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LIGHT PREFERENCES IN TWO LANDSCAPE MANAGEMENTS AND ONTOGENIC LIGHT REQUIREMENTS OF TERRESTRIAL FERNS IN KEBUN RAYA BATURRADEN, CENTRAL JAVA

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AGUNG SEDAYU
Program Studi Biologi, FMIPA, Universitas Negeri Jakarta, Gd. Hasjim Asjarie lt. 6., Jln. Rawamangun Muka, East Jakarta 13220, Indonesia. Email: asedayu@unj. ac.id

RAHADIAN AJENG SARASWATI
Program Studi Biologi, FMIPA, Universitas Negeri Jakarta, Gd. Hasjim Asjarie lt. 6., Jln. Rawamangun Muka, East Jakarta 13220, Indonesia. Email: rahadianajeng20@gmail.com

YULI PUJI ASTUTI
Balai Kebun Raya Baturraden, Jln. Pancuran Tujuh-Wanawisata Baturraden, Kabupaten Banyumas 53151, Central Java, Indonesia. Email: pujiastutiyuli123@gmail.com

ABSTRACT
SEDAYU, A., SARASWATI, R. A. & ASTUTI, Y. P. 2022. Light preferences in two landscape managements and ontogenic light requirements of terrestrial ferns in Kebun Raya Baturraden, Central Java. *Reinwardtia* 21(1): 25–33. — Human management on landscapes influences environmental requirements including solar irradiation, which may affect fern establishment in different age classes. Two contrasting terrestrial fern communities were inspected in Kebun Raya Baturraden, Central Java; the first thrives among the garden (collection) area, representing the well managed area, and the latter living on the less managed area closest to a natural forest remnant. We found 78.7% species living exclusively in either landscape type; only 21% were shared on both, indicating a light preference among ferns and lycophytes. The four most common species (out of 32 fern and lycophyte species), *Cyclosorus heterocarpus*, *Selaginella ornata, Nephrolepis biserrata*, and *Sphaerostephanos arbuscula* in three different age classes and under gradient canopy openness were surveyed. Statistical test on the canopy openness of individuals of *S. ornata* and *N. biserrata* showed that three age categories used significantly different canopy openness, which is not the case for *C. heterocarpus* and *S. arbuscula*. It showed that some ferns and lycophytes ontogenically have gradual requirements on light exposure, while others are able to live in wide range of light exposure. This implies that in terms of wild species management, including ferns, the Baturraden gardens landscape management must be directed toward the ecological understanding of species of interest for Botanical Gardens and conservation.

Key words: Canopy openness, density, garden, less managed area, lycophytes.

ABSTRAK
SEDAYU, A., SARASWATI, R. A. & ASTUTI, Y. P. 2022. Preferensi cahaya dalam dua pengelolaan lanskap dan kebutuhan cahaya ontogenik dari paku-pakuan terestrial di Kebun Raya Baturraden, Jawa Tengah. *Reinwardtia* 21(1): 25–33. — Pengelolaan oleh manusia pada lanskap mempengaruhi banyak persyaratan lingkungan paku-pakuan termasuk penyinaran matahari, yang dapat mempengaruhi kemampuan hidup paku-pakuan di kelas umur yang berbeda. Dua komunitas paku dan likofita yang kontras di Kebun Raya Baturraden telah diobservasi; yang pertama tumbuh di antara areal taman (koleksi), mewakili areal yang dikelola dengan baik, dan yang kedua hidup di areal yang kurang terkelola yang paling dekat dengan sisa-sisa hutan alam. Kami menemukan 78,7% jenis yang hidup secara eksklusif di kedua tipe lanskap; sementara hanya 21% yang berbagi pada keduanya, menandakan preferensi cahaya pada paku-pakuan dan likofita. Empat jenis yang paling umum (dari total 33 jenis paku dan likofita terestrial), *Cyclosorus heterocarpus, Selaginella ornata, Nephrolepis biserrata*, dan *Sphaerostephanos arbuscula* di tiga kelas umur yang berbeda dan di bawah gradien keterbukaan kanopi telah disurvei. Uji ANOVA dan *post-hoc* terhadap bukaan tajuk individu *S. ornata* dan *N. biserrata* menunjukkan bahwa ketiga kategori umur menggunakan bukaan tajuk yang berbeda nyata, tidak demikian untuk *C. heterocarpus* dan *S. arbuscula.* Hal ini menunjukkan bahwa beberapa paku-pakuan dan lycophytes secara ontogenik memiliki persyaratan paparan cahaya yang bertahap, sementara yang lain mampu hidup dalam rentang paparan cahaya yang luas. Hal ini menyiratkan bahwa dalam hal pengelolaan jenis liar - termasuk paku-pakuan, pengelolaan landskap kebun Baturraden harus diarahkan pada pemahaman ekologis jenis yang diminati dan penting bagi Kebun Raya dan konservasi.

