

MICROCLIMATE PREFERENCE AND HABITAT OF BEGONIA IN BEDUGUL, BALI

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ABSTRACT

A study on ecology of *Begonia* was conducted in two forest sites, a nature reserve and reboisation forest, in Bedugul, Bali. The objective of the study was to describe the *Begonia* species found in these forest sites, to gather information on microclimatic variables and to find the influences of these variables on the abundance of *Begonia* species. Three species were identified, *B. multangula*, *B. baliensis* and *B. longifolia*. There were two forms of *B. longifolia*, white and red. The multivariate analysis (PCA) showed that microclimatic variables measured were relatively similar among plots and hence, no particular microclimatic variable influenced *Begonia* species abundance. However, the multivariate analysis implied that *B. longifolia* has a different microclimate preference between forms (white and red). *B. longifolia* f. white was highly correlated to Axis 1 (99%) and *B. longifolia* f. red was highly correlated to Axis 2 (92%) of the PCA graph. The abundance of all species in the two forest sites was similar (t-test, $p=0.061$).

Key words: *Begonia* sp., microclimate, natural habitat, Bedugul, multivariate analysis

INTRODUCTION

Begoniaceae is easily distinguished from other forest herbs due to its distinctive habit. *Begonia* species can be found in several forms, either erect or creeping herbs, with succulent stems and asymmetric leaves. *Begonia* species are common to secondary and primary forest, along rivers or creeks, mostly in humid places, and around waterfalls (Kiew 2005). Many *Begonia* species have potential as ornamental plants, either as species or hybrids (Tebbit 2005; Purwantoro *et al.* 2010).

The main risks of plant species loss are possibly forest conversion and land use change as well as illegal logging. Fluctuating microclimate conditions caused by forest clearance and possibly by climate change may alter the germination and hence, composition of forest understorey. The genus *Begonia* should be a priority in *ex situ* conservation, potentially to allow reintroduction activity. *Begonia* species have

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considerable economic value as ornamental plants and some have potential as medicinal plants and as a vegetable (Tebbit 2005; Chiew 2005, Girmansyah 2008). In Banten, West Java, *B. multangula*, known as 'krokot', is popular among locals as vegetable (Djarwaningsih *et al.* 2010). In Bali, *B. multangula* is used for curing cough (Hartutiningsih 2005). In West Java, the Sundanese called *B. multangula* and *B. robusta* as hariang or asam-asam for substituting sour taste from *Tamarindus indica* in local dishes (Purwanto *et al.* 2010; Wiradinata *et al.* 2002) and it is also used for traditional medicine (Priyadi 2010).

A number of *Begonia* species are close to extinct due to habitat destruction (Chiew 2005). Research in *Begonia* is challenging as species are really under pressure in their natural habitat; research has to keep up with the pace of species loss due to habitat loss. Logging can destroy *Begonia* populations, and limestone quarries have contributed to the extinction of those endemic to limestone hills. The vulnerability of extinction for *Begonia* is compounded by the fact that many are extremely local endemics (Kiew 2005). In Peninsular Malaysia, of nearly 60 species, 26 are known from single localities and some of their populations are small (Kiew 2005). Therefore, *ex-situ* conservation finds its relevance here. Kebun Raya Eka Karya in Bali, an *ex-situ* conservation location in Indonesia, harbours more than 60 indigenous *Begonia* species (Thomas *et al.* 2009) and is regarded as the richest *Begonia* collection among botanical gardens in the world (Hartutiningsih 2005).

Ex-situ conservation efforts begin with exploration activity, which involves the inventory and collection of species, and habitat study. In addition to collection and taxonomic studies, there is a need for ecological study, in particular which environmental factors determine the existence of particular species in its natural habitat. There is very scant microclimate information available for tropical habitats, especially in the case of *Begonia*. Therefore, this study aims at describing: (i) which *Begonia* species are found in two forest sites in Bedugul, Bali, (ii) measure environmental variables in each habitat, and (iii) look for correlation between the recorded environmental parameters and the frequency of *Begonia* species.

