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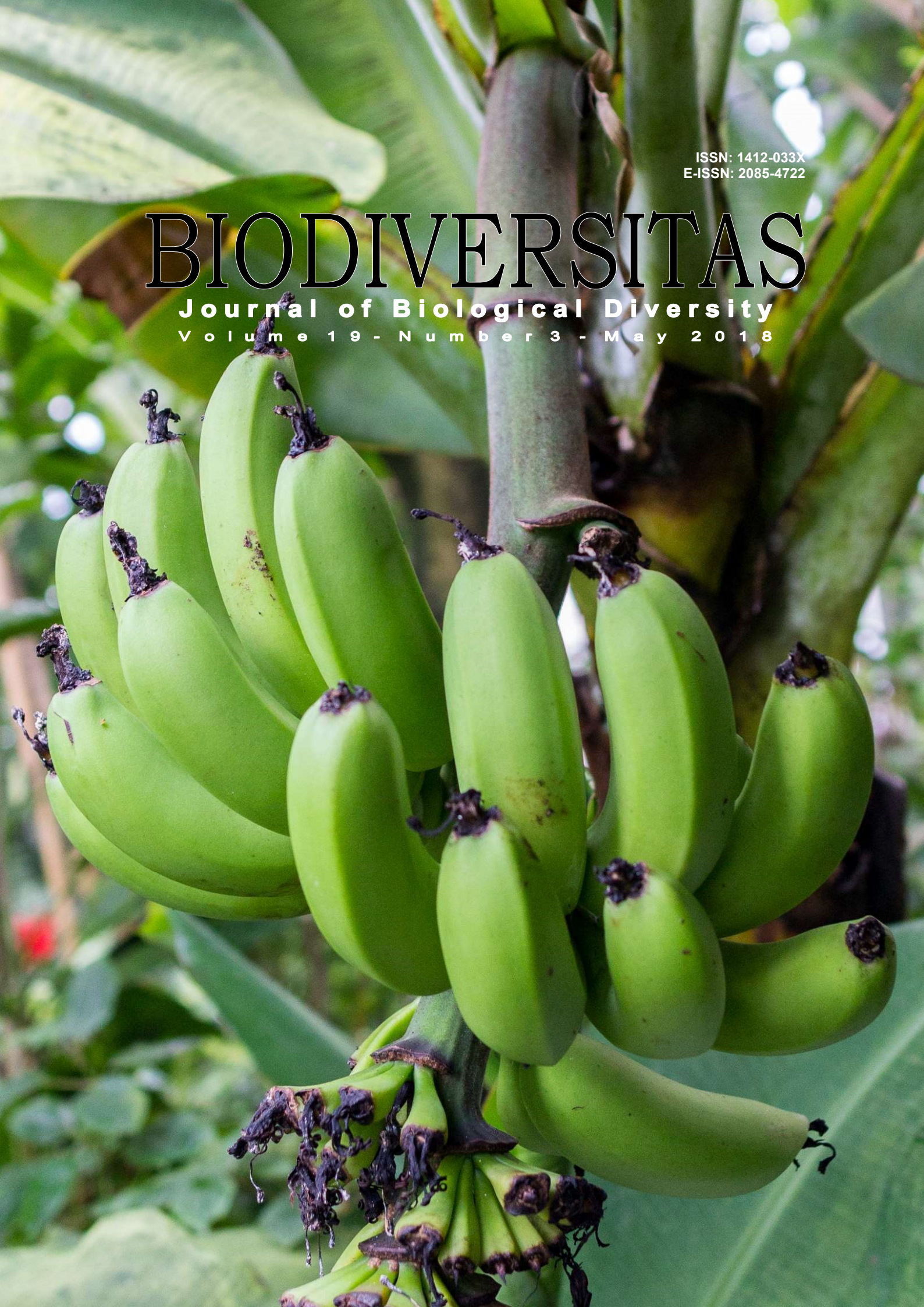
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Webb CO, Cannon CH, Davies SJ. 2008. Ecological organization, biogeography, and the phylogenetic structure of rainforest tree communities. In: Carson W, Schnitzer S (eds) *Tropical Forest Community Ecology*. Wiley-Blackwell, New York.