Kata kunci: Bukaan kanopi, densitas, kawasan yang kurang dikelola, likofita, taman.

INTRODUCTION

Terrestrial ferns and lycophytes are major components in both natural and man-made landscapes, especially in tropical regions as Indonesia. Due to airborne dispersal of lightweight spore, fern and lycophyte species are easily exchanged across different landscapes. Fern spores are capable to travel long distances by wind and colonize disjunct areas only from a single grain of spore (De Groot *et al.*, 2012). If long distance dispersal is common in ferns, seasonal or continuous short distance travel from two adjacent type of landscapes should be relatively easy (Hock *et al.*, 2006). Spore interchange between two adjacent landscapes means that a generalist species will be able to be found in two adjacent landscapes, while specialist species should be confined to one type of landscape.

One major habitat differentiation in natural and man-made landscape is light environment as a consequence of landscape management. In general, as also in Indonesia, a more natural landscape will be characterized by a more forested, thus higher canopy coverage which filters light on the undergrowth vegetation including ferns and lycophytes. The man-made landscape is abundance of light exposure in a more open landscape. Species of terrestrial ferns and lycophytes colonizing the two light environments may be distinct as classically expressed as *sun ferns* in the open and *shade ferns* in the more forested area (Holttum, 1966). The KR (*Kebun Raya* = Botanic Garden) Baturraden was designed as gardens adjoining the remnant forest on the slope of Mt. Slamet (3,428 m) in Central Java, providing suitable locations to study the ferns and lycophytes inhabiting two light environments, shaded on the less managed-forested area and open on the garden-well managed area.

Researches on the light environments of ferns and lycophytes have been conducted mostly in natural forest landscapes (Saldaña *et al.*, 2005; Sedayu, 2006; Saldaña *et al.*, 2007); however, as the growing population demand, and more land converted into man-made landscape, including gardens, it is important to understand the biology and ecology of species that reside in the garden. With the position of KR Baturraden adjoining the natural remnant forest, it is possible that certain parts of the garden may act as refugia for forest fern and lycophyte species, as also studied in the spermatophytes (Tadesse *et al.*, 2014; Atha *et al.*, 2016). Thus, understanding the light preference of ferns living in the garden (those excluding the collections) may also contribute to the conservation of Javan mountain forest ferns and lycophytes.

During their ontogenic course of development, plants, including ferns and lycophytes are constantly adjusting their energy requirements with the energy available (Lusk *et al.*, 2008). It is known that a seedling may require less light during their development, and larger saplings or trees require larger amount of light exposure for photosynthesis as they approach their generative cycle/maturity (Kenzo *et al.*, 2006), while the morphology, physiology and biochemistry of the plants are adjusting accordingly. We expect to understand this pattern in the fern and lycophyte assemblages within the KR Baturraden during their different ontogenic development (age classes). This study may contribute to understanding the life of forest, and perhaps, protected species, as well as open garden, and perhaps, potential weed species. In general, this study will broaden our understanding upon the less studied ferns and lycophytes in comparison to the studies largely for spermatophytes.

MATERIALS AND METHODS

Study Site

The KR Baturraden is a 143.5 hectares garden located right in the center of Java (Fig. 1, inset), with elevation between 702–1,076 m above sea level, and terrain inclination between 20–70%. The annual temperature ranged between 20–30°C, while humidity between 85–98% and precipitation between 5,000–6,174 mm, classified as *Af* (tropical rain forest) in Koppen-Geiger classification (Peel *et al.*, 2007). The gardens were laid in various landscape management, from reserve forest with natural-semi natural forest vegetation at the slope of Mt. Slamet, low utilization zone, on which, mid utilization zone, on which and intensive utilization zone where well managed gardens, amenities and public services are located.

Total of 135, 1 × 1 m, quadrats were purposely laid down to exemplify two contrasting environments. Sixty-eight quadrats were laid at the boundary between forest and gardens (Fig. 1, A), representing the less managed area of the gardens, while 67 we laid on the more managed areas or coincided with the intensive utilization zone (Fig.1, right). These 67 quadrats are 12 on Flora of Java Gardens I, 10 Flora of Java Gardens II, 15 on Liana Gardens, 15 White Latex Gardens and 15 on Fern Gardens, respectively (Fig. 1, B1–B5). The quadrats in B1–B5 coincide with the intensive utilization zone (Fig. 1, right).

