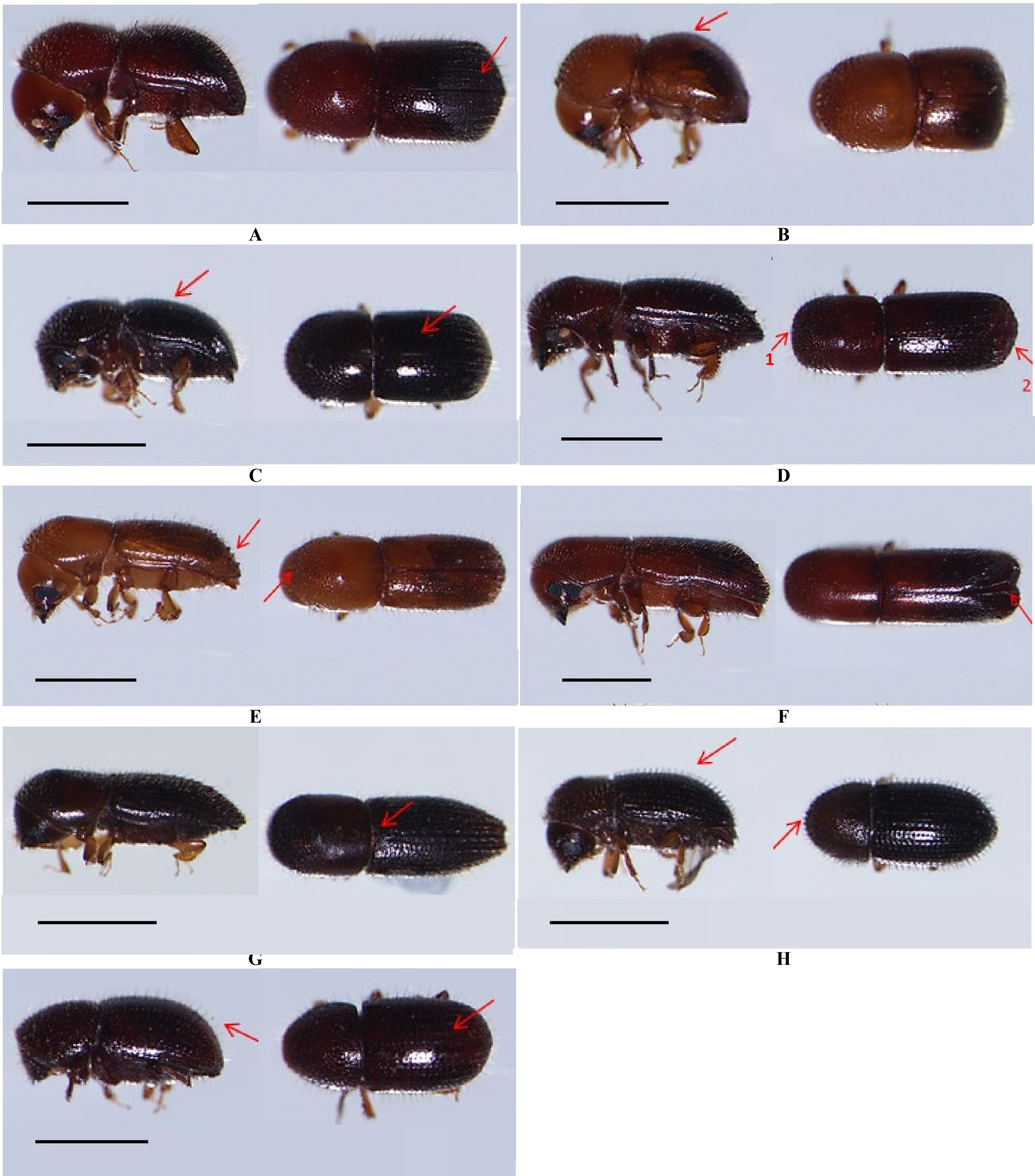

Figure 4. Morphology of ambrosia beetles (Coleoptera: Scolytidae) on teak forest in Malang District, East Java, Indonesia. A. *Xylosandrus crassiusculus*; Lateral side (*left*), and dorsal side, declivity more sloping, declivity surface dull, uniformly distributed granules (*right*). B. *Xylosandrus morigerus*; Lateral side, declivity commencing one-third elytra length from base (*left*), and dorsal side (*right*). C. *Xylosandrus compactus*; Lateral side, elytra more slender, evenly arched from middle of disc to apex (*left*), and dorsal side, surface of elytra shining (*right*). D. *Euwallacea similis*; Lateral side (*left*), and dorsal side, 1. Pronotum commonly subquadrate, 2. Two pairs of tubercle (*right*). E. *Xyleborus perforans*; Lateral side, small tubercle in elytra declivity (*left*) and dorsal side, pronotum commonly convex (*right*). F. *Premnobius cavipennis*; Lateral side (*left*), and dorsal side elytra declivity broadly, rather deeply, concavely excavated on posterior third of elytra length (*right*). G. *Xyleborinus andrewesi*; Lateral side (*left*), and dorsal side scutellum is depressed below the level of the elytra surface (*right*). H. *Hypothenemus hampei*; Lateral side, elytra declivity more gradual, declivity takes up more than half of the length of the elytra (*left*) and dorsal side, very noticeable bumps or teeth on pronotum (*right*). I. *Coccotrypes distinctus*; Lateral side, declivity convex (*left*), and dorsal side, strial punctures shallowly impressed, separated by distances equal to diameter of a puncture (*right*). Bar = 1 mm

Hypothenemus hampei. Body length was 1.1-1.6 mm Body color was black. Anterior margin had a row of serrations, irradiation on the elytra surface, and convex of elytra declivity. Pronotum slope, declivity more gradual, not as steep; declivity takes up more than half of the length of the elytra. Elytra were shiny, hairy or scaly, very noticeable bumps or teeth on pronotum (Figure 4.H). According to Wood (2007), Hulcr and Smith (2010), and Vega et al. (2015), ambrosia beetle with these morphological characters is *H. hampei.* The present distribution of *H. hampei* is in coffee growing areas of Africa, SE Asia, Indonesia, Pacific Islands, etc., Guatemala, Honduras, and Colombia to Brazil. The distribution of this species was also in Java (Kalshoven 1981; Wood 2007; Vega et al. 2015).

Coccotrypes distinctus. Body length was 1.9 mm. Body color was reddish brown (Figure 4.I). Pronotum was weakly to strongly arched, smooth to asperate on anterior half. Elytra were smooth, shining, striate, and convex declivity. Interstrial bristles were pointed, each about twice as long as distance between interstrial rows. Strial punctures were shallowly impressed, separated by distances equal to diameter of a puncture.

