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**JUNGLE RUBBER AND PIONEER TREE: INVESTIGATING LEAF MORPHOLOGICAL VARIATION OF *Alstonia scholaris* R. BR. IN JAMBI**

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***ABSTRACT***

*Human activity has reduced natural forests in Indonesia and triggered their transformation into, for example, jungle rubber land, as is often found in the Jambi Province of Sumatera. Forming jungle rubber through successional processes involves important pioneer trees such as Alstonia scholaris. The pioneer species' performance is influenced by site factors, the initial biodiversity status, cultivation treatment, and management inputs. The study reported here was conducted to assess leaf morphological variation of A. scholaris as preliminary indicators of difference in response and growth performance in several CRC990 plots (50 m x 50 m) of two distinct Landscapes: Bukit Dua Belas National Park and Harapan Rain Forest. Results of the analysis of variance showed that the difference in Landscapes gave rise to a significant effect on leaf morphology variable NV (venation number) for A. scholaris. Differences between Plots within the Landscapes were significant in the variables venation number (NV) and petiole ratio (PR) for A. scholaris. The results of the distribution of leaf morphological variation in A. scholaris based on Principal Component Analysis showed no clustering due to landscape effects.*

***Keywords:*** *A. scholaris, Bukit Duabelas National Park, jungle rubber****,*** *Harapan Rain Forest, leaf morphological variation, pioneer tree*

**INTRODUCTION**

The Jambi Province in Sumatra is home to an existing lowland tropical rainforest, which represents a remnant of the larger Southeast Asian tropical rainforest region. This rainforest is renowned for its exceptional biological diversity and unique ecological characteristics (Rahmani et al., 2022; Damayanti et al., 2017). Unfortunately, the Jambi rainforest is under significant threat due to various human activities that have detrimental effects on biodiversity. Deforestation, illegal logging, and land conversion for agricultural purposes present substantial challenges to preserving this distinctive ecosystem (Drescher et al., 2016; Panjaitan et al., 2020; Margono, 2014). The loss of the Jambi rainforest could lead to a rapid decline in biodiversity, potentially resulting in the extinction of numerous plant and animal species, disruption of ecological processes, and the loss of valuable genetic resources (Teuscher et al., 2016).

In Sumatra, the annual loss of forests is primarily driven by the conversion of these areas into plantations. Several studies, including Tilman et al. (2001), Fitzherbert et al. (2008), Koh et al. (2011), and Villamor et al. (2014), have documented the transformation of tropical forests into rubber (Hevea brasiliensis) plantations. The establishment of rubber agroforestry systems began in the early 1900s, and the economic potential of these plantations has since been recognized, leading to their dominance in land use practices. In Jambi Province, human activities have significantly diminished the extent of natural forest areas, resulting in diverse man-made land-use types. A landscape mapping study by Dewi et al. (2008) classified twelve land-use types in the province. One of these, this study's focus, is known as “rubber forest” (jungle rubber).

Jungle rubber is the term given to the agroforestry system of rubber plants with other plants that form a complex forest-like vegetation structure (Joshi et al., 2002). The formation of rubber forests can be attributed to a traditional farming system known as shifting cultivation or swidden agriculture. In this system, smallholders typically plant rubber trees with cash crops during the initial cultivation stage (Gouyon et al., 1993; Joshi et al., 2002). The formation of rubber forests is likely a result of land-clearing practices (Ningsih, 2009). The fallow period of the land leads to variations in land age, which influences the natural and directional changes in vegetation composition, known as succession (Barbour et al., 1999). Research has shown that if the fallow period is long enough, the community structure and vegetation composition development can resemble those of natural forests.

Pioneer tree species, such as Pulai (*Alstonia scholaris*), play a crucial role in the succession and restoration of degraded forest conditions. These species are capable of thriving in conditions that are unfavorable for established tree species in climax forests. Pioneer species initially colonize open areas, are relatively short-lived, and eventually give way to shade-tolerant and climax species (Manan, 1979). The growth of pioneer tree species is influenced by factors like soil type and climate, which contribute to variations in their performance. This performance is influenced by genetically influenced phenotypic plasticity, leading to phenotypic and genetic diversity (Koch et al., 2006). Understanding how land-use changes affect this plasticity pattern is crucial for assessing the impact on biodiversity in Jambi.

The study reported here aimed to analyze the causes of phenotypic variability in the leaf morphology of pioneer tree species, *A. scholaris*, in two different rubber forest Landscapes in Jambi. The study aimed to estimate the diversity in leaf morphology of *A. scholaris* and determine the effect of differences in Landscape and Plots within the Landscape as influences on this diversity in leaf form.

