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DIVERSITY OF EPIPHYTIC ORCHIDS AND HOST TREES (PHOROPHYTES) IN SECONDARY FOREST OF COBAN TRISULA, MALANG REGENCY, EAST JAVA, INDONESIA

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ABSTRACT

Epiphytic orchids are an integral component of forest ecosystems that contribute to a high proportion of plant diversity. The aim of this study was to investigate the diversity of orchids and their host trees (phorophytes) in a secondary forest of Coban Trisula (the Trisula waterfall) of Bromo Tengger Semeru National Park in East Java Province, Indonesia. Two line transects were established. Each transect was 150 m long and composed of fifteen 10 x 10 m plots, resulting in the total number of 30 sampling plots at the study site. The following data were recorded in each plot: species name and individual numbers of epiphytic orchids, species name and individual numbers of the phorophytes and vertical distribution of the orchids on the phorophyte. There were 15 epiphytic orchid species found from 13 genera in the secondary forest of Coban Trisula. *Appendicula angustifolia* was the most abundant epiphytic orchid species (Relative abundance = 52.4%), followed by *Trichotosia annulata* (29.9%). All recorded orchids grew on 21 individuals from nine phorophyte species. *Castanopsis javanica* (mean = 589.5 individuals/tree) and *Engelhardia spicata* (mean = 425.67 orchid individuals/tree) were phorophytes hosting the largest number of individual orchids, respectively. The greatest abundance of epiphytic orchids was on the basal and the middle part of phorophyte branches (zone 3 and zone 4). This study indicated that orchid conservation management is required in the Coban Trisula to protect the survival of orchids in this area from potential human disturbances, as Coban Trisula is one of tourist destination.

Keywords: Coban Trisula, diversity, epiphytic orchid, phorophyte, secondary forest

INTRODUCTION

Epiphytes are known as one of important components in forest ecosystems, contributing to a high proportion to floral diversity (Wolf 2005). The role of epiphytes is vital as the habitat for canopy invertebrates and as nutrient sources in the forest canopies (Nadkarni *et al*. 2004; Cardelus & Mack 2010). Contribution of epiphytes is also important to the total biomass and nutrient pools in the forest ecosystems (Nadkarni *et al.* 2004). The family Orchidaceae is among the most dominant groups of vascular epiphytes (Johansson 1974; Gentry & Dodson 1987; Annaselvam & Parthasarathy 2001; Kromer *et al.* 2005; Zotz & Schultz 2008).

Orchidaceae is one of the biggest families containing around 25,000-35,000 species (Dressler 1981; 1993), representing 1/10 of the total vascular plant species. However, Orchidaceae is also one of the threatened plant families (IUCN/SSC Orchid Specialist Group 1996; Mondragon & Elliott 2013), due to overexploitation, overcollection, deforestation and fire (Koopowitz & Dixon 2003). Orchids are highly sensitive to environmental changes (Newman *et al.* 2007) and highly dependent on other organisms (mycorrhizal fungi and insects as pollinators) for their survival (Swarts & Dixon 2009). Orchid conservation efforts need to be done by considering the biology, ecology and the nature of threats towards the orchids.

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Coban Trisula is a waterfall in Bromo Tengger Semeru National Park (BTSNP), which is administratively located in Ngadas Village, Malang Regency, East Java Province. This waterfall is a frequent tourist destination in East Java, usually visited as part of regular tours to Mount Bromo and Mount Semeru. Coban Trisula can be reached through a pathway in a secondary forest lined by epiphytic orchids growing on trees (host trees or phorophytes), making the orchids in this area vulnerable to human disturbances due to illegal orchid collection by visitors/tourists. Some studies showed the negative impact of tourism and recreation on various vascular plants, especially on orchids family (Orchidaceae) (Pickering & Hill 2007; Ballantyne & Pickering 2013; Rankin *et al.* 2015). Rankin *et al.* (2015) reported that more than 45 plant families have species listed as threatened, in which orchids were the most common species listed as at risk from threats. The most common threat is plant collection by visitors in protected areas. The aim of this study was to investigate the diversity of epiphytic orchids and the phorophytes along the pathway to Coban Trisula to develop conservation management of orchids in that area.