According (Wood 2007) and Hulcr and Smith (2010) ambrosia beetle with these morphological characters is *C. distinctus.* The present distribution of *C. distinctus* in Circumtropical areas worldwide such as SE Asia, Sri Lanka, New Guinea to Hawaii South USA, Honduras, Puerto Rico and Jamaica to Suriname, and Guiana (Beaver and Browne 1975; Wood 2007).

Discussion

A total of nine species of ambrosia beetles trapped in both monoculture and polyculture teak plant systems with the highest number of the individual was *X. crassiusculus* (Table 2). Of them, eight species had the higher individual number in the polyculture than in monoculture teak plant system. The higher individual number of those species in polyculture teak plant system was caused by the teaks grow in various vegetation types such as *C. arabica* and *S. mahogany*. While in the monoculture, there were only teak plants and grass as non-host of ambrosia beetle.

Xylosandrus crassiusculus is one of the species of ambrosia beetles that can breed in various hosts. Pennacchio et al. (2003) reported that *X. crassiusculus* had widely polyphagous species which able to colonize at least one hundred species belonging to various genera of plant forest and exhibits the ability to survive on many species of trees shrubs and vines. Horn and Horn (2006) stated that *X. crassiusculus* can breed on the wide variety of hosts, include 124 host and 48 families that mostly in the tropics region including pine, cocoa, coffee, mahogany, rubber, tea, and teak.

The highest individual number of *X. crassiusculus* in both locations was congruent with some research about monitoring of ambrosia beetles population with bottle trap baited with ethanol. Reding et al. (2011) demonstrated that bottle-style traps baited with ethanol captured *X. crassiusculus* and *X. germanus* effectively. Individual number of *H. hampei* in polyculture was also higher than in monoculture (Table 2), because in polyculture also consisted coffee plant. *H. hampei* is a major pest of coffee crop (Vega 2015).

The diversity of woody plants on the land indirectly provides an alternative host for ambrosia beetles. The ambrosia beetle is polyphagous and has no specific host. According to Dinnage et al. (2012), the impact of plant species abundance can positively affect the richness and diversity of herbivorous insects. Hulcr et al. (2007) suggested that ambrosia beetles had widely host variety because 95% of the species of ambrosia beetles did not show the preference for specific host species. Reed and Muzika (2010) also stated that the abundance of ambrosia beetle species was strongly influenced by the abundance and size of the host.