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Short Communication: The diversity of wild *Dendrobium* (Orchidaceae) in Central Bali, Indonesia

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Abstract. Darmawati IAP, Rai IN, Dwiyani R, Astarini IA. 2018. The diversity of wild *Dendrobium* (Orchidaceae) in Central Bali, Indonesia. *Biodiversitas* 19: 1110-1116. *Dendrobium* is the largest orchid genus of the Orchidaceae family. The research aimed to explore the species diversity of *Dendrobium*, dominance, and species similarity in some forest of Bali. The explored locations were grouped to lowland about 0-700 m asl. (Tejakula, Bukit Silangjana, Sepang Kelod, Mekori, and Busungbiu), transition land about 700-1100 m asl. (Sepang Kaje and Jatiluwih) and lower montane 1100-1500 m asl. (Natural Reserves of Lake Buyan-Tamblingan, Puncak Landep, and Lemukih). There were 24 species of *Dendrobium* in Central Bali, 2 species of which were not identified. The dominant species were *D. acuminatissimum*, *D. crumenatum* and *D. linearifolium*. The highest species diversity index of wild *Dendrobium* was present in lowland (16 species, 66.66%) followed by those in transition land and lower montane (12 species, 50.00% and 6 species, 20.83%, respectively). The pattern is also similar either for the species prosperity (3.875; 3.094, and 0.699, respectively). Uniformity of wild *Dendrobium* on transition land was 0.922, followed by those in lowland and lower montane (0.864 and 0.794). There were 6 similar species of *Dendrobium* found in lowlands and lower montane (42.857% equality index) and 2 similar species in lowlands and lower montane (19.047% equality index) and also 2 similar species in transition land and lower montane (23.359% equality index). *D. macrophyllum*, *D. heterocarpum* and *D. secundum*, their presence are prone to be threatened with extinction so conservation is necessary.

Keywords: exploration, diversity, *Dendrobium*, Central Bali

INTRODUCTION

Bali is geographically located at 8°3'40"-8°50'48" South and 114°25'53"-115°42'40" East. Central Bali Forest is a group of tropical rainforest areas covering of 14,651.32 ha including 4 districts in Bali, i.e., Badung, Bangli, Buleleng, and Tabanan managed by the Forest Management Unit (KPH) of the state forestry enterprise, Perhutani. In terms of the function of all forest areas in Central Bali is protected forest (Wibowo et al. 2015b). The tropical forest is having a high biodiversity of both fauna and flora, one of which is Orchidaceae. A total of one hundred and fifty-nine species of orchids are found in Bali (Tirta 2004; Paramitha et al. 2012; Wibowo et al. 2015a). The existence of orchids in the wild continues to decline, caused by the destruction of habitat and excessive exploitation.

Dendrobium is one of the orchid genera with wide distribution, from Southeast Asia to Australia and it consists of approximately 1.600 species (De et al. 2015). According to Gandawidjaya and Sastrapradja (1980), of about 275 species were found in Indonesia, including Bali. The genetic resources of wild *Dendrobium* have not been optimally utilized, although it has a wide possibility as parental in crosses to produce hybrid orchids that have characteristics as desired by consumers (Widiastoety et al. 2010).

Orchid exploration has been conducted in some areas in Bali, such as: (i) the natural forest in Eka Karya Bali Botanic Gardens, in which successfully identified 41 species of orchids, belonging to 18 genera, and 2 species of which are *Dendrobium* (Tirta 2004); (ii) the area of Lake Buyan-Tamblingan Nature Reserve with 30 species of orchids were identified, belonging to 17 genera, and 3 species of them are *Dendrobium* (Paramitha et al. 2012); (iii) Mount Batukaru Nature Reserve, in which 81 species of orchids were found, and 6 species of which are *Dendrobium* (Wibowo et al. 2015a).

Based on data of wild orchids in Bali, there is still the wide area of Bali where orchids are naturally growing has not been explored, particularly for the genus *Dendrobium*. The genus exploration in Bali was conducted at different altitudes with the assumption that *Dendrobium* has a wide range of habitats and each altitude has its own diversity. The purpose of this study is to explore the types of natural *Dendrobium* and to know the dominance, diversity, and similarity of the species.

MATERIALS AND METHODS

Area of study

Exploration activities were conducted on several forest areas in Bali, grouped into 3 habitats according to their

altitude, i.e.: lowland (0-700 m asl.) of Tejakula, Bukit Silangjana, Sepang Kelod, Mekori, and Busungbiu; transition land (700-1100 m asl.) of Sepang Kaje and Jatiluwih; and lower montane (1100-1500 m asl.) of Nature Reserve Park of Lake Buyan-Tamblingan, Landep Forest, and Lemukih (Nakashizuka et al. 1992). The location of the exploration is presented in Figure 1. The research was conducted from November 2016 to May 2017.

Materials

Materials used in this research include plastic bags, sacks, field books, descriptor books, label paper, newspapers, and ethanol 70%. While the tools used are meter, ruler, GPS (Global Positioning System), Canon Ixus 220 digital cameras, scissors, sliding, hook, and tool herbarium.