MATERIALS AND METHODS

Study site

Observation on *Begonia* populations and environmental data were conducted in two locations, namely Bukit Tapak (08°16'00" S and 115°08'00" E) and *butan kontrak* (reboisation forest, 08°16'00" S and 115°09'00" E). Bukit Tapak is mainly secondary forest with somewhat heavier canopy cover which is represented by lower solar radiation Lux values in general (Table 1, Fig. 1). Most of the *Begonia* in Bukit Tapak already produce either flower or fruits whereas in reboisation forest, the observation was done along small open roads which is intensively managed by mowing, leading to shorter plants with less reproductive organs (Fig. 2).



Figure 1. *B. multangula*; hutan Tapak site

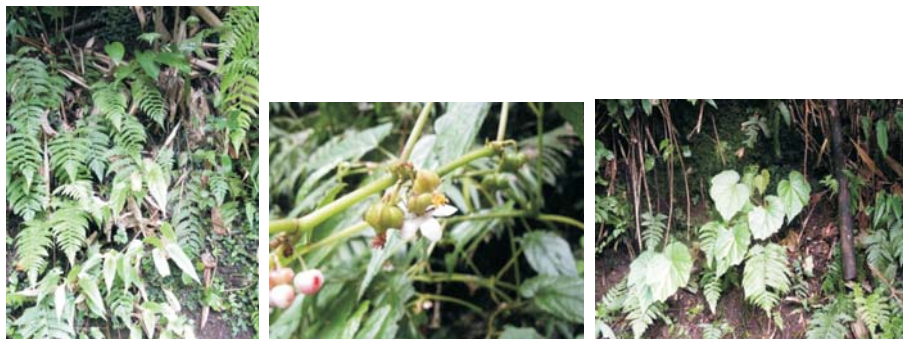


Figure 2. *B. longifolia* (left, middle) and *B. baliensis* (right); reboisation forest site

Bukit Tapak, Batukaru Nature Reserve, Bali

Batukaru Nature Reserve is located in Baturiti Subdistrict, Tabanan and Sukasade Subdistrict, Buleleng. The topography ranges variably from flat to steep, approximately 8% to 45% slope. The area of the reserve is 8557.98 ha, which consists of 3 sections which are resort Pemangkuan Hutan (RPH) Pupuan, RPH Penebel, and RPH Candikuning (KSDA-Bali 2009). The access to the nature reserve is via Wangaye gede village, subdistrict Penebel. The dominant vegetation consists of cemara pandak (*Dacrycarpus imbricatus*), cemara geseng (*Casuarina junghubniana*), kepelan (*Magnolia* sp.), juwet manting (*Crypteronia paniculata*), and seming (*Pometia* sp.). On forest floors, several species of *Begonia* can be found.

Reboisation Forest Area at “Eka Karya” Botanical Garden, Bali

The reboisation area (hereafter also written as *butan kontrak*) consists of flat, and hilly topography at an altitude of 1250-1400 m asl (Purwantoro 2010). The forest comprises 22-52 years old rasamala (*Altingia excelsa*), gintungan (*Bischofia javanica*) and cempaka (*Michelia champaca*). Other trees and herbs naturally exist including lateng (*Laportea microstigma*), *Eugenia uniflora*, *Garcinia* sp. and *Begonia* spp.

The submontane cool climate of Bali Botanical Garden facilitates good growth of *Begonia* species. The climate is type B with precipitation rate of 2000-3000 mm/year; a 7-9 month rainy season, and 1-3 month dry season, intercepted solar radiation of 46-60%, relative humidity of 78-96% and mean wind speed 7.27 km/hour (Hartutiningsih *et al.* 2005).

Species and data collection

The exploration is using a random purposive method, meaning that one track is taken for each site and standing from the line and observing the existing *Begonia* population, we decided where to establish the plot. We sampled 40 plots, 20 plots in each site. The size of the plot was 0.5 m × 0.5 m. Within the plot several measurements were taken for number of *Begonia* individuals as well as the following microclimatic factors: temperature (°C), solar radiation (Lux), Air Humidity (%), soil pH, soil moisture (%) and altitude (m). Temperature, solar radiation, and air humidity were measured using Lutron LM-8100. To measure temperature, solar radiation, and air humidity the device was located directly above *Begonia* individuals, at about 1.3 m above ground. Soil pH and soil moisture were measured using Soil Tester Takemura DM-5. The soil tester was placed about 10 cm (max 30 cm) from the main *Begonia* clumps. GPS Garmin 60 was used to indicate altitude and geographical coordinates. All measurements were carried out between 10 am and 3 pm. In addition, we collected plant samples within the plot, adjacent to *Begonia* for further identification in the lab. *Begonia* plant size, including diameter and height, number of seedlings, number of individuals in reproductive phase, were also measured (data not shown in this paper).