The peak flight activity of each species of ambrosia beetles was different, *X. crassiusculus* on 11 March 2017, while *E. similis* and *X. morigerus* on 22 March 2017 (Figure 3). The flight activity of ambrosia beetles might be related to environmental factors such as temperature. Reding et al. (2010) stated that the flight activity of *Xylosandrus* spp. often had the dip in activity usually coincides with cold temperatures. Another factor that influences the flight activity of ambrosia beetles was the high intensity of rains. Anu et al. (2009) reported that the high intensity of rainfalls had a negative correlation with flight activity of insects. However, the temperature and intensity of rainfall were not observed in this research. Further examination of this relationship between temperature and intensity of rainfall with flight activity of ambrosia beetles is needed.

In conclusion, Ambrosia beetles were trapped in monoculture and polyculture teak plants consist of nine species, i.e. *X. crassiusculus*, *X. morigerus*, *X. compactus*, *Xy. perforans*, *E. simillis*, *Xyl. andrewesi*, *P. cavipennis*, *C. distinctus* and *H. hampei*. The most abundant species in both locations was *X. crassiusculus*. The polyculture teak plant system had higher diversity index than monoculture, and both locations were categorized in the medium diversity category.

ACKNOWLEDGEMENTS

This research was supported by the Faculty of Agriculture Research Fund, University of Brawijaya with no. of contract 5180/UN10.F04.06/PN/2017 and Research Group of Sustainable Agriculture, University of Brawijaya. The authors would like to thanks to PERUM PERHUTANI KPH Malang which given permission to conduct this research. The authors also thank You Li and Andrew Johnson from the University of Florida, USA for their help to confirm the identification of the beetles.

REFERENCES

Anu A, Sabu TK, Vineesh PJ. 2009. Seasonality of litter insects and relationship with rainfall in a wet evergreen forest in South Western Ghats. Insect Sci 9 (46): 1-10.