Fig. 1. Study site: approximate location of quadrats (left); map of land utilization in KR Baturraden (right, Departemen Pekerjaan Umum, 2005); Inset: location of KR. Baturraden in Central Java.

Quadrat sampling and hierarchical clustering

Within a single quadrat, the presence and absence of species of terrestrial ferns and lycophytes were noted and arranged in a present-absent matrix. Only native taxa were noted in this study, with omitting cultivated species. In gardens (especially the fern gardens), extremely careful consideration was made to justify whether an individual sighted is regarded as wild (at least escapee) or as cultivated. Some native species, e.g. *Alsophila junghuhniana* might start as wild sporeling and kept as a decorative landscape adornment. The matrix is converted into a distance matrix using binary method and subsequently reconstructed using hierarchical clustering (*hclust*) into a fan-shaped dendrogram using *as.phylo* plotting method. Herarchical clustering was done in R Studio version 3.6.1 (R Studio Team, 2020). Identification was done using Flora Malesiana Series 2 Pteridophytes vol. 1–4 (1959–2012).

Fern and lycophyte density

As the number of every fern and lycophyte within all quadrats are noted, we were able to count the density of the species for the whole sampling area. The density of a species is denoted as the number of individual/the total of quadrat area. We then assigned four species of the highest density for the following study.

The canopy openness effect on different fern/ lycophyte age classes

We used four species with the highest densities to further study the effect of light exposure on different fern and lycophyte age classes. Every individual of these species (i.e. *Cyclosorus heterocarpus, Selaginella ornata, Nephrolepis biserrata,* and *Sphaerostephanos arbuscula*; see Table 1) were assigned to one of three age classes: (1) sporelings, i.e., individuals with few fronds and/or with primordial frond still visible; (2) juveniles, i.e., individuals with larger fronds, however non spore-producing; and (3) adults, i.e., individuals with sori-producing fronds.

We used canopy openness to exemplify the environmental solar exposure. Canopy openness was measured using GLAMA (Tichý, 2016) on Realme C2 mobile phone, right above the crown of each individual. The difference of canopy openness among age classes was calculated using one way ANOVA and was done in R Studio. When significant, Tukey's post-hoc test was applied on the pairs.

RESULTS

Clustering

Hierarchical clustering showed that the terrestrial fern and lycophyte communities within the study area are clustered distinctively based on land management. Fig. 2 shows that the quadrats