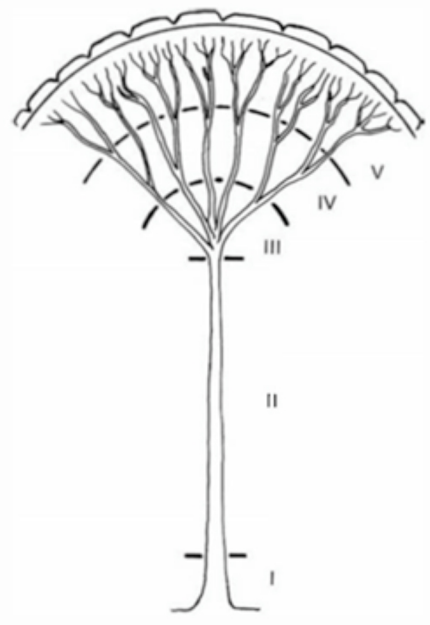
MATERIALS AND METHODS

Study Site

This study was conducted along the pathway to Coban Trisula located in the secondary forest, Village Ngadas, Malang Regency, East Java Province, Indonesia (08°00'213" S and 112°87'82" E), with elevation of 1,475 m above sea level (asl). The site is under the management of Bromo Tengger Semeru National Park (BTSNP). The dominant trees in this forest are *Macropanax dispermus* (pampung), *Lithocarpus sundaicus* (pasang) and *Engelhardia spicata* (danglu).

Data Collection

Records of diversity of epiphytic orchids and the phorophytes were conducted in two line-transects. Each transect was 150 m long and composed of 15 plots (each plot's size is 10 x 10 m), resulting in the total number of 30 sampling plots at the study site (Annaselvam & Parthasarathy 2001; Focho *et al*. 2010). Species name and individual number of the epiphytic orchids and the phorophytes were recorded. Further, the vertical distribution of epiphytic orchids on the phorophytes within the five zones determined by Johansson (1974) was recorded (Fig. 1).



Vertical distribution of epiphytic orchids on the host tree in five zones:

Zone 1 : the bottom part (1/3) of the main stem
Zone 2: the upper part (2/3) of the main stem
Zone 3: the bottom part of the branches
Zone 4: the middle part of the branches
Zone 5: the outer part of the branches.

(Johansson 1974)

Figure 1 Division of the phorophyte into five zones determined by Johansson (1974)

Data Analysis

Parameters measured and analyzed were relative frequency of phorophyte (% Ft), relative abundance of orchids (% Fo), the average number of individuals of orchids of each phorophyte species (Ji/Jt), the average number of epiphytic orchid species on a phorophyte species (Js/Jt), and the vertical distribution of the orchids on the phorophytes (Yulia & Budiharta 2012a; 2012b).

a. Relative frequency of phorophyte (% Ft)

$$\% Ft = \frac{Nt}{\text{Total number of all phorophytes}} \times 100\%$$

where: Nt = the number of trees in the plot hosting a particular orchid species

b. Relative abundance of orchid (% Fo)

$$\% Fo = \frac{No}{\text{Total number of all orchid species}} \times 100\%$$

where: No = the number of individuals of a particular orchid species within the plot

c. The average number of orchid individuals on a phorophyte species =

$$\frac{Ji}{Jt}$$

where: Ji = the number of orchid individuals
Jt = the number of individuals of each phorophyte species

d. The average number of orchid species on a phorophyte species =

$$\frac{Js}{Jt}$$

where: Js = the number of orchid species
Jt = the number of individual of each phorophyte species

e. Vertical distribution of epiphytic orchids on the phorophyte species were determined by mapping vertical distribution of each epiphytic orchid species on the phorophyte, from the trunk to outer branches in five zones (zone 1, zone 2, zone 3, zone 4 and zone 5) and by calculating the average number of individuals of epiphytic orchids in each zone.

