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THE BOTANICAL INVENTORY AND ECOLOGY OF SCALY TREE FERNS (CYATHEACEAE) OF MOUNT SALAK, JAVA - INDONESIA

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Abstract

Scaly tree ferns (Cyatheaceae) are considered a threatened species due to habitat destruction and over-exploitation. The new data dealing with the diversity and ecology of scaly tree ferns of Mount Salak, Java, Indonesia, are presented. A total of 1387 adult individuals belonging to seven species included in two genera were recorded at the elevation range of 1100-1450 m within an area of 4.5 ha. *Alsophila oinops* (Hassk.) R.M.Tryon, *Alsophila sp.*, and *Sphaeropteris persquamulifera* (Alderw.) R.M.Tryon were rare species. *Alsophila junghuhniana* Kunze and *A. polycarpa* (Jungh.) R.M.Tryon were found to be abundant in this area. *Sphaeropteris glauca* (Blume) R.M.Tryon, and *S. squamulata* (Blume) R.M.Tryon were included as common species. The finding of *A. oinops* on Mount Salak at 1200-1300 m asl. is a new ecological record for the Malesian region. Some species were found in relatively the same habitat characteristics but differed in their need for light intensity. Scaly tree ferns were found to show varied distribution patterns.

Introduction

Scaly tree ferns (Cyatheaceae) are the largest taxon within the tree fern alliances (Cyatheales) (Smith *et al.* 2006) and include 579 accepted species (POWO 2023). These plants are recognized by special characteristics, such as a tree-like habit, reaching a height of up to 20 m in some species, large and compound leaves with lamina up to five meters, and petiole diameters up to five centimeters, and the presence of scales on the stipes and petioles (Holttum 1963, Large and Braggins 2004). They are worldwide distributed in tropical rain forests, subtropical and temperate regions, and Montane to Alpine regions from the wet lowlands to mid-elevations (Conant *et al.* 1996, Lehnert *et al*. 2013), with the greatest species diversity in tropical areas of America and Malesia (Korall and Pryer 2014).

The taxonomic delimitation of genera within the Cyatheaceae has long been debated. Holttum (1963) used the concept of a single genus, *Cyathea*, with two subgenera, namely *Cyathea* and *Sphaeropteris.* Tryon (1970) proposed six genera, namely:, *Alsophila, Cnemidaria, Cyathea, Nephelea, Sphaeropteris*, and *Trichiperis.* The phylogenetic studies of Korall *et al*. (2007) resulted in the taxonomic recognition of four clades corresponding to the genera *Sphaeropteris* Bernh., *Gymnosphaer*a Blume, *Alsophila* R. Br., and *Cyathea* Sm. The work of Korall *et al.* (2007) would more or less represent a compromise between the generic systems of Holttum (1963) and Tryon (1970). Conant *et al.* (1996), using morphological and molecular information, suggest three well-defined groups of species within the supergenus *Cyathea*, namely:, the *Alsophila* clade, the *Sphaeropteris* clade, and the *Cyathea* clade. In this study, we followed PPG I (2016) in recognizing three genera in the family, namely, *Alsophila* R. Br., *Cyathea* Sm., and *Sphaeropteris* Bernh.

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Scaly tree ferns are important understory components of tropical rainforests and many of them are restricted to very small ranges on islands or at higher elevations (Holttum 1963). Their rapid growth rate and preference for open habitats suggest that some tree fern species may be useful in forest restoration strategies (Arens and Baracaldo 1998). Tree ferns also provide a habitat for many epiphytic species due to their long and erect caudices (Hasanah *et al.* 2021). Unfortunately, most tree ferns are illegally collected from the wild, even though they are listed on the International Red List and protected by the Convention on International Trade in Endangered Species (CITES). In the tropics of underdeveloped countries, fiber, trunks, or living specimens provide the basis for quick income (Dadang *et al*. 2020). This situation has decreased their population because most species of scaly tree fern take 5–20 years before they are old enough to reproduce (Large and Braggins 2004). Moreover, overexploitation of tree ferns has a negative impact on the availability of microhabitats for epiphytes that preferentially or exclusively occur on their caudices (Hasanah *et al*. 2021).

The prerequisite for developing and implementing a conservation plan for scaly tree ferns was the description of species, type of habitat, abundance, ecology, and possible threats for the sporophyte stage. This paper presents recently collected inventory data on scaly tree ferns in Java - Indonesia. The present study was aimed to: (i) to conduct a botanical inventory of scaly tree ferns on the submontane of the southern slopes of Mount Salak, West Java, (ii) to assess population size and the habitat characteristics of scaly tree fern species, and (iii) to identify distribution patterns of scaly tree fern species.