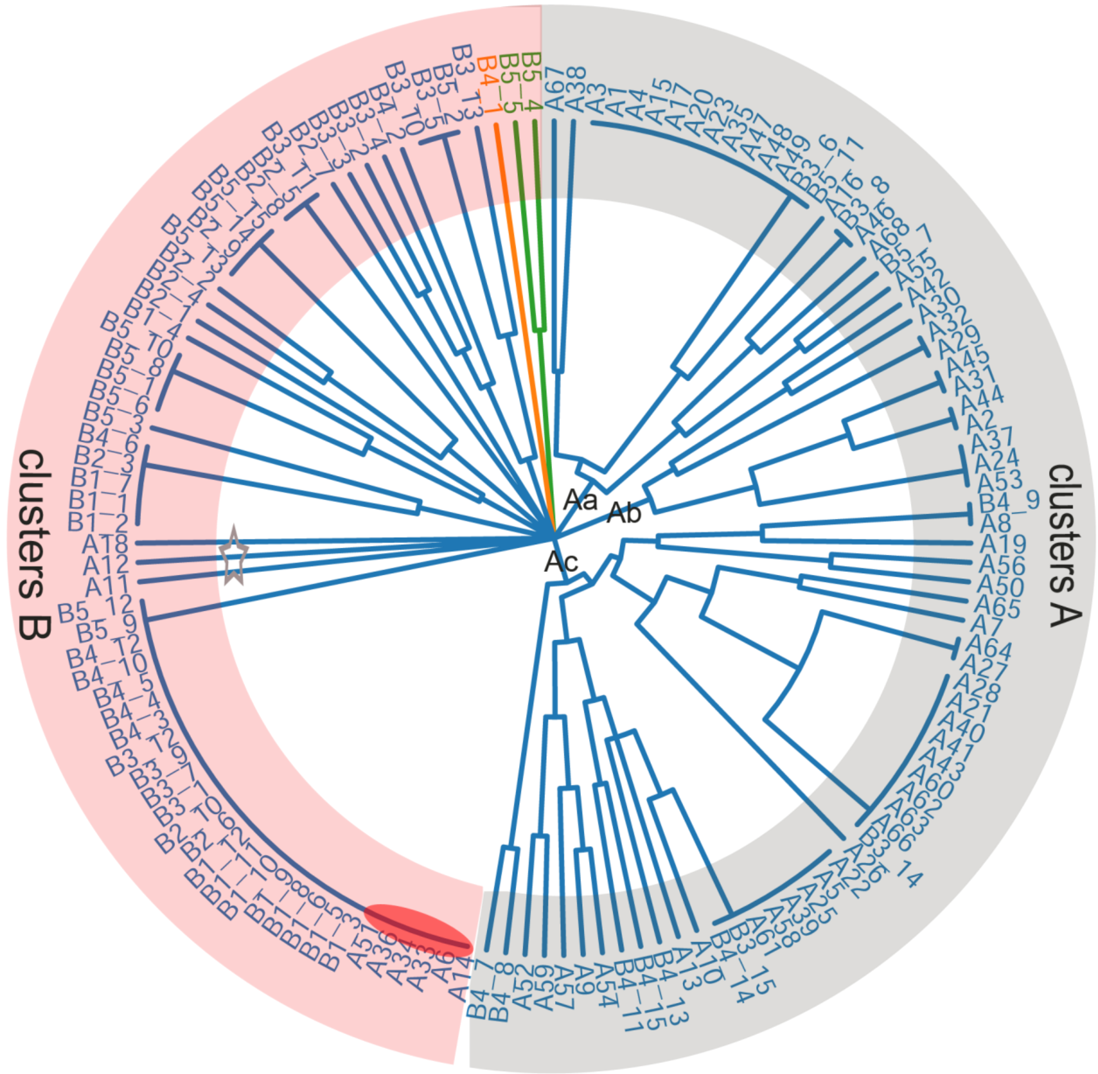

Fig. 2. Dendrogram of terrestrial ferns and lycophytes communities. Cluster A represents quadrats in forested-less managed area; Cluster B represents quadrats in gardens-well managed area.

laid on the forest-forest edge (A) are clustered into 3 major clusters (Aa, Ab and Ac; highlighted in grey) with some B quadrats, squeezed in among A, for instance B3_6 and B5_11 within cluster Aa and B5_7 in cluster Ab. Cluster Ac consist of 40 quadrats, with 39 (78%) belong to A group, with 9 quadrats belong to B group. The other part conversely composed of largely B quadrats (highlighted in pink) included only 9 quadrats belong to A group (6 in a red ellipse mark and 3 with the star mark); however, since the part collapsed in the base.

Species assemblage and the four highest density terrestrial ferns and lycophyte

We found 32 species of ferns and lycophytes, consisted of 27 species of ferns and five species of lycophytes, all of which from the genus *Selaginella* (Table 1). Twelve species were found exclusively in the forested-less manage quadrats (A), as opposed to 13 species found only in garden-well managed quadrats (B). Only seven species overlapped in both landscapes. The vegetation analysis reckoned four species with the highest density subsequently chosen for light environment study.

Light environment of four chosen ferns and lycophyte in in three age classes

Table 1 showed that *Cyclosorus heterocarpus* and *Sphaerostephanos arbuscula* did not indicate any distinction in light environments across three different age classes as showed by the non-significant ANOVA test. On the contrary,

Table 1. Density of the terrestrial ferns and lycophytes within two differently managed area in the KR Baturraden; boldface denotes species with highest density; A: forest-less managed area; B: gardens-well managed area; A+B: present in both A and B; 1: present; 0: absent; taxonomy follows PPG I (PPG I, 2016).