RESULTS AND DISCUSSION

The Occurrence of Epiphytic Orchids on the Phorophytes

There were 15 epiphytic orchid species and 9 phorophyte species recorded (Table 1). The results of the present study showed that the number of phorophyte species hosting each epiphytic orchid varied from 1 to 5 phorophyte species (Table 1). Some epiphytic orchid species occurred on a single phorophyte species; such as *Appendicula elegans* (100 individuals) were found exclusively on phorophyte *Lithocarpus sundaicus*; *Bryobium hyacinthoides* (10 individuals) were recorded only on phorophyte *Engelhardia spicata*; and *Dendrobium luxurians* (50 individuals) were only observed on phorophyte *Castanopsis javanica* (Table 1). Other epiphytic orchid species occurred on multiple phorophyte species; such as *Appendicula angustifolia* grew on four phorophyte species (*Macropanax dispermus*, *Lithocarpus sundaicus*, *Drypetes sumatrana* and *Castanopsis javanica*). *Parapteroceras odoratissimum* was hosted by 5 phorophyte species in the study site i.e. *Engelhardia spicata*, *Ficus* sp., *Syzygium* sp., *Lithocarpus sundaicus* and *Drypetes sumatrana* (Table 1).

The results of the present study were similar to other studies which showed that the number of phorophyte species hosting epiphytic orchids varied from a single to multiple phorophyte species. Adhikari *et al.* (2012) reported that the orchid *Dendrobium nobile* occurred on one phorophyte species, while the orchid *Rhynchostylis retusa* was found on many different phorophyte species. Rosa-Manzano *et al.* (2014) also reported that most epiphytic orchids in tropical dry forests of Yucatan, Mexico occurred on a single tree species. Tremblay *et al.* (1998) also showed a Puerto Rican orchid, *Lepanthes caritensis* hosted by one phorophyte species, while other epiphytic orchids were reported to occur in many phorophyte species. Annaselvam and Parthasarathy (2001) reported that epiphytic orchids in tropical evergreen forest at Varagalaiar, Western Ghats, India grew on many phorophyte species. Trapnell and Hamrick (2006) also showed 33 phorophyte species hosting epiphytic orchid *Laelia rubescens* at one site.

Table 1 The epiphytic orchid species and the phorophytes in the secondary forest of Coban Trisula

No	Epiphytic orchids	Number of phorophyte species	Phorophyte species
1	*Appendicula angustifolia* Blume	4	*Macropanax dispermus* (Blume) Kuntze *Lithocarpus sundaicus* (Blume) Rehder *Drypetes sumatrana* (Miq.) Pax & K.Hoffm *Castanopsis javanica* (Blume) A.DC.
2	*Appendicula elegans* Rchb.f	1	*Lithocarpus sundaicus* (Blume) Rehder
3	*Bryobium hyacinthoides* (Blume) Y.P.Ng & P.J.Cribb	1	*Engelhardia spicata* var. *colebrookeana* (Lindl. ex Wall.) Koord. & Valeton
4	*Bulbophyllum odoratissimum* (Sm.) Lindl. ex Wall.	1	*Engelhardia spicata* var. *colebrookeana* (Lindl. ex Wall.) Koord. & Valeton
5	*Ceratostylis brevibrachiata* J.J. Sm .	2	*Engelhardia spicata* var. *colebrookeana* (Lindl. ex Wall.) Koord. & Valeton *Actinodaphne procera*
6	*Cymbidium* sp.	1	*Engelhardia spicata* var. *colebrookeana* (Lindl. ex Wall.) Koord. & Valeton
7	*Dendrobium luxurians* J.J.Sm.	1	*Castanopsis javanica* (Blume) A.DC.
8	*Dendrobium spathilingue* J.J.Sm.	2	*Lithocarpus sundaicus* (Blume) Rehder *Castanopsis javanica* (Blume) A.DC.
9	*Dendrochilum abbreviatum* Blume	1	*Engelhardia spicata* var. *colebrookeana* (Lindl. ex Wall.) Koord. & Valeton
10	*Mycaranthes oblitterata* Blume	1	*Castanopsis javanica* (Blume) A.DC.
11	*Parapteroceras odoratissimum* (J.J.Sm.) J.J. Wood	5	*Engelhardia spicata* var. *colebrookeana* (Lindl. ex Wall.) Koord. & Valeton *Ficus* sp. *Syzygium* sp. *Lithocarpus sundaicus* (Blume) Rehder *Drypetes sumatrana* (Miq.) Pax & K.Hoffm
12	*Schoenorchis juncifolia* Reinw. Ex Blume	3	*Engelhardia spicata* var. *colebrookeana* (Lindl. ex Wall.) Koord. & Valeton *Lithocarpus sundaicus* (Blume) Rehder *Ficus grossularioides* Burm.f.
13	*Thrixspermum subulatum* (Blume) Rchb.f	1	*Castanopsis javanica* (Blume) A.DC.
14	*Trichotosia annulata* Blume	4	*Engelhardia spicata* var. *colebrookeana* (Lindl. ex Wall.) Koord. & Valeton *Lithocarpus sundaicus*, (Blume) Rehder *Drypetes sumatrana* (Miq.) Pax & K.Hoffm *Castanopsis javanica* (Blume) A.DC.
15	*Vanda tricolor* Lindl.	2	*Engelhardia spicata* var. *colebrookeana* (Lindl. ex Wall.) Koord. & Valeton *Castanopsis javanica* (Blume) A.DC.