Data analysis

Univariate analysis

Differences between plots of each environmental factor, viz. temperature (°C), solar radiation (Lux), air humidity (%), soil pH, soil moisture (%) and altitude (m) were observed using univariate analysis, viz. t-test performed in SPSS for Windows (version 19.0). In addition, t-test was also performed to find whether there was difference between *Begonia* species abundance of the two forests, Bukit Tapak and *butan kontrak*. For this analysis, the *Begonia* species are considered as four variables: *B. multangula*, *B. baliensis*, *B. longifolia* f. white and *B. longifolia* f. red. Subsequently, separate analysis for each forest site was also conducted. Within each forest site, *Begonia* species were treated as four (*B. multangula*, *B. baliensis*, *B. longifolia* f. white and *B. longifolia* f. red) or three variables (*B. multangula*, *B. baliensis*, and *B. longifolia*) which will be further explained in the discussion. For the analysis in each forest, Analysis of Variance, one-

way ANOVA was planned to be employed. However, due to the nature of the data which were not normally distributed and the variance was not homogeneous, while the data remained the same upon transformation efforts, non-parametric data analysis was then carried out. Kruskal Wallis test was hence performed to investigate whether there was difference in *Begonia* species (considered as either four or three variables) within each forest.

Multivariate analysis

Multivariate analysis was used to see the simultaneous correlation between *Begonia* species and the measured environmental factors across forty sites and how these variables may explain the abundance of *Begonia* species. PCOrd5 for Windows was employed for Detrended Correspondence Analysis (DCA). The DCA showed that the length of gradient resulted as 1.880, and based on this we re-conduct the analysis using Principal Component Analysis (PCA). To observe how species abundance is explained by environmental factors we established a graph by determining the main matrix as *Begonia* species abundance in each plot and the second matrix as environmental factors of each plot. As a rule of thumb, when given r^2 -cutoff ≥ 0.300 the environmental variables shown in the graph are considered significant enough to explain the abundance of species. However, it was not possible to get the environmental variables vectors with r^2 -cutoff ≥ 0.300 from our data. Consequently, we chose r^2 -cutoff 0.004 to show the vectors in the *Begonia* species abundance and microclimate graph.

RESULTS AND DISCUSSIONS

Species descriptions

B. multangula Blume (Fig. 1)

Herbs, height 100 - 150 cm. Green stem, hairy, segment swollen, segment 10 - 12 cm. Leaves hairy, clear venation, length 10 - 15 cm, width 8 - 10 cm, margins clearly serrate. Flower white, fruit capsule, without wing, smooth. Flowering whole year, distinguishable from large leaf, growth in group and abundant in certain patches. Distribution: mountain forest in Java, Sumatra, and Bali, altitude up to 2400 m asl. For nomenclatural information and a full description, refer to Hughes (2008) and Hughes and Girmansyah (2011).

B. longifolia Blume (Fig. 2, left and middle)

Erect herb, cane like growth, 50 cm height, smooth stem. Leaves surface smooth, tip either sharp or blunt, size 12 - 20 × 6 - 12 cm. Flower emerges from axillary leaf, short; male flower white, tepals 4; female tepals 5 - 6. Fruits without wing, surface with dots. Commonly found on humid places, slopes, grow solitary. In Indonesia, *B. longifolia* frequently found in the islands of Java, Sumatra, Bali and Sulawesi. For nomenclatural information and a full description, see Kiew (2005), Hughes (2008), Hughes and Girmansyah (2011).

***Begonia baliensis* Girm.** (Fig. 2, right)

Erect and cane-like, seldom branched, 15 - 100 cm tall, stem brownish green to reddish brown; nodes brownish green to reddish brown, swollen. Leaves distant, lamina oblique, broadly ovate, asymmetric, basal lobe rounded, 3.5 - 7.5 cm long. Inflorescences axillary, few flowered. Fruits berry, 4 - 5 mm long, green when ripe, fleshy, globose, elongated into a fleshy beak, glabrous, 3-lobed, with one larger wing, not splitting. Seeds barrel-shaped, 0.25 - 0.3 mm long. Distribution: Bali. For nomenclatural information and a full description, see Girmansyah (2008).

