The Phenetic Relationship of Ferns (Polypodiaceae) at the Ascent of Cemoro Kandang, Mount Lawu

Abstract

The fern is one of the highly diverse vascular plant species, which has a unique characteristic. The closely related at the family level because the genera within each family have some uniformity so that the relationship and groupings cannot be distinguished. One example of a diverse fern family is Polypodiaceae. Consequently, it is necessary to simplify the classification; one of them is through phenetic relationship analysis. This study aimed to analyze the phenetic relationship of the Polypodiaceae ferns in Climbing Cemoro, Mouth Lawu enclosure, Karangayar Regency, based on the similarity index on the dendogram. The data were collected using the exploration method and the sporophyte morphological characters were observed. The observations obtained 13 variations of characters. The relationship analysis was carried out with the hierarchical cluster program using SPSS 23. There were six species found from the Polypodiaceae family, there were including Belvisia mucronata, Goniophlebium sp, Lepisorus sp, Pyrrosia piloselloides, Crypsinus taeniatus and Drynaria sparsisora. The finding suggests that six species are divided into two clusters, the Group I consisting of Goniophlebium sp, Lepisorus sp, and Pyrrosia piloselloides with a similarity coefficient index of 53% and Group II consisting of Drynaria sparsisora, Crypsinus taeniatus and Pyrrosia piloselloides with a similarity index of 46%.

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The diversity of ferns is very large in nature, so the availability of water and the type of habitat are crucial factors in determining the distribution of fern species. Ferns are often found in humid areas such as forests, swamps, and near rivers. According to Krebs (1985), soil moisture plays a significant role in the distribution of ferns. Ferns require stable light intensity, and other environmental factors that affect the growth of ferns are temperature, air humidity, soil pH, and light intensity. Other environmental factors that affect the growth of ferns are temperature, air humidity, soil pH, and light intensity.

Data Collection

The steps of data collection were as follows:

1. Collection of data on fern species using direct methods in the field, namely at the Kandang hiking trail, Mount Lawu, Karangayar, East Java Province.
2. Collection of data on fern species using indirect methods obtained from literature, namely from the literature by Nurchayati (2007) and Rege (2015).
3. Data collection was carried out from September 2017 to February 2019.
4. The parameters used in the study were morphological characteristics of the species, namely habitat (type of habitat), stem (color and shape of the rachis surface), leaf (type, size, number, and shape), sorus, sporophyte (type, size, and shape), and gametophyte (type, size, and shape).

Analysis and Discussion

This study aimed to determine the distribution of fern species at the Kandang hiking trail, Mount Lawu, Karangayar, East Java Province. The highest diversity of Pteridophyta species found in Indonesia is ferns (Pteridophyta). The diversity of Pteridophyta species in the archipelago is revealed and recorded, both their identity and characteristics from each group. The aim of this study was to provide a basis for the conservation and inventory of relationship to prevent biodiversity extinction. The study was conducted from September 2017 to February 2019. The parameters used in the study were morphological characteristics of the species, namely habitat (type of habitat), stem (color and shape of the rachis surface), leaf (type, size, number, and shape), sorus, sporophyte (type, size, and shape), and gametophyte (type, size, and shape).

Classification and Relationship of Pteridophyta

The classification and relationship of Pteridophyta have been conducted through various stages of evolution, starting from the Devonian to the present. However, research on the classification and relationship of Pteridophyta has not been widely carried out, however, only a few classifications have been conducted since the Devonian to the present. The classification and relationship of Pteridophyta has been conducted through various stages of evolution, starting from the Devonian to the present. The classification and relationship of Pteridophyta have been conducted through various stages of evolution, starting from the Devonian to the present.

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INTRODUCTION

Indonesia is one of the countries that has the highest biodiversity in the world, both plant and animal diversity. One of the species of plant division found in Indonesia is ferns (Pteridophyta). The number of Pteridophyta species in Indonesia was 2,197 species and the latest study results in the last 2019 showed that the Pteridophyta in Indonesia reached 1,611 taxa from 37 families (Nurchayati, 2007). This amount is obtained when using the classification basis used in the Herbarium Bogoriensa (Wijayanti et al., 2015).