Epiphytic Orchids

The present study showed that the secondary forest of Coban Trisula contained 15 epiphytic orchid species, in which the diversity was lower compared to the diversity of epiphytic orchids in other areas within the Bromo Tengger Semeru National Park; such as in Resort Senduro that had 42 epiphytic orchid species (Utama 2005). The lower diversity of epiphytic orchids in Coban Trisula compared to Resort Senduro may have been caused by the difference in ecosystem types in which Coban Trisula is secondary forest, while Resort Senduro is a primary forest. The difference of primary forest and secondary forest in terms of their plant diversity has been widely studied. Primary forest has higher plant diversity than that of secondary forest, including epiphytic orchid diversity (Barthlott *et al.* 2001; Kubota *et al.* 2005). Studies in the Venezuelan Andes and Japan comparing the diversity of vascular epiphytes in

Table 2 The epiphytic orchid species in Coban Trisula and the parameter values

No	Epiphytic orchid species	Nt	No	% Ft	% Fo
1	*Appendicula angustifolia* Blume	6	2,056	15	52.4
2	*Appendicula elegans* Rchb.f	1	100	2.5	2.55
3	*Bryobium hyacinthoides* (Blume) Y.P.Ng & P.J.Cribb	1	10	2.5	0.25
4	*Bulbophyllum odoratissimum* (Sm.) Lindl. ex Wall.	1	120	2.5	3.06
5	*Ceratostylis brevibrachiata* J.J. Sm.	2	50	5	1.27
6	*Cymbidium* sp.	1	2	2.5	0.05
7	*Dendrobium luxurians* J.J.Sm.	1	50	2.5	1.27
8	*Dendrobium spathilingue* J.J.Sm.	2	16	5	0.41
9	*Dendrochilum abbreviatum* Blume	1	75	2.5	1.91
10	*Mycaranthes oblitterata* Blume	1	100	2.5	2.55
11	*Parapteroceras odoratissimum* (J.J.Sm.) J.J. Wood	9	74	22.5	1.89
12	*Schoenorchis juncifolia* Reinw. Ex Blume	4	41	10	1.05
13	*Thrixspermum subulatum* (Blume) Rchb.f	1	50	2.5	1.27
14	*Trichotosia annulata* Blume	5	1,172	12.5	29.9
15	*Vanda tricolor* Lindl.	4	7	10	0.18

Notes: Nt = the number of trees in the plot hosting a particular orchid species
No = the number of individuals of a particular orchid species within the plot
% Ft = relative frequency of phorophytes
% Fo = relative abundance of orchids

primary forests and secondary forests showed that primary forests had higher diversity of epiphytic orchids compared to secondary forests (Barthlott *et al.* 2001; Kubota *et al.* 2005).

The present study also showed that the most abundant epiphytic orchid was *Appendicula angustifolia* with relative abundance (% Fo) of 52.41%, followed by *Trichotosia annulata* with % Fo of 29.9% (Table 2). The most abundant orchid in this study site, *Appendicula angustifolia* is a sympodial orchid, that has continuous lateral growth of the the stems through rhizome, which is an effective vegetative reproduction to grow a large number of individuals. *Appendicula angustifolia* also has many flowers along the stems, with each rachis bears 10–15 flowers (Comber 1990; 2001). The large number of *A. angustifolia* flowers increase the chance for the fruit and seed sets to produce large population. All these characters of *A. angustifolia* support the high abundance of *Appendicula angustifolia* at the study site. Comber (1990) also reported a tree covered by high density of *A. angustifolia.* In Indonesia, *Appendicula angustifolia* is widely distributed and found all over Java and Sumatera, from 800 to 1,700 m asl elevation (Comber 1990).