Collection methods

The diversity data of *Dendrobium* was conducted by exploring the plots that have been made on each side of the forest paths. The size of each plot was 20x20 m, with the distance of 2 m from the edge of the forest path, and 100 m apart between plots (Rugayah et al. 2005). Total plots from 12 locations are 96 plot. The number of plots of each

location varies depends on field conditions from 5 to 16 plots. All *Dendrobium* found were recorded and documented.

The collection of orchids was done following Rugayah et al. (2005), by which of taking each different suspected species of *Dendrobium*, a species that has been discovered and taken in the previous plot were not recollected, but recorded for its distribution. Observations *in situ* were included species names, number of species, number of individuals, ordinate points, and their ecology. Some of the orchid's flower which found were collected as wet herbarium in ethanol 70%. The orchid specimen collected as living plant and were kept in the collection garden in Eka Karya Bali Botanic Gardens, personal collection, and Dhika Bali orchids.

Species were identified through morphological characters and matched with reference books of Flora of Bali: An Annotated Checklist (Girmansyah et al. 2013), The *Dendrobium* (Howard 2006), Fundamentals of Orchids Biology (Arditti 1992). Those explored specimens (as wet herbarium) that could not be identified by those books were then identified by comparing them with the collection of *Dendrobium* orchids species grown in the "Eka Karya" Botanic Gardens Bali.