Materials and Methods

Mount Salak is a part of the Mount Halimun-Salak National Park. It is located within the Bogor and Sukabumi regencies of West Java Province. The geographical position of Mount Salak is 6°42′32″–6°43’32″S and 106°37′41″–106°40′50″E with an elevation range of 500–2211 m asl.. Mount Salak receives 4,000 to 6,000 mm of rain annually, and the minimum and maximum temperatures are 19.6–19.8^{o}C and 31.2–31.8^{o}C, respectively. Mount Salak is an evergreen rainforest that covers 31,327.4 ha of protected forest. The vegetation of Mount Salak is dominated by the species of Theaceae, Hamamelidaceae (e.g., *Altingia exelsa*), Moraceae (*Ficus* spp.), Fagaceae (*Quercus* spp.), and Lauraceae (*Litsea* spp.).

Opportunistic sampling to account for and determine the total number of species of scaly tree ferns at the southern slopes of Mount Salak, West Java, has been carried out by observing the species along the four tourist tracks, namely Kawah Ratu, Cibogo (06º 44’ 13.3” S; 106º 41’ 18.5” E), Pameungpeuk (06º 44’ 45.3” S; 106º 42’ 43.1” E) and Mount Perbakti (06º 44’ 44.9” S; 106º 42’ 42.9” E). All tracks are in the submontane zone (1100–1450 m asl). Specimens were made according to the standard method for making herbarium specimens for tree ferns. Plant identification was carried out by consulting Holttum (1963).

The random search with a belt transect was set up to estimate the population size or the abundance of an adult plant of scaly tree ferns on the Kawah Ratu track, from hm 0 to hm 25 (hm = hectometer), with the transect wide at 20 m. It was set up in 20 x 125 m subplots. Environmental conditions around the species of scaly tree ferns, such as the elevation, slope, air temperature and air humidity, canopy cover, and soil acidity, were recorded.

Analysis of the scaly tree fern distribution pattern was carried out using the index of dispersion (Ludwig and Reynolds 1988). The index of dispersion equations is $ID = S2/\bar{x}$. Where ID was the index of dispersion, S2 was the sample variance, and $\bar{x}$ was the sample mean. Random distribution if ID = 1, uniform distribution if ID < 1, and aggregate distribution if ID > 1.

Results and Discussion

Seven species of scaly tree ferns included in two genera were found in the submontane of the southern slope of Mount Salak (Table 1). Holttum (1963) recognized 15 species of scaly tree ferns in Java. Adopting the concept of Conant *et al.* (1996), PPG 1 (2016), and the accepted name POWO (2023),. accordingly, we fourteen species of scaly tree ferns in Java, which are included into two genera, *Alsophila* R.Br. and *Sphaeropteris* Bernh. The genus *Asophila* is differentiated from *Sphaeropteris* by the petiole scale characteristics. Petiole scales of *Sphaeropteris* are without differentiated margins, i.e., the cells of the petiole scales (nearly) all of the same size and orientation (no distinct margin of smaller cells), but dark marginal teeth or setae may be present; petiole scales are basifixed on ± truncate bases, never with indurated bases or with transitions to black prickles. Meanwhile, *Alsophila* has petiole scales with differentiated margins, i.e., the cells of the petiole scale margins are smaller and have a different orientation than those of the scale bodies, margins may be very narrow and reduced to one row of small teeth in the distal part of the scales; and scales with at least one dark apical seta protruding from the scale center (supported by more than one cell row below) (Lehnert and Kessler 2018).

Table 1. Population size and habitat characteristics of the scaly tree ferns of Mount Salak – West Java, Indonesia.