**METHOD**

**Materials**

Sixty-one leaf samples of *A. scholaris* were studied. Voucher materials of all individuals were taken from the sub-project B03 CRC (Collaborative Research Center) 990/Efforts (http://www.uni-goettingen.de/efforts) conducted in two Landscapes in Jambi, namely, Harapan Jungle Rubber (HJ) and Bukit Duabelas Jungle Rubber (BJ). The environmental conditions of these two landscapes are presented in Table 1. The list of locations, species, codes, and number of analyzed individuals of *A. scholaris* used in the study are presented in Table 2.

*Table 1. Environmental conditions of the two Landscapes (HJ and BJ) studied in Jambi.*

| Environmental factor | Landscape |
| --- | --- |
| Harapan Jungle Rubber (HJ) | Bukit Duabelas Jungle Rubber (BJ) |
| Location | 1o44’ – 1o58’ Lat 102o29’ – 102049’ Long | 2º2’16” – 2º21’14” Lat 103º7’55” – 103º27’39” Long  |
| Topography | Flat to undulating medium | Flat to moderately steep |
| Altitude | 50 – 400 m asl | 30 – 120 m asl |
| Temperature | 28 0C – 36 0C | 26 0C |
| Annual rainfall | 3,294 – 3,669 mm/year | 2,306 mm/year |
| Soil type | Red yellow Podsolic, Aluvial | Aluvial, Latosol, Planosol, Red yellow Podsolic  |
| Climate classification (Schmidt-Fergusson) | A climate | A climate |

Source: Reki (2009), Dephut (2006)

*Table 2. List of location, species, codes, and number of analyzed individuals of A. scholaris used in the study.*

| Landscape dan Plot | Species | Number of samples | Plot code |
| --- | --- | --- | --- |
| Harapan Jungle Rubber | *Alstonia scholaris* | 10 | HJ1 2 |
| Harapan Jungle Rubber | *Alstonia scholaris* | 8 | HJ2 7 |
| Harapan Jungle Rubber | *Alstonia scholaris* | 9 | HJ3 10 |
| Harapan Jungle Rubber | *Alstonia scholaris* | 8 | HJ4 2 |
| Subtotal |  | 35 |  |
| Bukit Duabelas Jungle Rubber | *Alstonia scholaris* | 10 | BJ2 10 |
| Bukit Duabelas Jungle Rubber | *Alstonia scholaris* | 9 | BJ3 7 |
| Bukit Duabelas Jungle Rubber | *Alstonia scholaris* | 7 | BJ4 4 |
| Subtotal |  | 26 |  |
| Total |  | 61 |  |

1. Leaf Morphological Assessment

Leaf morphology assessment methods were based on Kremer et al. (2001), with some modifications to simplify the procedures. The variables measured and observed for each leaf were divided into three assessment categories they were:

1. Four leaf-dimension characters:

Lamina length (LL); Petiole length (PL); Leaf width (LW); Length from the widest part of the leaf to the base of the petiole (WP).

1. Count variable:

Venation number (NV). The number of primary and secondary veins visible on the leaves.

1. Transformed variables

Lamina shape (LS) = 100 × WP / LL

Petiole ratio (PR) = 100 × PL / (LL + PL)



*Figure 1. Measured variables of leaf morphology for A. scholaris*

1. Experimental Design

This study's experimental design was a Nested Design with two factors: Landscapes (Bukit Duabelas National Park and Harapan Forest) and Plots (50 m x 50 m quadrats). The data obtained by measurement was analyzed using the linear model:

$$Yijk=μ+αi+ji+ε\left(ij\right)kj$$

Where :

Yijk = The value of the observation on the kth sample, in the jth Plot nested in the ith

 Landscape

µ = Mean

αi = The influence of factor A (Landscape) at the ith-level

j(i) = The influence of factor B (Plot) at the jth-level nested in factor A (Landscape) at the

 ith-level

ε(ij)k = Error value due to the kth sample in the jth-level nested in the ith-level

i = Level of A factor (Landscape)

j = Level of B factor (Plot) nested in each level of factor A

k = Sample level

1. Analysis of Leaf Morphological Data
2. Effect of difference in landscape and plots on individual leaf characters.

The influence of differences in landscape on variation in individual leaf morphological characters was analyzed using Analysis of Variance (ANOVA). Data on leaf morphological characteristics in the different Landscapes were processed using Microsoft Excel and SAS 9.1 portable software.