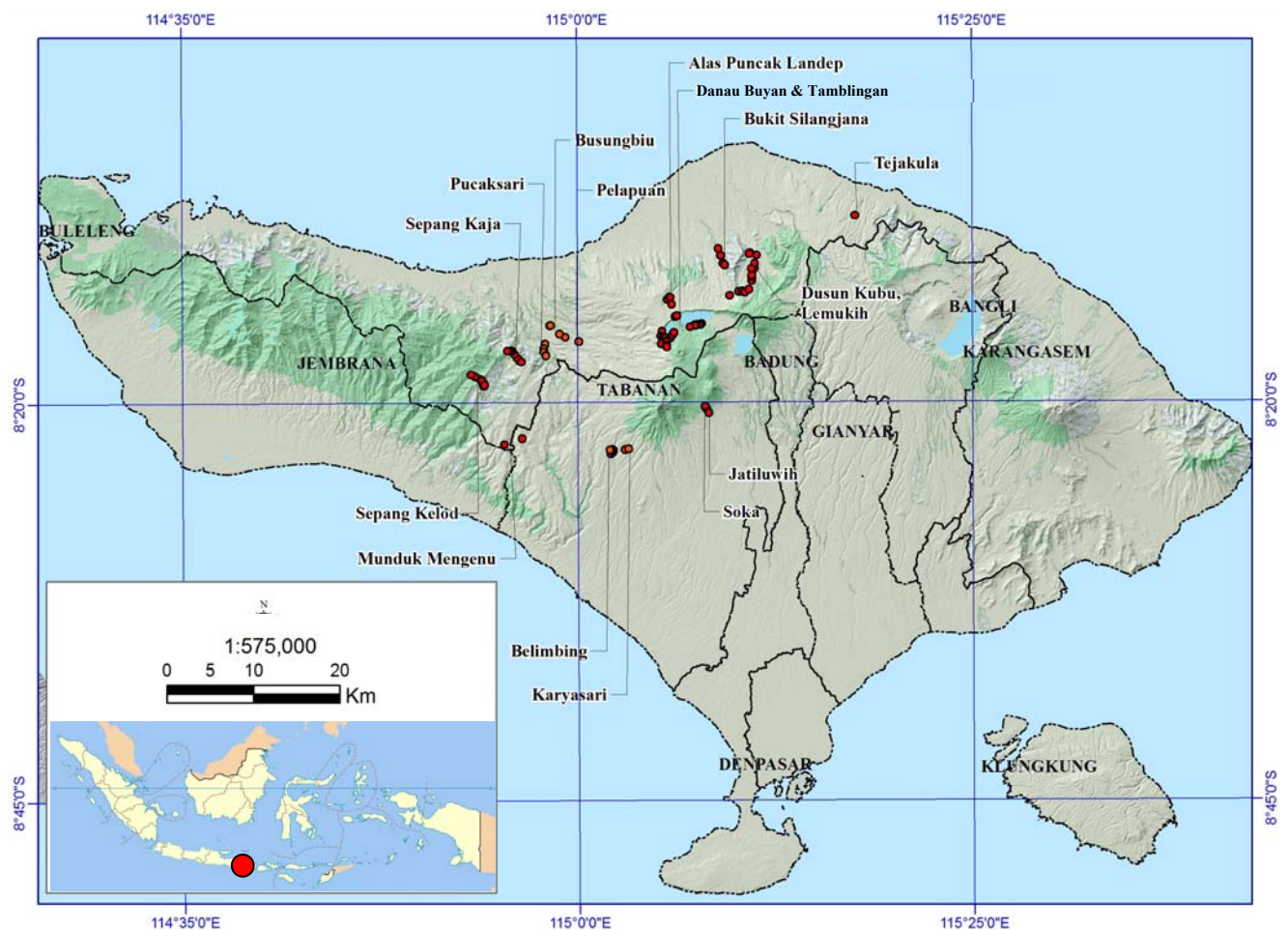


Figure 1. The sampling locations of the wild *Dendrobium* orchid (●) in Bali, Indonesia

Data analysis

The data collected were analyzed to obtain the values of dominance, diversity, uniformity, prosperity, and similarity of species calculated on the basis of the following equations:

Index of dominance

$$D_i = \frac{n_i}{N} \times 100 \quad (1)$$

D_i = index of the dominance of a species, n_i = number of individuals species I , N = total of the individual. The range of dominance index value used is $> 5\%$ for dominant type, 2-5% for subdominant type, and $< 2\%$ for non-dominant type (Odum 1971).

Index of diversity

$$F_a = \frac{\sum \text{path with the species (a)}}{\sum \text{all paths}} \times 100\% \quad (2)$$

F_a = Frequency of species a

$$H' = -\sum \{ (n_i/N \log (n_i/N)) \} \quad (3)$$

H' = The Diversity Species Index, the Shannon-Wiener diversity index is defined as follows: if $H' > 3$ (high diversity of species), when $H' 1 \leq H' \leq 3$ (moderate diversity of species) and when $H' < 1$ (low diversity of species) (Fachrul 2007).

Index of uniformity

$$e = \frac{H'}{\log S} \quad (4)$$

Similarity Index (e) According to Krebs (1989) in Gundo (2010); the similarity index of species ranges from the value of 0 – 1; which is then classified into, $e < 1$ (high uniformity of species); $0,4 < e < 0,6$ (medium uniformity of species) and $e < 0,4$ (low uniformity of species).

Index of prosperity

$$D_a = \frac{(S - 1)}{\ln N} \quad (5)$$

Prosperity Index of Species (D_a), S = number of species observed (Fachrul 2007).

Index of Similarity

$$IS = \frac{2c}{A + B} \times 100 \quad (6)$$

IS = Sorensen type similarity index, c = number of species present in both locations, A = number of species

present in first habitat, B = number of species present in the second habitat. IS has a range of values from 0%-100%, if $IS < 25\%$ the orchid diversity at two sites is less similar, if $25\% < IS < 50\%$ the diversity of orchids in two locations has similarities and if $IS > 50\%$, the orchid diversity in two the location has a high similarity (Fachrul 2007).

RESULTS AND DISCUSSION

Diversity of *Dendrobium*

The wild *Dendrobium* that has been found throughout 12 locations were 131 individuals, comprised of 24 species (Figure 2), 22 species of which were identified, while 2 species were not identified yet in Eka Karya Botanic Gardens by comparing the collected specimen and reference book and not reported elsewhere.

Identification key of *Dendrobium*

1. a. Pseudobulb persistent 2
 - b. No pseudobulb 3
2. a. Pseudobulb oval *Dendrobium cruminatum*
 - b. Pseudobulb not oval 4
3. a. Leaf triangular *Dendrobium aloifolium*
 - b. Leaf not triangular 5
4. a. Inflorescence terminal *Dendrobium plicatule*
 - b. Inflorescence subterminal 7
5. a. Sepals oblong *Dendrobium linearifolium*
 - b. Sepals ligulate *Dendrobium acuminatissimum*
 - c. Sepals oval *Dendrobium inflatum*
 - d. Sepals slightly round *Dendrobium rugosum*
6. a. Petals and sepals grooved inward *Dendrobium arcuatum*
 - b. Petals and sepals grooved outward .. *Dendrobium truncatum*
 - c. Petals and sepals stretched *Dendrobium fimbriatum*
7. a. Sepals dorsal striped *Dendrobium aphyllum*
 - b. Sepals dorsal pattern is not striped 8
8. a. Petals obovate *Dendrobium spathilingue*
 - b. Petals ligulate *Dendrobium salacense*
 - c. Petals hastate *Dendrobium macrophyllum*
9. a. Labellum ovoid *Dendrobium conspicuum*
 - b. Labellum not ovoid 10
10. a. Labellum side triangular *Dendrobium heterocarpum*
 - b. Labellum side tot triangular 11
11. a. Middle labellum rhomboid *Dendrobium secundum*
 - b. Middle labellum reniforme *Dendrobium spurium*
 - c. Middle labellum not both 12
12. a. Flowers with smell good *Dendrobium stuartii*
 - b. Flower not flavorful 13
13. a. Flower light greenish yellow *Dendrobium stuposum*
 - b. Flower yellowish white *Dendrobium subulatum*
 - c. Flower pale yellowish pink *Dendrobium tetraedre*