The fern is a division that has horns, meaning that its body can differentiate into three main parts, namely roots, stems, and leaves. Besides, this plant also has a vessel/file system in the form of xylem and phloem, which is not found in moss. Roots in ferns are like fibers and the ends are protected by calyptra (root caps). The stems of most ferns are not visible because they are in the soil in the form of rhizomes/rhizomes (Holtum, 1959). Ferns have unique characteristics in sporophyte and gametophyte generation, which is mutually independent. One of the ferns’ unique characteristics lies in the morphological character of the sporophyte, which is used as a determinant of ferns in terms of shape, size, location, and spores’ types (Suryadi et al., 2020, Apriyanti et al., 2017). Ferns are very heterogeneous when viewed in terms of habitus and way of life. Based on the habit, there are a few species of ferns with small leaves and a very simple structure. On the others, there were large with leaves that could reach up to two or more with a complex structure. Based on the way of life, there are species of ferns that live on the ground (terrestrial), some live on other plants (epiphytes), and also water ferns (hygrophilous). Ferns tend to like shady places with a high degree of humidity and cannot stand it, in conditions with limited water availability.

There are five families of pteridophytes with the largest proportion included Polypodiaceae, Thelypteridaceae, Pteridaceae, Hymenophyllaceae, and Cyatheaceae families, which cover almost 50% of the total diversity (Tjitraoseopoeno, 1993). This value has decreased significantly from the previous pteridophyte diversity data, considering that this time information on the status of scientific names is more widely available and the progress of taxonomic revisions is quite rapid. However, it should be noted that there are still many species richness or taxa under species that have not been revealed and recorded, both their identity and presence in the archipelago.

The diversity of ferns is very large in nature, so that ferns are one of the plants that cannot be separated from the effort to simplify the object of study. Ferns are the most primitive vascular plants than other vascular plants. The fern has gone through various stages of evolution from the Devonian to the present. However, research on the classification and relationship of Pteridophyta has not been widely carried out, however, only a few studies on fern relationship have been conducted (Nurchayati, 2007). Ferns play important roles in maintaining the forest ecosystem (Suryadi et al., 2020), therefore, it is required to improve conservation and inventory of relationship to prevent biodiversity extinction. Phenetic relationship is a pattern of relationship or total similarity between groups based on their certain characteristics from each group.

Ferns are often found in humid areas such as mountain areas. One of the habitat ferns is Mount Lawu, or Gunung Lawu, this mount massive compound stratovolcano, straddling the border between Central Java and East Java, Indonesia. Mount Lawu has an important function for the protection of natural resources and ecosystems. This area is a buffer zone that limits the distribution of dry-type ecosystems in eastern Java and wet-type ecosystems in western Java. The high diversity of ferns is caused by environmental factors where the elevation of the area increases, the soil condition changes. According to Krebs (1985), soil moisture affects the geographic distribution of most trees in mountain forests and affects the content/ availability of groundwater where the relationship with temperature can affect the balance of plant water. Other environmental factors that affect the growth of ferns are temperature, air humidity, soil pH, and light intensity.

MATERIALS AND METHODS

This study was conducted in the Cemoro Kandang hiking trail, Mount Lawu, Karangayar Regency, Central Java Province. The parameters used in the study were morphological characteristics of habitat, stems, roots, leaves, and sorsus.

The steps of data collection were as follows. (a) The morphological observation of the species include habitat (the type of habitat), stem (color and fiddlehead; color, shape, and stipe characteristics; color and shape of the rachis surface), leaf (type,
location, structure, shape, venation, and costa), root (rhizome and rhizoid) and sorus (location, shape, and color). (b) Designing observation table (table of Operational Taxonomy Unit) by providing numeric symbols. The description of Operational Taxonomy Unit feature can be described as number 0 if the feature does not have number 1 as well as if the observed characteristics are in that type. (c) Perform calculations using the SPSS program in the observation table. (d) The determination of the relationship between the ferns of the Polypodiaceae family was carried out by measuring the similarity or Similarity Index (IS) and measuring the dissimilarity or dissimilarity index (ID) using the following formula:

\[
(IS) = \frac{2 \times \frac{(\Sigma C)}{\Sigma A} + \frac{(\Sigma B)}{\Sigma A}}{100}
\]

(Hasanuddin & Fitriana, 2014)

Note:
ID = Dissimilarity Index
IS = Similarity Index
\(\Sigma C\) = Number of the same Characteristics in individuals being compared
\(\Sigma A\) = number of individual characteristics A
\(\Sigma B\) = number of individual characteristics B

Analysis of sample data that has been identified in accordance with Operational Taxonomy Unit was then analyzed using Taxonomic Distance formula to identify the relationship, which will be presented in the form of dendogram.