No	Family	Species	Density (indvidu/m^2)	A	B	A+B
1	Athyriaceae	*Deparia confluens* (Kunze) M.Kato	0.0963	0	1	0
2	Athyriaceae	*Deparia petersenii* (Kunze) M.Kato	0.02222	0	1	0
3	Athyriaceae	*Diplazium bantamense* Blume	0.2	1	0	0
4	Athyriaceae	*Diplazium pallidum* (Blume) T.Moore	0.18519	1	0	0
5	Athyriaceae	*Diplazium subserratum* (Blume) T.Moore	0.4444	1	1	1
6	Blechnaceae	*Blechnum orientale* L.	0.03704	0	1	0
7	Cyatheaceae	*Alsophila junghuhniana* Kunze	0.02222	1	1	1
8	Cyatheaceae	*Sphaeropteris glauca* (Blume) R.M.Tryon	0.04444	0	1	0
9	Cyatheaceae	*Sphaeropteris squamulata* (Blume) R.M.Tryon	0,02963	1	0	0
10	Dennstaedtiaceae	*Histiopteris incisa* (Thunb.) J.Sm.	0.04444	1	0	0
11	Didymochlaenaceae	*Didymochlaena truncatula* (Sw.) J.Sm.	0.00741	0	1	0
12	Dryopteridaceae	*Dryopteris sparsa* (D.Don) Kuntze	0.03704	1	1	1
13	Gleichenicaeae	*Dicranopteris linearis* (Burm.F.) Underw.	0.00741	1	0	0
14	Lindsaeaceae	*Lindsaea lobata* Poir.	0.02222	1	0	0
15	Lindsaeaceae	*Nesolindsaea caudata* (Hook.) Lehtonen & Christenh	0.01481	1	0	0
16	Nephrolepidaceae	***Nephrolepis biserrata* (Sw.) Schott (3)**	**0.85926**	1	1	1
17	Pteridaceae	*Pityrogramma calomelanos* (L.) Link	0.04444	1	1	1
18	Selaginellaceae	*Selaginella doederleinii* Hieron	0.35556	0	1	0
19	Selaginellaceae	***Selaginella ornata* (Hook. & Grev.) Spring. (2)**	**1.05185**	1	1	1
20	Selaginellaceae	*Selaginella plana* (Desv. ex Poir.) Hieron	0.16296	0	1	0
21	Selaginellaceae	*Selaginella* sp.1	0.02222	1	0	0
22	Selaginellaceae	*Selaginella willdenowii* (Desv. ex Poir.) Baker	0.01481	1	0	0
23	Tectariaceae	*Tectaria* sp.1	0.05185	0	1	0
24	Thelypteridaceae	*Christella dentata* (Forssk.) Brownsey & Jermy	0.05926	0	1	0
25	Thelypteridaceae	*Christella* sp.1	0.02222	0	1	0
26	Thelypteridaceae	***Cyclosorus heterocarpus* (Blume) Ching (1)**	**1.08148**	1	1	1
27	Thelypteridaceae	*Cyclosorus repandus* (Fée) B.K.Nayar & S.Kaur	0.05185	0	1	0
28	Thelypteridaceae	*Amblovenatum terminans* (Wall. ex Hook.) J.P.Roux	0.01481	1	0	0
29	Thelypteridaceae	*Pneumatopteris* sp.1	0.17037	0	1	0
30	Thelypteridaceae	***Sphaerostephanos arbuscula* (Willd.) Holttum (4)**	**0.77778**	0	1	0
31	Thelypteridaceae	*Thelypteridaceae* sp.1	0.00741	1	0	0
32	Thelypteridaceae	*Thelypteridaceae* sp.2	0.00741	1	0	0
				19	20	
			TOTAL	(12+7)	(13+7)	7

Table 2. Canopy openness above terrestrial fern and lycophyte individuals in three age classes and its ANOVA test; mean in percent followed by same letter on the same line does not differ significantly (0.05) according the Tukey's post hoc test; species sequence sorted from largest density; boldface denotes P-value < 0.05.

No	Species	Sporeling		Juvenile		Adult		F	P-value
		Mean	± SE	Mean	± SE	Mean	± SE		
1	*Cyclosorus heterocarpus*	12.43	1.1	16.24	0.85	15.08	1.29	2.865	0.06
2	*Nephrolepis biserrata*	15.33[a]	1.34	16.23[a]	1.15	32.99[b]	0.87	5.364	**0.006**
3	*Selaginella ornata*	14.7[ab]	1.1	17.39[b]	1.13	11.07[a]	0.77	5.809	**0.004**
4	*Sphaerostephanos arbuscula*	23.65	1.26	27.58	1.79	-	-	3.403	0.069

Nephrolepis biserrata showed significant difference in adult age class while *Selaginella ornata* in all three age classes with slightly different trend.