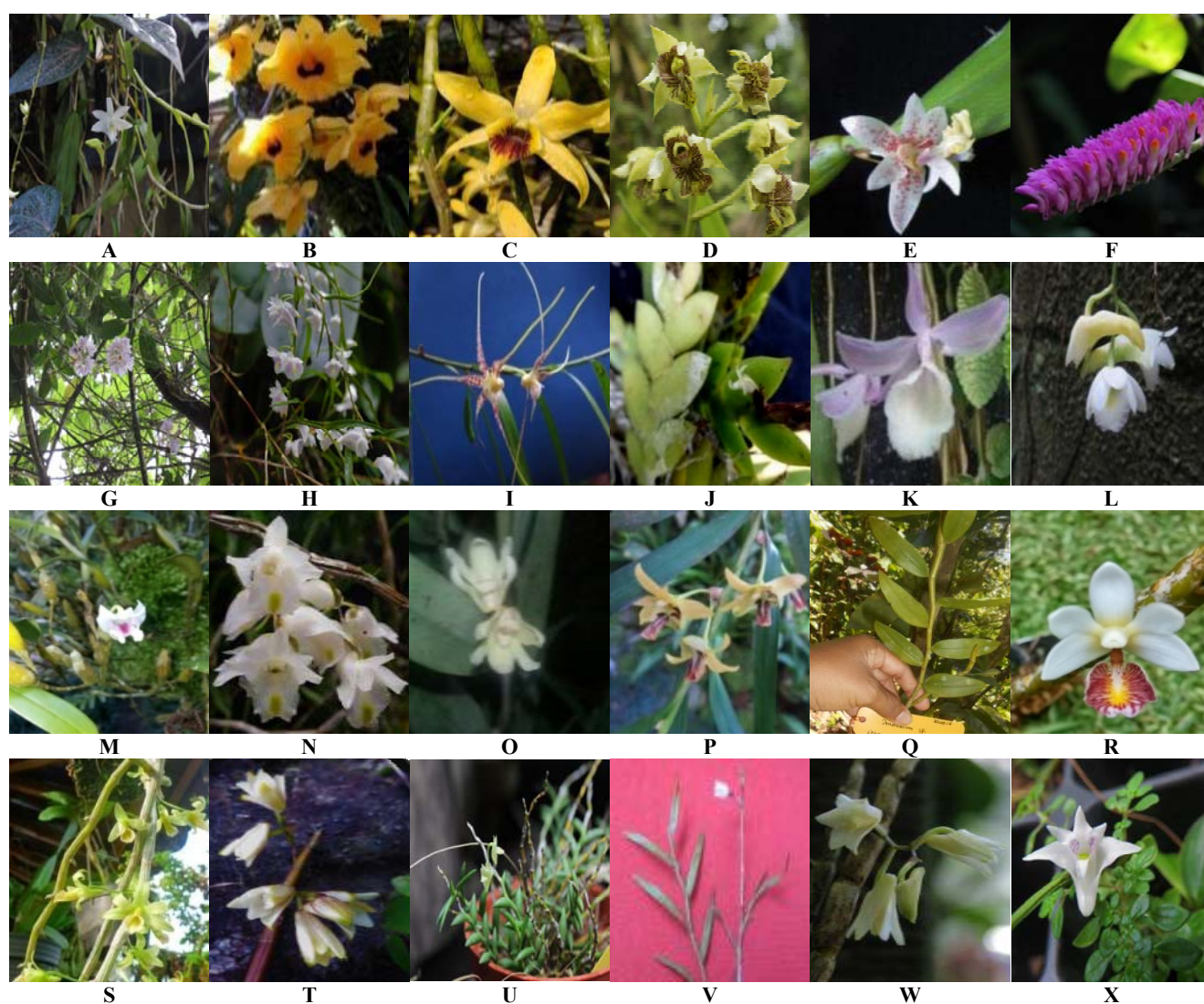


Figure 2. The *Dendrobium* in Central Bali, Indonesia. A. *D. cruminatum*, B. *D. fimbriatum*, C. *D. heterocarpum*, D. *D. macrophyllum*, E. *D. plicatile*, F. *D. secundum*, G. *D. spathilingue*, H. *D. linearifolium*, I. *D. acuminatissimum*, J. *D. aloifolium*, K. *D. aphyllum*, L. *D. arcuatum*, M. *D. conspicuum*, N. *D. inflatum*, O. *D. rugosum*, P. *D. salaccense*, Q. *Dendrobium* sp. Sepang, P. *D. spurium*, S. *D. stuartii*, T. *D. stuposum*, U. *D. subulatum*, V. *D. tetraedre*, W. *Dendrobium* sp. Wanagiri, Q. *D. truncatum*.

Dendrobium acuminatissimum, *D. cruminatum* and *D. linearifolium* were known as dominant species. Those species were found throughout the exploration area ($Di > 5\%$) (Table 1). In lowland area (0-700 m asl.) 16 species of *Dendrobium* were found with the abundance of 48 individuals (Table 3), where *D. acuminatissimum*, *D. cruminatum*, *D. linearifolium*, *D. rugosum* and *D. salaccense* were dominant. The highest dominancy index (18.750%) were *D. acuminatissimum*, *D. cruminatum*, (Table 2). In the transition area (700-1100 m asl.), 12 species of *Dendrobium* were found with the abundance of

20 individuals and all species were dominant (Table 3). The species of *Dendrobium* found in lower montane exploration areas were 6 species with the abundance of 14 individuals, all species were dominant (Table 4). The presence of dominant *Dendrobium* species in a community and ecosystem indicates that the *Dendrobium* type has a higher adaptation capability to the environment. According to Saharjo and Cornelio (2011), a species may be dominant in a community if it succeeds in placing most of the available resources over other species.

Table 1. List of *Dendrobium* species with type of habitat, number of individuals and dominance

Species name	Ni	Di (%)	Dominance	Type of habitat