Host Tree (Phorophyte) Species

The results of the present study also showed that there were 9 phorophyte species in Coban Trisula, which the diversity is lower than that in Resort Senduro located within the same national park (Bromo Tengger Semeru National Park). Utama (2005) reported 16 phorophyte species in Resort Senduro. The lower diversity of phorophyte in Coban Trisula compared to Resort Senduro may have been caused by different ecosystem types (secondary forest in Coban Trisula and primary forest in Resort Senduro). Other studies also showed similar results.

Table 3 The phorophyte species in Coban Trisula and the parameter values

No	Phorophyte species	Jt	Js	Ji	Js/Jt	Ji/Jt
1	*Actinodaphne procera* Nees	1	1	15	1	15
2	*Castanopsis javanica* (Blume) A.DC.	4	7	2,358	1.75	589.5
3	*Drypetes sumatrana* (Miq.) Pax & K.Hoffm.	2	3	13	1.5	6.5
4	*Engelhardia spicata* var. *colebrookeana* (Lindl. ex Wall.) Koord. & Valeton	3	8	1,277	2.67	425.67
5	*Ficus grossularioides* Burm.f.	2	1	30	0.5	15
6	*Ficus* sp.	1	1	10	1	10
7	*Lithocarpus sundaicus* (Blume) Rehder	5	6	175	1.2	35
8	*Macropanax dispermus* (Blume) Kuntze	2	1	35	0.5	17.5
9	*Syzygium* sp.	1	1	10	1	10

Notes: Jt = the individual number of each phorophyte species
Js = number of orchid species
Ji = number of orchid individuals
Js/Jt = the average number of epiphytic orchid species on a phorophyte species
Ji/Jt = the average number of epiphytic orchid individuals on a phorophyte species

Barthlott *et al.* (2001) reported that the diversity of phorophytes in the secondary forest was lower than that of the primary forest in the Venezuelan Andes.

The individual number of orchids growing on a phorophyte ranged from 6.5 to 589.5 individuals/tree (Ji/Jt) (Table 3). The largest individual numbers of epiphytic orchids were found on *Castanopsis javanica* (Ji/Jt = 589.5 individuals of orchids/tree), followed by *Engelhardia spicata* (Ji/Jt = 425.6 individuals of orchids/tree). *Castanopsis javanica* and *Engelhardia spicata* not only had a large individual number of epiphytic orchids, but also had the highest species richness of epiphytic orchids. Eight orchid species had been recorded growing on the phorophyte *Engelhardia spicata* and seven species on the phorophyte *Castanopsis javanica*. Other phorophytes such as *Actinodaphne procera* and *Macropanax dispermus* only hosted one orchid species.

All recorded phorophytes were specialized on sub-montane and montane areas (Hardyanti & Hakim 2014). Most of them such as *Castanopsis javanica, Engelhardia spicata, Macropanax dispermus* and *Lithocarpus sundaicus* had rough or fissured bark. This bark structure might support litter accumulation and therefore, build a nutrient and humidity reservoir providing a comfort habitat for epiphytic orchids (Annaselvam & Pathasarathy 2001). The thickness of organic substrates layer on the tree bark varied within the vertical distribution of a single tree species from bare bark (thin substrates < 1 cm) to 5 cm thick substrates. The variety of substrate thickness covering the phorophyte was also observed by Johansson (1974) in West African rainforests and Barthlott *et al.* (2001) in the Venezuelan Andes.

In our study the highest abundance of orchids occurred on thick substrates. This is consistent with the results of the study conducted by Annaselvam and Parthasarathy (2001) showing that most thick branches were densely covered with vascular epiphytes, accumulating substantial amounts of humus, nutrients and moisture. Rosa-Manzano *et al.* (2014) also reported that bark roughness and substrate area were the most important phorophyte characteristics affecting the epiphytic orchids abundance.