The observed morphological characteristics of ferns consisted of several types (Table 1). The sporophyte morphological character data were analyzed using a phenetic approach using the SPSS 23 Hierarchical Cluster dendogram program.

RESULTS AND DISCUSSION

The ferns were found and identified on Mount Lawu, the Cemoro Kandang hiking trail consists of 15 families including Gleicheniaceae, Woodsiaaceae, Vittariaceae, Pteridaceae, Neopolepidaceae, Davalliaceae, Polypodiaceae, Marattiacae, Lycopodiaceae, Dennstaedtiaceae, Dipteridaceae, Blechnaceae, Adiantaceae, distributed in 33 species. The highest number of species found were in the Polypodiaceae family as many as 6 species. The relationship of several species of ferns in the Polypodiaceae family of other species has been previously studied at the Purwodadi Botanical Garden, Pasuruan.

Table 1. List of characters for phenetic analysis of Family Polypodiaceae

| No. | Character                  | Character code                  |
|-----|----------------------------|---------------------------------|
| 1.  | Habitat                    | Terrestrial (0), Epiphytic (1)  |
| 2.  | Leaf                       | Single or pinnatifid (0), leaves1 - pinnate (1) |
| 3.  | Leaf margins               | Flat (0), Pinnatifid (1)        |
| 4.  | Build leaves               | Lanset (0), elliptical-lancet (1) |
| 5.  | Leaf shape                 | Monomorphic (0), dimorphic (1)  |
| 6.  | Rhizome                    | Upright (0), Creeping (1)       |
| 7.  | Sorus                      | Small circle, near midrib (0), linear, marginal (1) |
| 8.  | Sorus location             | On the lower surface of the leaf, Varies (0), at the tip of the fertile leaf spike (1), Sorus linear, ablique, extending from midrib to margin (0), sorus round, forming a single row to several irregular rows (1) |
| 9.  | Sorus form                 | Sorus until 2/3 of the leaves are towards the base (0), sorus until 2/3 - 1/3 towards the apex (1) |
| 10. | Sorus size                 | Less than 0.1 cm (0), less than 0.2 cm (1) |
| 11. | Sorus diameter             | Forming irregular, rather dense (0), regular sorus (1) |
| 12. | Sorus arrangement          | There are 1 species, leaves foliage (0), there are 2 species of leaves, nest leaves and foliage leaves (1) |
The results showed that *Adiantum caudatum* was related to *Nephropleis falcate* with a similarity coefficient of 66.7% (Nurchayati, 2016). The results of sporophyte morphological observations of the sporophyte family of the Polypodiaceae Gunung Lawu climbing Cemoro Kandang were obtained as follows:

**Belvisia mucronata**

Epiphytic, short creeping rhizomes, growing 4–6 tightly, dense scaly, 3 cm long stipe, linear lanceolata leaves, single, sterile leaves 15–18 cm long, 2 cm wide, shrinking at the base and tip, curling at the margins, narrowing at junction with fertile leaf, short winged towards the stipe, veins generally not clear, midrib visible on both surfaces, sorus at apical fertile leaf, linear shape with tapered tip, 12 cm long, 0.4 cm wide, sporangium covering the abaxial leaves except midrib (Figure 1.A).

**Crypsinus taeniatus**

Terrestrial, creeping rhizome, dense scaly, scales taper slowly to the apex, pale brown, slightly dark in the middle, flat edges slightly jagged, stipe 15–30 cm; pinnate leaf, 30 - 40 cm long, with 7-10 pairs of pinna, narrow ellipse shape, long apex acuminate, thickened edges, with short serrations of each main vein, round sorus, forming a single row between midrib and pina edge, slightly raised adaxial, a diameter of 2 - 3 mm. The sporangium is reddish brown in color (Figure 1.B).