<i>Dendrobium acuminatissimum</i> (Blume) Lindl.	12	9.16	Dominant	Epiphyte
<i>Dendrobium aloifolium</i> (Blume) Rchb.f.	2	1.53	Not dominant	Epiphyte
<i>Dendrobium aphyllum</i> (Roxb.) C.E.C. Fisch.	2	1.53	Not dominant	Epiphyte
<i>Dendrobium arcuatum</i> J.J. Sm.	2	1.00	Not dominant	Epiphyte
<i>Dendrobium conspicuum</i> Bakh.f.	3	2.29	Subdominant	Epiphyte
<i>Dendrobium crumenatum</i> Sw.	18	13.74	Dominant	Epiphyte
<i>Dendrobium fimbriatum</i> Hook.	2	1.00	Not dominant	Epiphyte
<i>Dendrobium heterocarpum</i> Wall.ex Lindl.	1	0.76	Not dominant	Epiphyte
<i>Dendrobium inflatum</i> Rolfe	7	5.34	Subdominant	Epiphyte
<i>Dendrobium linearifolium</i> Teijsm. & Binn.	45	34.35	Dominant	Epiphyte
<i>Dendrobium macrophyllum</i> A. Rich.	1	1.00	Not dominant	Epiphyte
<i>Dendrobium plicatile</i> Lindl.	5	3.82	Subdominant	Epiphyte
<i>Dendrobium rugosum</i> (Blume) Lindl.	4	3.05	Subdominant	Epiphyte
<i>Dendrobium salaccense</i> (Blume) Lindl.	4	3.00	Subdominant	Epiphyte
<i>Dendrobium secundum</i> (Blume) Lindl. ex Wall.	1	1.00	Not dominant	Epiphyte
<i>Dendrobium</i> sp. Sepang	1	1.00	Not dominant	Epiphyte
<i>Dendrobium</i> sp. Wanagiri	1	1.00	Not dominant	Epiphyte
<i>Dendrobium spathilingue</i> J.J. Sm.	4	3.05	Subdominant	Epiphyte
<i>Dendrobium spurium</i> (Blume) J.J.Sm.	1	1.00	Not dominant	Epiphyte
<i>Dendrobium stuartii</i> F. M. Bail.	2	1.00	Not dominant	Epiphyte
<i>Dendrobium stuposum</i> Lindl.	5	4.00	Subdominant	Epiphyte
<i>Dendrobium subulatum</i> (Blume) Lindl.	2	1.00	Not dominant	Epiphyte
<i>Dendrobium tetraedre</i> (Blume) Lindl.	1	1.00	Not dominant	Epiphyte
<i>Dendrobium truncatum</i> Lindl.	5	4.00	Subdominant	Epiphyte
Total	131	100.00		

Note: Ni = number of individuals species, Di = index of dominance of a species

Table 2. Species dominance and relative frequency of the wild *Dendrobium* in lowland areas (0-700 m asl.)