No.	Species	Pop. size (in 4.5 ha)	Habitat characteristics					
			Slope (º)	Altitude (m asl)	Air temp. (ºC)	Humidity (%)	Canopy cover (%)	Soil acidity
1	*Sphaeropteris glauca* (Blume) R.M.Tryon	30	30-45	1100-1450	22.0-29.0	82-90	0-30	5.6
2	*Alsophila polycarpa* (Jungh.) R.M.Tryon	1116	0-35	1100-1450	22.5-29.0	82-85	30-60	5.6
3	*Alsophila junghuhniana* Kunze	213	0-35	1100-1300	22.6-29.0	82-85	50-60	5.4
4	*Alsophila oinops* (Hassk.) R.M.Tryon	3	30-35	1200-1300	23.5-24.0	82-85	30-40	6.0
5	*Alsophila sp.*	1	0-20	1400-1450	23.4-24.0	82-90	30-40	5.8
6	*Sphaeropteris persquamulifera* (Alderw.) R.M.Tryon	1	0-20	1400-1450	23.2-24.0	92-95	10-20	5.8
7	*Sphaeropteris squamulata* (Blume) R.M.Tryon	23	30-40	1100-1450	21.4-29.0	86-87	30-40	5.6

Fourteen species of *Cyathea* of Java recognized by Holttum (1963) are now considered synonyms of (1) *Sphaeropteris glauca* (Blume) R.M.Tryon, (2) *Alsophila polycarpa (Jungh.)* R.M.Tryon, (3) *A. gigantea* Wall. ex Hook., (4) *A. glabra* (Blume) Hook., (5) *A. javanica* (Blume) R.M.Tryon (6) *A. junghuhniana* Kunze, (7) *A. lurida* (Blume) Hook., (8) *A. oinops* (Hassk.) R.M.Tryon, (9) *S. persquamulifera* (Alderw.) R.M.Tryon, (10) *S. squamulata* (Blume) R.M.Tryon, (11) *A. subdubia* Alderw., (12) *S. tenggerensis* (Rosenst.) R.M.Tryon, (13) *S. tomentosa* (Blume) R.M.Tryon, and (14) *S. tripinnata* (Copel.) R.M.Tryon. Meanwhile, the concept of *Cyathea raciborskii* Copel. presented by Holttum (1963) has been merged into

Alsophila polycarpa (Jungh.) R.M.Tryon. Therefore, *C. raciborskii* Copel. is a synonym of *Alsophila polycarpa* (Jungh.) R.M.Tryon (POWO 2023).

Based on the number of species observed in the 4.5 ha (Table 1), three species have small abundances and are included in the rare category: *A. oinops*, *Alsophila sp.*, and *S. persquamulifera*. The three species were only found in the upper submontane areas. There was only one individual each of *Alsophila sp.* and *S. persquamulifera*. *Sphaeropteris glauca*, and *S. squamulata* were included in the common species. Meanwhile, *A. junghuhniana* and *A. polycarpa* were categorized as abundant species. The representatives of the rare, common, and abundant species are presented in Fig. 1. Three species that are considered rare species, *viz.*, *A. oinops*, *Alsophila sp*., and *A. persquamulifera*, should be intensively inventoried in their distribution ranges to assess their conservation status formally based on the IUCN Red List criteria.

Based on their ecological characteristics, most species of Cyatheaceae can be grouped into two broad types: sun-loving species that naturally grow in open habitats such as on landslides and along watercourses and shade-loving forest-interior species (Lehnert and Kessler 2018). The habitat characteristics of the scaly tree ferns on Mount Salak presented in Table 1 showed that all species of scaly tree ferns found on Mount Salak grow well in areas with an altitude of 1100–1450 m asl., an air temperature of 21.4–29^{0}C, and high humidity (82–95%). In general, all species of scaly tree ferns were found to grow well in soils with a pH ranging from 5.4 to 6.0 (strongly to moderately acidic). Some species show relatively the same range of elevation and some habitat characteristics, but they differ in need for light intensity and slope.

The vegetation canopy cover is related to the amount of light reaching the scaly tree ferns or the forest floor. *Sphaeropteris glauca* and S. *persquamulifera* can be found in more open areas, in full sun or slightly shaded conditions, with a canopy cover of 0–30%. Recently field survey on scaly tree ferns in the Philippines also revealed that *S. glauca* could grow with full exposure to the sun and are very abundant in the clearings and open places in the forest (Dadang *et al.* 2020). Meanwhile, other species of tree ferns (*Alsophila polycarpa, A. junghuhniana, A. oniops, Alsophila sp.*, and *S. squamulata*) were more commonly found in more shaded areas with a canopy cover of around 30-60%.

It should be noted that *A. oinops* is reported to have existed at the elevation range of 2000–2500 m asl. (Holttum 1963) can be found in the submontane zone of Mount Salak (Table 1.). The finding of *A. oinops* on Mount Salak at a low altitude of 1200–1300 m asl., is a new ecological record for the species in the Malesian region.