DISCUSSION

Fern and lycophyte communities in two contrasting landscapes

The results of clustering analysis (Fig. 1) can be considered as a clear grouping of terrestrial fern and lycophyte communities in the study area, with the more forest-less managed area (A) forming into clear clusters but B did not form apparent clusters. Since the clusters was made of the present-absent data of ferns and lycophytes species, this implied that species living in the more forested-less managed area are composed of different species compared to more open gardens-well managed area. The tendency of fern and lycophyte to occupy different light exposure in the forest had been studies (Sedayu, 2006), however light exposure effects on the ferns in man-made landscape as gardens are not well documented.

The clear clustering of the As separated from the Bs can be explained in the high number of species living exclusively in only one type of landscape management. Out of 19 species found in As, 12 species found exclusively in the A, while the opposite, out of 20 species found in B, another different 13 species found living there. Both (12 in A and 13 in B) made up 25 species or 78.1% of overall species in the study area living solely in one type of landscape management. This clearly shows that species established in forest-less managed area differ from those in gardens-well managed area.

One of the most important determinants for species diversity is land cover (Čepelová & Münzbergová, 2012). Our finding at Kebun Raya Baturraden confirmed this, as there is high number of species living in only in forest-less managed area, absent in the gardens-well managed area. In forest-less managed area, the land cover is denser due to its proximity to the forest, while sparser on gardens-well managed areas. Ecologically, ferns and lycophytes are traditionally grouped into sun fern with the tendency of living in the open area and shade fern living under the cover of trees (Holttum, 1938; 1966). Our finding might have reflected this as species found in the forest-less managed area are mostly known shade/forest fern. One exception is *Dicranopteris linearis*, which is largely considered as sun fern (Yang *et al*., 2020), found in this study only in forest-less managed area. *D. linearis* is infamously noxious, that they are always weeded out in their early life stages in gardens-well managed area.

Many species living in the gardens-well managed area are indeed sun ferns. One notable species is *Christella dentata*, a well-known sun-loving ferns, sometimes considered as weed (Yañez *et al*., 2020) found only in gardens-well managed area. Others, like *Sphaeropteris glauca, Blechnum orientale* and *Selaginella plana* are also known for their resilience for high solar exposure on their crown (Holttum, 1966).

Only seven species of ferns and lycophytes are found on both A and B (*Diplazium subserratum, Alsophila junghuhniana, Dryopteris sparsa, Nephrolepis biserrata, Pityrogramma calomelanos, Selaginella ornate*, and *Cyclosorus heterocarpus*; Table 1). This means that the two landscape management types shared only 21.8% of their fern and lycophyte species, not with standing the adjacent position of the two landscape managements.

Out of seven species found on both forest-less managed and gardens-well managed area (*Diplazium subserratum, Cyathea junghuhniana,* *Dryopteris expansa, Selaginella ornata, Nephrolepis biserrata, Pityrogramma calomelanos,* and *Cyclosorus heterocarpus*), first four were forest species, while the latter three are known to thrive prolifically in wide range of habitats, even in cities. It is not surprising that all three latter species are included in the list of species with highest density (Table 1) in the study area.

The occurrence of two tree fern species, *Sphaeropteris glauca* and *Alsophila junghuhniana*, in the gardens-well managed area must be noted particularly. These two native forest species found in gardens-well managed area are evidences that gardens-well managed area may serve as refugium of wild species from forest (Vojík *et al.*, 2020). In our study this role is highlighted as *S. glauca* and *A. junghuhniana* are among those regulated by CITES Appendix II, and coincidentally showing decorative appearance as garden adornment. The gardeners of KR Baturraden might inadvertently keep the attractive tree ferns within the garden proper though they are adventive plants (spontaneous recruits). By letting those two species thrive in the garden, the keeper not only accommodate the refuge of forest species in the garden, but also conserves two species listed in CITES Appendix II. As ferns mostly are dispersed by airborne spores, gardens-well managed area may receive 'spore rain' from the forest, as well as other place, thus serve as refugium for forest species. When adequately directed on forest species conservation priority, garden managements, operators and possibly visitors may have important role in the conservation of forest (and protected) species.

Light exposure on three age classes of the common fern species

To further understand the role of solar irradiation in the life stages of common ferns and lycophytes, we chose the four species with highest density within our study site and measured the canopy openness above the plots. It turns out that two species, *Selaginella ornata* and *Nephrolepis biserrata*, prefer significantly different degrees of canopy openness among the three age classes (Table 2). Conversely, two species of Thelypteridaceae, *Cyclosorus heterocarpus,* and *Sphaerostephanos arbuscula*, did not show any preference for a certain canopy openness regime. They tend to occupy similar light exposures at all stages; however, *Sphaerostephanos arbuscula* is found only in two age classes in the study area. The adult individual of this species is quite robust and might be spotted and weeded out by the garden keepers.