Species name	N	F	FR (%)	Di (%)	Dominance
<i>Dendrobium acuminatissimum</i>	9	2.00	7.407	18.750	Dominant
<i>Dendrobium aphyllum</i>	2	1.00	3.704	4.167	Subdominant
<i>Dendrobium arcuatum</i>	1	1.00	3.704	2.083	Subdominant
<i>Dendrobium conspicuum</i>	2	2.00	7.407	4.167	Dominant
<i>Dendrobium cruminatum</i>	9	4.00	14.815	18.750	Dominant
<i>Dendrobium heterocarpum</i>	1	1.00	3.704	2.083	Subdominant
<i>Dendrobium linearifolium</i>	8	4.00	14.815	16.667	Dominant
<i>Dendrobium macrophyllum</i>	1	1.00	3.704	2.083	Subdominant
<i>Dendrobium rugosum</i>	4	3.00	11.111	8.333	Dominant
<i>Dendrobium salaccense</i>	3	1.00	3.704	6.250	Dominant
<i>Dendrobium secundum</i>	1	1.00	3.704	2.083	Subdominant
<i>Dendrobium</i> sp. sepang	1	1.00	3.704	2.083	Subdominant
<i>Dendrobium spathilingue</i>	2	2.00	7.407	4.167	Subdominant
<i>Dendrobium subulatum</i>	2	1.00	3.704	4.167	Subdominant
<i>Dendrobium stuartii</i>	1	1.00	3.704	2.083	Subdominant
<i>Dendrobium truncatum</i>	1	1.00	3.704	2.083	Subdominant
Total	48	27	100.000	77.083	

Note: N = total of individual, F = frequency, FR = relative frequency, Di = Index of dominance

Diversity, prosperity, uniformity, and similarity index of *Dendrobium* at different altitudes

The index of diversity, prosperity, and uniformity of species in the exploration area in different altitudes was analyzed by combining all data obtained at each altitude, and the result was shown in Table 5.

Table 3. Species dominance and relative frequency of the wild *Dendrobium* in transition Area (700-1100 m asl.)

Species name	N	F	FR (%)	Di (%)	Dominance
<i>Dendrobium acuminatissimum</i>	3	3	12.000	15.000	Dominant
<i>Dendrobium aloifolium</i>	2	1	4.000	10.000	Dominant
<i>Dendrobium arcuatum</i>	1	1	4.000	5.000	Dominant
<i>Dendrobium cruminatum</i>	1	1	8.000	5.000	Dominant
<i>Dendrobium fimbriatum</i>	1	1	12.000	5.000	Dominant
<i>Dendrobium inflatum</i>	1	1	4.000	5.000	Dominant
<i>Dendrobium linearifolium</i>	5	2	20.000	25.000	Dominant
<i>Dendrobium plicatile</i>	1	1	3.125	5.000	Dominant
<i>Dendrobium rugosum</i>	1	1	3.125	5.000	Dominant
<i>Dendrobium salaccense</i>	2	2	16.000	10.000	Dominant
<i>Dendrobium spathilingue</i>	1	1	3.125	5.000	Dominant
<i>Dendrobium tetraedre</i>	1	1	95.625	5.000	Dominant
Total	20	16	100.00		

Table 4. Species dominance and relative frequency of the wild *Dendrobium* in lower montane areas (1100-1500 m asl)

Species name	N	F	FR (%)	Di (%)	Dominance
<i>Dendrobium fimbriatum</i>	1	1	10.000	7.143	Dominant
<i>Dendrobium inflatum</i>	2	2	20.000	14.286	Dominant
<i>Dendrobium</i>	8	4	40.000	57.143	Dominant
<i>Dendrobium</i> sp. Wanagiri	1	1	10.000	7.143	Dominant
<i>Dendrobium stuposum</i>	1	1	10.000	7.143	Dominant
<i>Dendrobium spurium</i>	1	1	10.000	7.143	Dominant
Total	14	10	100.000		

Table 5. The index of diversity, prosperity, and uniformity of *Dendrobium* at different altitudes

Index	Lowland (%)	Transition land (%)	Lower montane (%)
Species diversity (H')	1.040	0.991	0.555
Species prosperity (Da)	3.875	3.094	1.559
Species uniformity (e)	0.864	0.922	0.713