Vertical Distribution of Epiphytic Orchids on Phorophyte Species

The present study showed a range of vertical distribution of epiphytic orchid species from zone 2 to zone 5 (Table 4). The most abundant orchid, *Appendicula angustifolia,* was found to have the widest vertical distribution ranging from zone 2 to zone 5. The ability of *A. angustifolia* to occupy a large area and different zones supported population growth resulting in the abundance of

Table 4 Zones of the occurrence of epiphytic orchids on their phorophytes and the number of orchid individuals in each zone

No	Epiphytic orchid species	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
1	*Appendicula angustifolia* Blume		20	796	800	200
2	*Appendicula elegans* Rchb.f			10	100	
3	*Bryobium hyacinthoides* (Blume) Y.P.Ng & P.J. Cribb				10	
4	*Bulbophyllum odoratissimum* (Sm.) Lindl. Ex. Wall.			20	100	
5	*Ceratostylis brevibrachiata* J.J. Sm.			45	5	
6	*Cymbidium* sp.					2
7	*Dendrobium luxurians* J. J. Sm.					50
8	*Dendrobium spathilingue* J. J. Sm.			11	5	
9	*Dendrochilum abbreviatum* Blume				30	
10	*Mycaranthes oblitterata* Blume			33	33	33
11	*Parapteroceras odoratissimum* (J. J. Sm.) J.J. Wood		5	34	35	
12	*Schoenorchis juncifolia* Reinw. Ex Blume			25	6	10
13	*Thrixspermum subulatum* (Blume) Rchb.f				50	
14	*Trichotosia annulata* Blume			152	1,020	
15	*Vanda tricolor* Lindl.			3	77	2
	Total number of orchid individuals	0	25	1,129	2,271	297

the orchids. *Cymbidium* sp. and *Dendrobium luxurians* were observed to occur in zone 5 only (Table 4). Most epiphytic orchid species grew on zone 3 and zone 4. A small number of orchid species occurred on the trunk (only two orchid species grew on zone 2 and no orchid species grew on zone 1.

The pattern of vertical distribution of epiphytic orchids in the forest of Coban Trisula was similar to that of other regions i.e. in Africa, South America and Mexico where vascular epiphyte abundance were higher in zone 3-5 (tree crown) than in zone 1-2 (along the trunk) due to better light intensity nearby the tree crown (Johansson 1974; Kromer *et al.* 2005; Rosa-Manzano *et al.* 2014).

Implications for Conservation

Coban Trisula is one of tourist destination within the area of Bromo Tengger Semeru National Park. The tourist number to Bromo Tengger Semeru National Park was very high (Table 5). The number of visitors increased sharply from 2011 to 2014, with the peak of tourist number reached 551,644 visitors in 2013 (Table 5).

Table 5 The number of visitors to Bromo Tengger Semeru National Park

Visitors	Year			
	2011	2012	2013	2014
Domestic	103,091	249,577	518,746	512,887
Foreign	22,380	26,297	32,898	23,451
Total visitors	125,471	275,874	551,644	536,338

Source: Balai Besar Taman Nasional Bromo Tengger Semeru

Management of orchid conservation is required to protect the orchids in Coban Trisula and other places within Bromo Tengger Semeru National Park from population decrease and loss of diversity. This is related to the impact of tourism and recreation activities on the survival of plants, especially orchids (Pickering & Hill 2007; Rankin *et al*. 2015). The most common type of threat in the tourism and recreation area is plant collection by visitors which can decrease plant species diversity (Rankin *et al*. 2015; Calderon-Aguilera *et al.* 2012). A recommendation to protect the epiphytic orchids in this area from human disturbances is required.

CONCLUSIONS

Fifteen epiphytic orchid species from 13 genera were found in the secondary forest of Coban Trisula, Bromo Tengger Semeru National Park. Nine phorophyte species were found to be the host of the epiphytic orchid species in Coban Trisula. The most abundant orchid species was *Appendicula angustifolia* and the phorophyte species hosting the largest number of orchids was *Castanopsis javanica*. Management of orchid conservation is required to protect the survival of orchids in Coban Trisula.

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