***Begonia longifolia*, *B. baliensis*, *B. multangula* in their natural habitat and their association**

The number of individuals found and recorded in each forest is shown in Figure 3, where it depicts the total number of individuals recorded across plots. *B. baliensis*, *B. multangula* and *B. longifolia* (red and white forms), were all found in Bukit Tapak and *hutan kontrak*. As we did not conduct association study, we will not present association *per se* for *Begonia* in the respective forest. Instead, we will elaborate list of other species found in the plot as follows. *Begonia baliensis* was found with *Smilax* sp. (Smilacaceae), *Elaeocarpus* sp. (Elaeocarpaceae), *Diplazium esculentum* (Pteridophyta), *Clautylon* sp. (Euphorbiaceae). *B. longifolia* was recorded adjacent to *Homalanthus giganteus* (Euphorbiaceae), *Ardisia* sp. (Myrsinaceae), *Cyrtandra* sp. (Gesneriaceae), *Procris rublandii* (Urticaceae), *Adiantum* sp., *Alyxia* sp. (Apocynaceae), *Adiantum* sp. (Adiantaceae), *Smilax* sp. (Smilacaceae), *Glochidion* sp. (Euphorbiaceae), *Digitaria* sp. (Poaceae), *Diplazium* sp. (Denst.), *Flacourtia* sp. (Flacourtiaceae), *Nephrolepis biserrata* (Nephr.), *Homalanthus giganteus* (Euph.), *Polygonum chinense* (Polygon.), *Raphidopora* sp. (Araceae), *Elatostema stigosum* (Urticaceae), *Eupatorium triplinerve* (Asteraceae), *Diplazium* sp. (Denst.), *Pilea* sp. (Urticaceae), *Syzygium* sp. (Myrtaceae). *B. multangula* was found with *Meliosma peruginea* (Sab.), and *Digitaria* sp. (Poaceae).

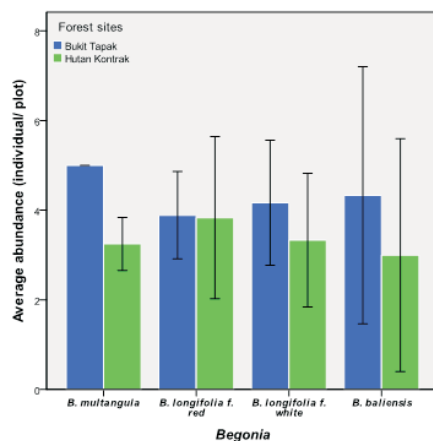


Figure 3. *Begonia* species average abundance across 40 plots in *Hutan Tapak* (20 plots) and *hutan kontrak* (20 plots); error bars show 95% CI.

Microclimate conditions

The average value of microclimatic factors, viz. air humidity, temperature, solar radiation, soil pH and moisture between two habitats of *Begonia* in Bedugul differed (Table 1), except for soil moisture or humidity. The overview of the environmental variables or microclimate can be found in Figure 4. The habitat conditions in both forests were somewhat different. *Hutan kontrak* was frequently disturbed by mowing or herbs cutting and received more abundant light and is relatively warmer (Table 1, Figure 4).

In order to understand the habitat preferences of each *Begonia* species, with respect to microclimate, we used multivariate analysis. For the analysis, *Begonia* species abundance was used as main matrix whereas environmental variables recorded across forty plots were used as second matrix. In general, we found that the three species of *Begonia* occupy similar microhabitats, as shown by the short vectors of the environmental variables (Figure 5). In other words, in each plot there was no characterizing environmental variable that distinguished *Begonia* species preference. Other factors that were not measured, on the other hand, may determine *Begonia* habitat preference. Such factors may refer to for example, nutrient availability, soil texture, mineral structure, root competition, litter layer, topsoil depth, allelopathy or competition with bryophytes, etc. In fact, *Begonia* species are able to occupy wide range of habitat type and microclimate, as in the case recorded for *Begonia* in Thailand (Phutthai *et al.* 2009).