In *Nephrolepis biserrata* and *S. ornata* the significant inclination toward canopy openness in different age classes signifies that each age class in both species thrive in different light exposure. In *N. biserrata,* difference between adults and sporeling-juvenile was significant by the post-hoc test (p-value = 0.006, Table 3). This might be an indication that during the age class of spore germination (sporeling) through the establishment of the sporophytes (juvenile), *N. biserrata* may thrive in less light exposed area; while as adult, during the spore producing age class, with larger energy demand in spore production, *N. biserrata* are found more in the open canopy area. This means that during the establishment through the adult stage, many individuals of *N. biserrata* were singled out in the less exposed area. Those living in the more exposed area would thrive better and reaching the adult, spore producing stage, more than those in closed area.

It is almost similar case in *S. ornata*, regardless the difference the data may look. It looks that the juvenile age class occupies higher light exposure area compared to the sporeling age class, while the adults occupied in the area with lowest light exposure. Is it because that the adult, spore producing *S. ornata* requires less solar energy for photosynthesis? We believe this is unlikely the case, since the trend of *S. ornata* light requirement in sporeling age class is significantly (p-value = 0.004) increasing in the juvenile age class, and supposedly even higher in adult age class.

The significant drop of light exposure in the adult age class individuals may not reflect the physiological demand of *S. ornata*, but instead the garden management. Many *Selaginella* grow into untidy bush-like clumps, and may be seen as potential weed by gardeners. We think this is exactly the reason why more individuals of adult age class of *S. ornata* found in low canopy openness area, closest to the forest-less manages area, for those living in the open, garden-well managed area are weeded out by the gardeners. The result is many sporeling and many more juvenile individuals in garden-well managed area.

These results in general show that different species of ferns and lycophytes may perform differently under the same light exposure at different age classes. Thelypteridaceae species like *Cyclosorus heterocarpus* and *Sphaerostephanos arbuscula* may not demand light exposure differently during their different age classes; however, species like *N. biserrata* and *S. ornata* may require different light environment during their life stages. The case of *N. biserrata* and *S. ornata* may be comparable to several Bornean tropical rain forest Dipterocarps

(*Dipterocarpus globosus, Dryobalanops aromatica, Shorea acuta, S. beccariana,* and *S. macroptera*), which not only exhibit different light requirement during the growth of the stem, but also different morphological and ecophysiological traits during different life stages (Kenzo *et al.*, 2006). Reflecting to this study in Dipterocarps, it is implied that there should be further study in ferns and lycophytes in terms of morphology and physiology and biochemical properties during different life stages, affected by light environment as comparisons to the widely studied spermatophytes.

Our findings suggest that while fulfilling its task as education and scientific center in providing *ex situ* specimens of living plants, Kebun Raya Baturraden has a great potential to fulfill another task as *in situ* conservation and refugium area for species from the neighboring forest. This may be accomplished by adjusting its management according to protected species, like *Sphaeropteris glauca* and *Alsophila junghuhniana*. Furthermore, Kebun Raya Baturraden may participate in the conservation of forest ferns and lycophytes of Java by adjusting its management according to the ecophysiology, including ontogenetic light requirements, of ferns and lycophytes living in garden-well managed area as well as forest-less managed area.

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REFERENCES

ATHA, D. E., FORREST, T., NACZI, R. F. C., PACE, M. C., RUBIN, M., SCHULER, J. A. & NEE, M. 2016. The historic and extant spontaneous vascular flora of The New York Botanical Garden. *Brittonia* 68(3): 245–277.

ČEPELOVÁ, B. & MÜNZBERGOVÁ, Z. 2012. Factors determining the plant species diversity and species composition in a suburban landscape. *Landscape and Urban Planning* 106(4): 336–346.

DEPARTEMEN PEKERJAAN UMUM RI. 2005. Laporan Pembuatan Masterplan dan Studi Kawasan Kebun Raya Indonesia Baturraden - Jawa Tengah. *Project Report* (in Indonesian).

DE GROOT, G. A., DURING, H. J., ANSELL, S. W., SCHNEIDER, H., BREMER, P., WUBS, E. R. J., MAAS, J. W., KORPELAINEN, H. & ERKENS, R. H. J. 2012. Diverse spore rains and limited local exchange shape fern genetic diversity in a recently created habitat colonized by long-distance dispersal. *Annals of Botany* 109(5): 965–978.