Alsophila polycarpa, A. junghuhniana, Alsophila sp., and *S. persquamulifera* can be found on flat to very steep slopes (0–35^0). However, this condition differs from *Sphaeropteris glauca, A. oniops*, and *S. squamulata*, where the three species are only found in areas with very steep slopes (30–45^0). The degree of the slope has a relationship with the soil water content, where the steep slope has a lower soil water content than the gentle slope (Siswanto *et al*. 2012). *Sphaeropteris glauca, A. oniops,* and *S. squamulata* prefer well-drained habitats, and no inundation occurs in these areas. Scaly tree ferns generally prefer areas with moist soil (Ho *et al*. 2016). Mount Salak's relatively high soil humidity is also influenced by high rainfall ranging from 4,000 to 6,000 mm/year.

Species of scaly tree ferns on Mount Salak have different distribution patterns. The analysis of the index of dipersion showed that four species had an aggregate distribution, namely *Sphaeropteris glauca, Alsophila polycarpa,* A. *junghuhniana*, and *S. squamulata* with index of dispersion (ID) of 9.65, 59.28, 6.15, and 8.98 respectively. Meanwhile, one species has a uniform distribution, namely *A. oinops* (ID=0.92). Two species fell into the category of a random distribution, *viz.*, *Alsophila* sp. and *S. persquamulifera* (ID=1).

Fig. 1. The scaly tree ferns of Mount Salak, West Java, Indonesia. A – C. *Alsophila oinops*. A. Upper part of trunk showing brown stipes covered by pale brown scales; B. Part of pinna with pinnulae; C. Part of fertile pinnule bearing 5-7 pairs of sori in each lobe. D - F. *Sphaeropteris squamulata*. D. Upper part of trunk showing young frond and green stripes covered by pale brown scales; E. Part of pinna with pinnulae; F. Part of fertile pinnule with 3-4 pairs of sori in each lobe. G – I. *A. polycarpa*. G. Trunck covered by persistent bases of fallen stipes; H. Part of fertile pinna with pinnulae; I. Part of fertile pinnule with 3-5 pairs of sori in each lobe.

Results showed that species of scaly tree fern with an aggregate distribution pattern usually have a high population and are found in many sampling plots. The distribution pattern of scaly tree fern species in Mount Salak is similar to that of *Cyathea delgadii* Sternb. in Cerrado areas in Brazil (Silva *et al*. 2019). Most scaly tree ferns have an aggregated distribution, which might be caused by the selection of habitat factors (such as topography, soil, light, and climate) that support their growth. The aggregate distribution can also be associated with the resources needed by the species concentrated in small locations or in suitable habitats that are not evenly available in large areas (Walker 2011).

Scaly tree fern species with random and uniform distributions have small populations and are found in only a few sampling plots. The random dispersal pattern is generally caused by spore dispersal agents, which are generally dispersed by the wind. Spores are minute and easily transported by wind, suggesting that successful long-distance fern dispersal should be easy and common (Korall and Pryer 2014). However, recent studies show that the reproductive biology of ferns is more complex than previously assumed. Most diploid ferns are predominantly obligate outcrosses (Haufler 2007), requiring the male and female gametes to originate from different gametophytes that, in turn, each originated from spores from different sporophytic individuals, termed inter gametophytic crossing (Klekowski 1973). Therefore, a fern usually needs at least two spores from different individuals to migrate into a new environment. Furthermore, the spores must land in such proximity that the male gamete can swim to the female gamete in a thin film of water. Many mature spores will be distributed randomly and grow into new individuals in places with environmental conditions that support the germination of the spore.

In conclusion, seven species of scaly tree ferns occurred in the submontane of the southern slope of Mount Salak, representing 50% of Java's entire scaly tree fern species. Three species are categorized as rare species, with a very small population size (less than five individuals per ha), *viz. A. oinops, Alsophila* sp., and *S. persquamulifera.* Three species should be intensively inventoried in their distribution ranges to assess their conservation status formally based on the IUCN Red List criteria. Scaly tree ferns of Mount Salak grow well in areas with an altitude of 1100–1450 m asl., an air temperature of 21.4–29.0°C, and high humidity (82–95%), with a pH ranging from 5.4 to 6.0. The species of scaly tree ferns have three distribution patterns, namely aggregate (*Sphaeropteris glauca, Alsophila polycarpa, A. junghuhniana*, and *S. Ssquamulata*), uniform (*A. oinops*), and random distribution (*Alsophila* sp., *S. persquamulifera*). The account of scaly tree ferns in this area would provide a basis for knowing species diversity in the modern sense.

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