Figure 6 depicts the distribution and abundance of *Begonia* species across plots. Main matrix and second matrix were both *Begonia* species abundance across plots. When r2-cutoff is set to higher threshold i.e. 0.600, only *B. longifolia* f. white and *B. longifolia* f. red vectors were able to show up indicating that plots significant characters the frequency of found in *B. longifolia*. When r2-cutoff reduced to 0.300, vectors produced were for *B. longifolia* f. red, *B. longifolia* f. white, and *B. baliensis*. Thus, the presence of these *Begonia* species were able to be grouped based on plots, except for

Table 1. Microclimatic features of two natural habitats of *Begonia*. T- test was applied to define statistical difference of each factor between two sites

Abiotic Factor	Forest Site	Mean	SE of Mean	p-value
Temperature (°C)	Bukit Tapak	23.6	0.169	0.000
	Reboisation Forest	27.1	0.475	**
Solar radiation (Lux)	Bukit Tapak	472.95	107.0367	0.000
	Reboisation Forest	2246.197	502.2649	**
Air Humidity (%)	Bukit Tapak	71.86	0.4245	0.043
	Reboisation Forest	70.175	0.6871	*
Soil pH	Bukit Tapak	6.225	0.571	0.043
	Reboisation Forest	6.02	0.793	*
Soil Moisture (%)	Bukit Tapak	78.057	1.652	0.801
	Reboisation Forest	78.759	2.203	(ns)
Altitude (m asl)	Bukit Tapak	1428.95	2.259	0.000
	Reboisation Forest	1351.1	7.021	**

p-value indicates * as significant; ** as highly significant; (ns) as not significant at 95% confidence interval

B. multangula. However, from Figure 5, Environmental variables to characterize each plot were not found.

B. longifolia f. white had a high correlation with Axis 1, and on the other hand, *B. longifolia* f. red had a high correlation with Axis 2. Interestingly, within *B. longifolia*, white and red form has a tendency to be present in different plots. Further investigation on how these two forms differ in occupying site shall be carried out. Based on Figure 6, *B. baliensis* and *B. multangula* were relatively frequent to occupy similar plots, even though not significant (higher r^2 -cutoff= 0.106). *B. baliensis*, *B. multangula*, and *B. longifolia* f. red were somewhat found to occupy similar sites, but completely apart from *B. longifolia* f. white.