**Drynaria sparsisora**

Epiphyte, erect rhizome, short scaly, tapering from the round base, stiff, deciduous after growing leaves (base leaves / nest leaves and foliage leaves), dense, short scaly, shrinking, from apex to ovate, dimorphic leaves, foliage, pinna-tifid, length 60-70 cm including stipe, sorus generally small, in regular rows, always with irregular space between rows (Figure 1.C).

**Goniophlebium sp**

Epiphyte, creeping rhizome, white chalky surface, scaly young part, light brown scales, slightly jagged edges, pinnate leaves, 0.7 cm in diameter, brown, slightly scaly stipe and rachis. Sorus forms a single row on each side of the midrib, between the veinlets, the hollow, shallow, yellowish sporangium (Figure 1.D).

**Lepisorus sp**

Epiphytic, rhizome spreads long, grows 2 rows of leaves, 1 cm apart, dense scaly, 4 - 6 cm long, wingless, fertile leaf type is longer than fertile leaves, dark brown scaly at the base, single lamina, 10 - 12 cm long, 2 cm wide, sorus forms a single row at each midrib, round, 2 mm in diameter, brown sinks in the cavity, adaxial embossed (Figure 1.E).

**Pyrrosia pilosellides**

Epiphytes, creeping rhizomes, small scales with long hairy edges, no stipe on sterile leaves, 1 cm long fertile leaves, 3-6 cm long sterile leaves, and 1 cm wide, close to blat, sometimes elliptic widened, crossed, tapers slowly to base, wide round apex, very fleshy texture, smooth surface, scattered stellate hairs, clear midrib on half of the leaves from the base, 3-6 cm long and 0.8 cm wide fertile leaves, tapers slowly to the base, wide round apex, very fleshy texture, sorus forms a wide band at the marginal, present in a semicircle from the apex to almost near the base (Figure 1.F).

![Figure 1. A) Belvisia mucronata; B) Crypsinus taeniatus; C) Drynaria sparsisora; D) Goniophlebium sp; E) Lepisorus sp; F) Pyrrosia pilosellides](image-url)
The results of the dendogram construction using 13 morphological features showed that the six species of ferns found were divided into two main clusters, namely cluster I consists of Goniopeltis sp., Lepisorus sp., and Pyrrosia and cluster II consists of Drynaria sparsisora, Goniopeltis sp., and Pyrrosia pilloselloides. The following is the dendogram of the results of cluster analysis of 6 plant species that have been analyzed for their morphological characterization.

Based on the calculation of the Similarity Index, Goniopeltis sp is closely related to Lepisorus sp at a similarity coefficient of 53% and also Lepisorus sp is closely related to Pyrrosia pilloselloides at a coefficient of 53%. Drynaria sparsisora and Goniopeltis sp. are closely related to Pyrrosia pilloselloides with a similarity coefficient of 46%. Then followed by Cryptsins taeniatus which is related to Goniopeltis sp., Lepisorus and Pyrrosia pilloselloides with a similarity index of 38%. Belvisia mucronata is closely related to Lepisorus sp and Pyrrosia. In addition, the influence of diversity in a type is caused by two factors, namely the environment and traits inherited by genetics (Chao & Huang, 2018).

Group I consisted of Goniopeltis sp., Lepisorus sp., and Pyrrosia pilloselloides. Those that are united based on the same habitat are epiphytes, creeping rhizomes, and have scales on the rhizomes. Group II consisted of Drynaria sparsisora, Goniopeltis sp., and Pyrrosia pilloselloides which were united by habitat type characteristics, rhizomes and spore arrangement that were single rows in each midrib sequence.

In accordance with the opinion of Radford (1986), the closely related relationship can be seen by the number of similarities in characters or characteristics, so they have a kinship with a greater similarity coefficient, hence the relationship is closer. This is same opinion with (Vasco et al., 2013) opinion that the classification is based on the characters’ correlation so that two plants that have similar characteristics are considered closely relationship than two plants that have few characters in common. Based on the dendogram above, a grouping system can also be made among species in the Polypodiaceae family based on their relationship. While, Apriyanti et al. (2017) stated that more similarities of characteristics they have, the smaller the number of taxonomic distance value based on plant combinations. Besides that, it was concluded that the grouping based on the percentage of similarity of qualitative and quantitative characters observed produce a picture of the position of each accession in a dendrogram, generic distance values as well as showing the closeness of relationships or the similarity of characters between accessions.

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