HOCK, Z., SZÖVÉNYI, P. & TÓTH, Z. 2006. Seasonal variation in the spore bank of ferns in grasslands on dolomite rock. *Plant Ecology* 187 (2): 289–296.

HOLTTUM, R. E. 1938. The ecology of tropical Pteridophytes. In: VERDOORN, F., ALSTON, A. H. G., ANDERSSON-KOTTÖ, I., ATKINSON, L. R., BURGEDD, H., DU BUY, H. G., CHRISTENSEN, C., DOPP, W., DOCTERS VAN LEEUWEN, W. M., GAMS, H., GREGOR, M. J. F., HIRMER, M., HOLTTUM, R. E., KRÄUSEL, R., NUERBERGK, E. L., SCHOUTE, J. C., WALTON, J. WETZEL, K., WILLIAMS, S., WINKLER, H. & ZIMMERMANN, W. (Eds.). *Manual of Pteridology*. Springer. Dordrecht. Pp. 420–450.

HOLTTUM, R. E. 1966. *Flora of Malaya Volume II. Ferns of Malaya. 2nd. ed.* Government Printing Office, Singapore.

KENZO, T., ICHIE, T., WATANABE, Y., YONEDA, R., NINOMIYA, I. & KOIKE, T. 2006. Changes in photosynthesis and leaf characteristics with tree height in five dipterocarp species in a tropical rain forest. *Tree Physiology* 26(7): 865–873.

LUSK, C. H., FALSTER, D. S., JARA-VERGARA, C. K., JIMENEZ-CASTILLO, M. & SALDAÑA-MENDOZA, A. 2008. Ontogenetic variation in light requirements of juvenile rainforest evergreens. *Functional Ecology* 22(3): 454–459.

PEEL, M. C., FINLAYSON, B. L. & MCMAHON, T. A. 2007. Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences* 11(5): 1633–1644.

PPG I. 2016. A community-derived classification for extant lycophytes and ferns. *Journal of Systematics and Evolution* 54(6): 563–603.

RSTUDIO TEAM. 2020. RStudio: Integrated Development for R. RStudio, PBC, Boston, MA. URL http://www.rstudio.com/.

SALDAÑA, A., GIANOLI, E. & LUSK, C. H. 2005. Ecophysiological responses to light availability in three *Blechnum* species (Pteridophyta, Blechnaceae) of different ecological Breadth. *Oecologia* 145(2): 252–257.

SALDAÑA, A., LUSK, C. H., GONZÁLES, W. L. & GIANOLI, E. 2007. Natural selection on ecophysiological traits of a fern species in a temperate rainforest. *Evolutionary Ecology* 21 (5): 651–662.

SEDAYU, A. 2006. Distribution of terrestrial pteridophytes with respect to topography and light exposure in tropical rain forest. In: KHOO, M. S., HONG-WA, C. & HARRISON, R. (Eds.). *Proceedings of the Center for Tropical Forest Science-Arnold Arboretum International Field Biology Course 2006*. CTFS-Arnold Arboretum Asia Program, University of Peradeniya & Forest Department Sri Lanka, Peradeniya. pp. 95–97.

TADESSE, G., ZAVALETA, E. S. & SHENNAN, C. 2014. Coffee landscapes as refugia for native woody biodiversity as forest loss continues in southwest Ethiopia. *Biological Conservation* 169: 384–391.

TICHÝ, L. 2016. Field test of canopy cover estimation by hemispherical photographs taken with a smartphone. *Journal of Vegetation Science* 27(2): 427–435.

VOJÍK, M., SÁDLO, J., PETŘÍK, P., PYŠEK, P., MAN, M. & PERGL, J. 2020. Two faces of parks: sources of invasion and habitat for threatened native plants. *Preslia* 92(4): 353–373.

YAÑEZ, A., GUTIÉRREZ, D. G. & PONCE, M. M. 2020. Weedy ferns (Polypodiopsida) in Argentina: diversity, distribution and impact on human activities and ecosystems. *Anais da Academia Brasileira de Ciências* 92(1): 1–36.

YANG, L., HUANG, Y., LIMA, L. V., SUN, Z., LIU, M., WANG, J., LIU, N. & REN, H. 2020. Rethinking the ecosystem functions of *Dicranopteris*, a widespread genus of ferns. *Frontiers in Plant Science* 11: 1–10 (article 581513).