Bateman CC, Hulcr J. 2014. A Guide to Florida's Common Bark and Ambrosia Beetles. UF IFAS Ext: 1-36.
Beaver RA, Browne FG. 1975. The Scolytidae and Platypodidae (Coleoptera) of Thailand. Oriental Insects 9 (3): 283-211
Beaver RA, Browne FG. 1978. The Scolytidae and Platypodidae (Coleoptera) of Penang, Malaysia. Oriental Insects 12 (4): 575-624
Bermejo I, Canellas I, San Miguel A. 2004. Growth and yield models for teak plantations in Costa Rica. For Ecol Manage 189 (1-3): 97-110.
Bumrungsri S, Beaver R, Phongpaichit S, Sittichaya W. 2008. The infestation by an exotic ambrosia beetle, *Euplatypus parallelus* (F.) (Coleoptera: Curculionidae: Platypodinae) of angsana trees (*Pterocarpus indicus* Willd.) in southern Thailand. Songklanakarin Sci Technol 30 (5): 579-582.
Burbano EG, Wright MG, Gillette NE, Mori S, Dudley N, Jones T, Kaufmann M. 2012. Efficacy of traps, lures, and repellents for *Xylosandrus compactus* (Coleoptera: Curculionidae) and other ambrosia beetles on *Coffea arabica* plantations and *Acacia koa* nurseries in Hawaii. Environ Entomol 41 (1): 133-140.
Dinnage R, Cadotte MW, Haddad NM, Crutsinger GM, Tilman D. 2012. Diversity of plant evolutionary lineages promotes arthropod diversity. Ecol Lett 15 (11): 1308-1317.
Dixon W N, Woodruff RE, Foltz JL. 2003. Black Twig Borer, *Xylosandrus compactus* (Eichhoff) (Insecta: Coleoptera: Curculionidae: Scolytinae). UF IFAS.
Galko J, Nikolov C, Kimoto T, Kunca A, Gubka A, Vakula J, Zúbrik M, Ostrihoň M. 2014. Attraction of ambrosia beetles to ethanol-baited traps in a Slovakian oak forest. Biologia 69 (10): 1376-1383.
Gomez DF, Rabaglia RJ, Fairbanks KEO, Hulcr J. 2018. North American Xyleborini north of Mexico: a review and key to genera and species (Coleoptera, Curculionidae, Scolytinae). ZooKeys 768: 19-68.
Horn S, Horn GN. 2006. New host record for the Asian ambrosia beetle, *Xylosandrus crassiusculus* (Wlotschulsky) (Coleoptera: Curculionidae). Entomol Sci 41 (1): 90-91.
Hulcr J, Smith S. 2010. Xyleborini ambrosia beetles: an identification tool to the world genera. http://itp.lucidcentral.org/id/wbb/xyleborini/index.htm.
Hulcr J, Mogia M, Isua B, Novotny V. 2007. Host specificity of ambrosia and bark beetles (Col., Coleoptera, Curculionidae: Scolytinae and Platypodinae) in a New Guinea rainforest. Ecol Entomol 32: 762-772.
Kalshoven LGE. 1981. Pest of Crops in Indonesia. Ichtiar Baru, Jakarta.
Kirkendall LR, Biedermann PHW, Jordal BH. 2015. Evolution and diversity of bark and ambrosia beetles. In: Vega FE, Hofstetter RW (eds) Bark Beetles. Elsevier, UK.
Lindgren BS, Raffa KF. 2013. Evolution of tree-killing in bark beetles (Coleoptera: Curculionidae): trade-offs between the maddening crowds and a sticky situation. Can Entomol 145 (5): 471-495.
Nair KSS. 2007. Tropical Forest Insect Pests. Cambridge University Press, UK.
Okins K E, Thomas MC. 2009. Another Asian Ambrosia Bettle Established in Florida (Coleoptera: Curculionidae: Scolytinae: Xyleborini). Florida Department of Agriculture and Consumer Services, Division of Plant Industry Charles H. Bronson, Commissioner of Agriculture, FL, USA.
Oksanen J. 2015. Multivariate Analysis of Ecological Communities in R : vegan tutorial.
Oliver JB, Youssef NN, Halcomb MA. 2004. Comparison of different trap types for collection of Asian ambrosia beetle, pp. 158-163. In: B. Oliver (ed), Proc 49th Ann South Nursery Assoc Res Conf. Atlanta, GA, 11-12 Aug. 2004 4Patil SS, Sutar MV, Sathe TV. 2016. Diversity, biology, and control of insect pests of teak *Tectona grandis* (Linnaeus) from western Maharashtra. Biolife 4 (1): 141-146.
Pennacchio F, Roversi PF, Francardi V, Gatti E. 2003. *Xylosandrus crassiusculus* (Motschulsky) a bark beetle new to Europe (Coleoptera Scolytidae). Redia 86 (2): 77-80.
Perum Pehutani KPH Malang. 2002. Buku Rencana Pengaturan Kelestarian Hutan (RPKH) BH Kelas Perusahaan Jati. Malang: KPH Malang. [Indonesian]
Pratiwi, Lust N. 1994. Teak (*Tectona grandis* L.f.) forests in Java, Indonesia plantations, management and policy. Silva Gandavensis. 59: 97-118.
Rabaglia RJ, Dole SA, Cognato AI. 2006. Review of American *Xyleborina* (Coleoptera : Curculionidae : Scolytinae) occurring North of Mexico, with an illustrated key. Ann Entomol Soc Am 99 (6): 1034.
R Core Team. 2017. R: A Language and environment for statistical computing. https://www.R-project.org/.
Reding ME, Oliver JB, Schultz PB, Ranger CM. 2010. Monitoring fight activity of ambrosia beetles in ornamental nurseries with ethanol-baited traps: influence of trap height on captures. J Environ Hort 28: 85-90.
Reding ME, Schultz PB, Ranger CM, Oliver JB. 2011. Optimizing ethanol-baited traps for monitoring damaging ambrosia beetles (Coleoptera: Curculionidae, Scolytinae) in ornamental nurseries. Econ Entomol 104 (6): 2017-2024.
Reed SE, Muzika RM. 2010. The influence of forest stand and site characteristics on the composition of exotic-dominated ambrosia beetle communities (Coleoptera: Curculionidae: Scolytinae). Environ Entomol 39: 1482-1491.
Steininger MS, Hulcr J, Šigut M, Lucky A. 2015. Simple and efficient trap for bark and ambrosia beetles (Coleoptera: Curculionidae) to facilitate invasive species monitoring and citizen involvement. Econ Entomol 108 (3): 1115-1123.
Tarno H, Septia ED, Aini LQ. 2016. Microbial community associated with ambrosia beetle, *Euplatypus parallelus* on sonokembang, *Pterocarpus indicus* in Malang. Agrivita J Agric Sci 38 (3): 312-320.
Vega FE, Infante F, and A. J. Johnson. The genus *Hypothenemus*, with emphasis on *H. hampei*, the coffee berry borer. In: Vega FE, Hofstetter RW (eds.) Bark Beetles. Elsevier Inc, UK.
Werle CT, Sampson BJ, Oliver JB. 2011. Diversity, abundance, and seasonality of ambrosia beetles (Coleoptera: Curculionidae) in southern Mississippi. MidSouth Entomol 5: 1-5.
Wood SL. 2007. Bark and Ambrosia Beetles of South America (Coleoptera: Scolytidae). Print and Mail Production Center, Provo Utah, USA.