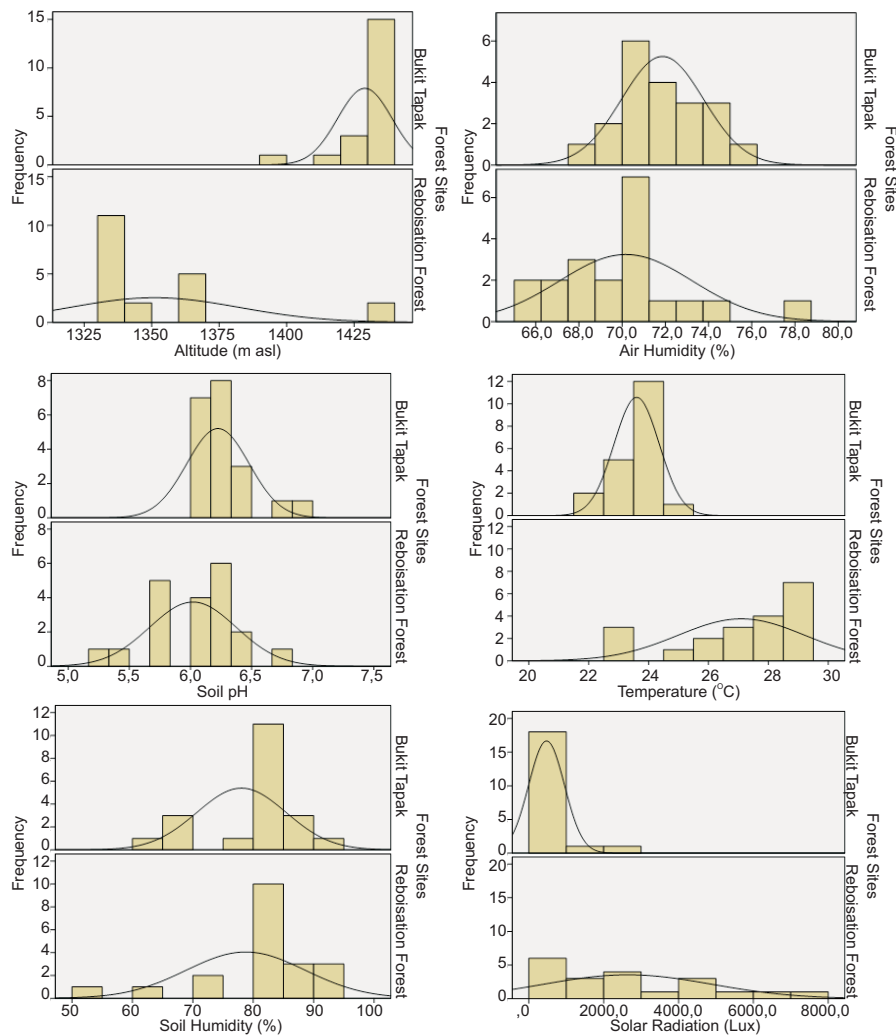


Figure 4. The microclimatic features of the 40 study plots (20 plots in Bukit Tapak and 20 plots in *butan kontrak* or reboisation forest)

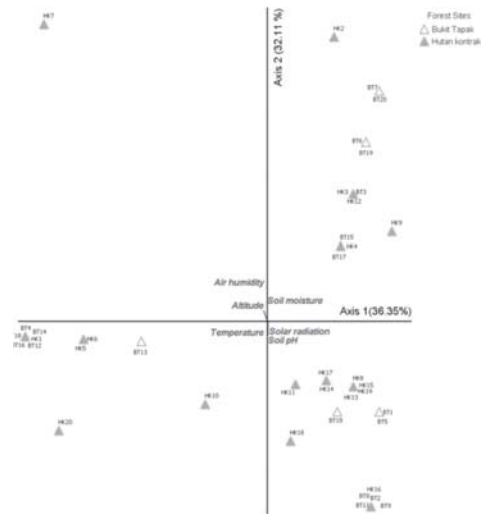


Figure 5. Principal Component Analysis of *Begonia* species abundance and measured environmental factors in Bukit Tapak (BT) dan Hutan Reboisasi (HK) (r^2 -cutoff=0.04; length of gradient Axis 1=1.996, Axis 2=1.763). These environmental variables were not significant (when r^2 -cutoff ≥ 0.300 , no vectors was produced) related to plots and hence, could not explain *Begonia* species abundance.

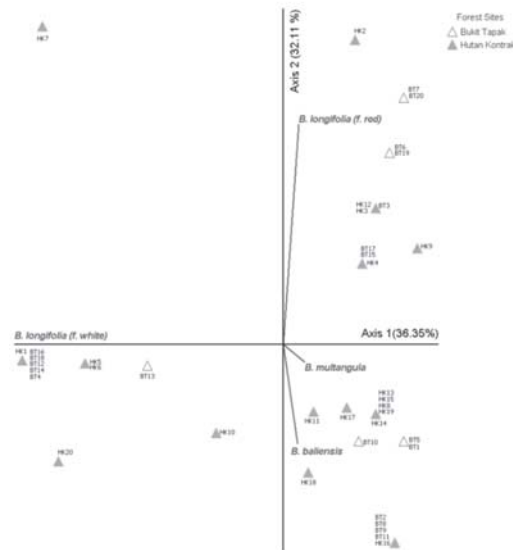


Figure 6. Principal Component Analysis of *B. longifolia* (form red and white), *B. multangula* and *B. baliensis* (r^2 - cutoff=0.004). Correlation of *B. multangula*, *B. baliensis*, *B. longifolia* f. red and *B. longifolia* f. white to Axis 1 were 0.285, 0.235, 0.243, and -0.989, respectively; whereas the correlation value of *Begonia* species to Axis 2 were -0.263, -0.620, 0.923, and 0.04, respectively.