Table 6. Sorensen Similarity Index (SI) at different altitudes of exploration sites

Habitat	Lowland (%)	Transition land (%)	Lower montane (%)
Lowland	–	42.857	19.047
Transitionland	42.857	–	23.359
Lower montane	19.047	23.359	–

The diversity of *Dendrobium* found in the lowlands was considered as moderate ($H' = 1.040$), while those in transition and lower montane were categorized as low ($H' = 0.991$ and 0.555 , respectively). The similar pattern also occurs in species prosperity index, where the species prosperity index lowland *Dendrobium* was higher ($Da = 3.875$) than those both in transition land ($Da = 3.094$) and lower montane ($Da = 1.559$). This was due to the amount of *Dendrobium* species found in lowland was higher (16 species), as much as 48 individuals compared with transition land and lower montane. These results are consistent with the findings of Paramitha (2012), diversity and prosperity of *Dendrobium* found in lower montane are low ($H = 0.0086$ and $Da = 0.868$). Van Steenis (1972) mentioned that generally, orchids grow well in mountain areas with altitude ranging from 500 to 1500 m asl, and their variation decreases in out site of this range (below 500 m asl or above 2000 m asl) but Waston (2004) states that the genus *Dendrobium* grows well at an altitude of 0-500 m asl with moisture of 60-80%. These results in study indicate that genus *Dendrobium* is a trend more suited to live in lowland environmental conditions.

The highest species uniformity index was found in transition land areas (0.922), but slightly different from the low and high altitudes. Overall, based on the uniformity indexes of the founding species were not uniform at each elevation of exploration site. The index value of species uniformity (e) ranges from 0.713 to 0.922, which indicated that the uniformity index was close to the value of one, meaning that the spread of individuals numbers of each species is equal and there is no tendency to dominate by one species and can be assumed that *Dendrobium* orchid is categorized as having medium level of uniformity.

The similarity index values were obtained by comparing species composition and individuals at each area of exploration. The value of *Dendrobium* similarity index in the three exploration areas is presented in Table 6.

In lowland and transition land areas, 6 similar species of *Dendrobium* (*D. acuminatissimum*, *D. conspicuum*, *D.*

cruminatum, *D. linearifolium*, *D. salacense* and *D. spathilingue*) were found, with IS value of 42.857%. This means that the two comparable sites have quite different plant species. In lowland and lower montane exploration areas, there were 2 types of *Dendrobium* was found, with IS of 19.047%. In transition land and lower montane, also 2 similar species of *Dendrobium* (*D. fimbriatum* and *D. linearifolium*) were found, with IS value 23.359%. According to Odum (1971), if the value of the same-species index is between 25% and 50%, the two comparing sites have quite different plant species, this is because the vegetation and the microclimate are also different.

Potential of Bali natural *Dendrobium* orchid as a source of germplasm

The development of the last five years orchid (2010-2015) has increased with an average growth of 5.19%, Bali contributes 6.62% from 96.73% to the Indonesian orchid production. While the development of Indonesian orchid exports during the period of 2000-2014, mostly in the form of orchid plants with an average contribution of 70.94%, while in the form of orchid seedlings of 29.06% (PDSIP 2015). Export of orchids is mostly hybrid orchid and *Dendrobium* genus occupy the first position, but the potential of wild *Dendrobium* Indonesia has not been optimally used to produce hybrid orchids and up to now only 2 sections of 20 section of *Dendrobium* are used as broodstock (Widiastoety et al. 2010). Therefore *Dendrobium* orchid diversity found in the exploration site is a great potential as a source of Bali's germplasm for the development of Indonesian orchids. One potential that can be done is the selection of broodstock breed crossings, to produce a new hybrid with the certain uniqueness. Several species of *Dendrobium* which can be selected as broodstock based on the character of the flowers possessed (unique shape, color and size) are *Dendrobium* species which includes; *D. macrophyllum* (Emerald orchid), *D. secundum* (brush orchid), *D. heterocarpum* (fountain orchid), *D. cruminatum*, *D. fimbriatum*, *D. linearifolium*, *D. spathilingue*, and *D. plicatile*. (Figure 2). However, the seven potential *Dendrobium* species, *D. macrophyllum*, *D. secundum* and *D. heterocarpum* are vulnerable, due to the very low population caused by poaching, habitat destruction, and forest conversion. Therefore, in addition to exploiting its potential as a parent crosses, conservation actions through in vitro propagation is needed to produce large amounts of the orchid seedling.

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