B. multangula is actually known to have a wide distribution range and is present in Java, Sumatra and Lesser Sunda Islands (Hughes 2008). Girmansyah (2008) in his study on *Begonia* of Bali and Lombok described the distribution of *B. longifolia* which extends from the Himalayas (India) to south China, Vietnam and through Thailand, peninsular Malaysia, and Indonesia (Sumatra, Java, Bali, and Lombok). *B. baliensis* is endemic to Bali and is known to occupy humid forest along trails at 1300 – 1800 m either in small colonies or large populations (Girmansyah 2008).

Through univariate analysis, the difference between *Begonia* species abundance between the two forest types was similar (t-test, $p=0.0061$). Subsequently, for Bukit Tapak the four *Begonia* species (*B. multangula*, *B. baliensis*, *B. longifolia* f. red, *B. longifolia* f. white) abundance did not differ among species (Chi-square=1.913, $p=0.591$) neither when the two forms of *B. longifolia* was pooled together (Chi-square=2.018, $p=0.365$). The results were similar to *butan kontrak*, *Begonia* species did not differ among each other, either way when considered as four (Chi-square=0.556, $p=0.906$) or three (Chi-square=0.476, $p=0.788$) different species.

A plant diversity study in Resort Cidahu Gunung Halimun Salak, West Java (Larashati *et al.* 2010) pointed out that *B. multangula* is abundant in areas which intercept higher solar radiation, whereas within the same research site *B. longifolia* tended to prefer areas with heavier shade such as the forest floor. *B. multangula* and *B. robusta* were found to be abundant along paths, and around an open, frequently disturbed helicopter pad. Furthermore, *B. longifolia*, *B. muricata*, and *B. bracteata* were found mostly in forest under heavy shade. However, on the forest floor, *B. multangula* was also found. It seems that *B. multangula* has a wide range of preference and therefore it confirms our PCA result (Figure 6) that the correlation to Axis 1 and Axis 2 were the lowest amongst other *Begonia* species observed, which were 0.235 and -0.263, respectively.

Another study in Gunung Halimun National Park by Wiradinata *et al.* (2002) recorded that *B. multangula* was very abundant. The distribution of this species is within ground cover of mountainous forests in Java up to 2400 m altitude. In Gunung Halimun, it was always found to grow in clumps or groups at a wide range of altitudes, 900-1800 m. The flowering and fruiting period is all year round, and it prefers medium soil moisture and humidity. Surprisingly, they also found that *B. longifolia* is on the contrary rare (only found in two spots in Cikaniki and Ciptarasa), grows solitary, and prefers very moist substrates or semi-waterlogged. *B. longifolia* was found only at 900-1000 m altitude in this study. These studies did not mention any differentiation (colour) of *B. longifolia* in the forest in Java.

B. longifolia (both forms) and *B. multangula* are cane-like, whereas *B. baliensis* is shrub like. This trait can be further analyzed using correlation with specific abiotic factors, such as light interception or shade tolerance. However, a study by Shiodera and Kohyama (2005) showed that in Gunung Halimun Salak, at 1000-2000 m altitude, population of *B. multangula* observed were found generally under medium light intensity. Unfortunately, no further information refers to the extent of how light intensity determines the abundance of *Begonia* sp. On the other hand, its close relative, i.e. *B. robusta*, present in similar forest, showed a tolerance to a wider low-medium- and high light intensity. Further ecological studies on habitat preference should address more features of the environment such as nutrient availability,

competition, and disturbance level as many *Begonia* species are known for their narrow endemism, but a small number of species have a wide distributional range as well. As it has been hypothesized in several previous studies that light might determine the abundance of *B. multangula* and *B. longifolia*, further research is needed to address this aspect in addition to that presented here.

CONCLUSIONS

The abundance of all species between two forest types and within each forest were not significantly different. Microclimate factors of two observed habitats of *Begonia* in Bedugul were relatively equal between two forests and do not characterize habitat. However, there was a strong habitat separation between *B. longifolia* f. white and f. red. Even though not statistically evident, *B. longifolia* (f. red), *B. multangula*, and *B. baliensis* tend to occupy similar plots. Unfortunately, environmental variables measured in the study did not appear significant to characterize each plot, and hence we could not able to identify which abiotic factors were able to determine the occurrence of *Begonia* species. Several previous studies emphasized light intensity as explaining abiotic factor that distinguish the abundance in *B. multangula* and *B. longifolia* in Java, and hence, further elaborative study should address this matter.

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