1. Morphological variability of *A. scholaris* in HJ and BJ.

The complete leaf morphology data set for *A. scholaris* were subject to separate Cluster Analyses (CA) using SPSS version 13.0 software. The results of the CA were displayed in the form of dendrograms.

1. Distribution of variation in leaf morphology of *A. scholaris* across two landscapes (HJ and BJ).

Principal Component Analysis (PCA) was used to analyze the combined data from seven observed leaf morphological variables. The analysis techniques are separate approaches to combining the seven original variables into independent synthetic variables that explain the largest part of the total variation observed amongst the leaves. The analyses were carried out using SPSS 13.0 software.

**RESULTS AND DISCUSSION**

**Individual Leaf Characteristics of *A. scholaris***

Leaves are essential organs in the plant body, and plants typically have many leaves. The species analyzed had the basic morphological pattern described for the family. In the case of *A. scholaris*, the leaves are arranged in a circular pattern, with 4-8 leaves located in the upper axils. The leaf lamina or body is obovate to elliptical or elliptical-lanceolate in shape, and it is generally smooth, although occasionally, it may have some hairs. The leaves gradually narrow towards the base. The leaf exhibits a dark green color on the upper surface, and the leaf tip is rounded while tapering toward the base (Corner, 1952). Table 3 shows the compatibility between reports in the literature and the direct measurement of some characters of *A. scholaris* leaves. It was suspected that leaf morphological data for *A. scholaris* drawn from the broad environmental range across the Landscapes might be significantly related to the overall size of the leaves (Kramer et al., 2001). Therefore, correlations between leaf length (LL) and each other leaf variable were computed within species.

*Table 3. Leaf characters of A. scholaris*

|  |  |  |
| --- | --- | --- |
| Variable | Direct measurement (cm) | Reference (cm) |
| Petiole length (PL)  | 1.25 ± 0.48 | 1 – 1.5 |
| Leaf length (LL) | 10.49 ± 2.58 | 11.5 – 23 |
| Leaf width (LW) | 3.66 ± 0.93 | 4 – 7.5 |
| Venation number (NV) | 91.94 ± 8.91 | 52 – 92 |
| Leaf shape | Elliptical lancet | Elliptical lancet |

Source: (Corner, 1952; <http://www.efloras.org>; <http://www.worldagroforesstry.com>)

The data analysis on *A. scholaris* reveals certain correlations among the dimensional feature variables (Table 4). Specifically, variables such as PL, LW, WP, and NV demonstrate a positive correlation with LL. This positive correlation implies that an increase in PL, LW, WP, and NV values is associated with an increase in LL. On the other hand, transformation variables such as LS and PR exhibit a negative correlation with LL. This negative correlation suggests that LS and PR decrease as the length of the leaf increases. Notably, the three transformation variables in *A. scholaris* demonstrate a significant correlation.

LW and WP exhibit the strongest correlation with LL among the dimensional characteristic variables, with respective correlation coefficients of 0.721 and 0.804. In contrast, variables such as PL and NV show a weak correlation with LL. This implies that changes in PL and NV values do not substantially impact changes in LL values. This observation is further supported by the fact that leaves with the same area often display different petiole lengths and numbers of veins when measured.

*Table 4. The correlation between LL and other variables in the leaves of A. scholaris*

|  |  |
| --- | --- |
| Variable | Coeficient of correlation |
| PL | 0.297\* |
| LW | 0.721\* |
| WP | 0.804\* |
| NV | 0.399\* |
| LS | -0.209\* |
| PR | -0.307\* |

\*= significant at α=5%; ns= not significant at α=5%

**Effect of Landscape and Plot on Leaf Morphological Variation of *A. scholaris***

Plants are living organisms that cannot migrate and must adapt to environmental conditions. Differences in site conditions may affect a plant's structure, physiology, and reproduction (Jones & Luchsinger, 1987). Environmental factors influencing plant species variation can be abiotic and biotic. Abiotic factors include temperature, humidity, rainfall, soil, and light. Biotic factors encompass intraspecific and interspecific interactions such as predation and competition (Cox & Moore, 1980).

The summary of the analysis results on the influence of Landscape differences on the leaf morphology variables of *A. scholaris* can be seen in Table 5. The results show that out of the seven leaf morphology characters, Landscape differences significantly influenced only the NV variable for *A. scholaris*. In contrast, Plot differences impacted the NV and PR variables.

*Table 5 Analysis of variance of the influence of Landscape and Plot (in Landscape) on individual leaf morphological characters in A. scholaris*

|  |  |
| --- | --- |
| Treatment | Variable |
| LL | PL | LW | WP | NV | LS | PR |
| Landscape | 0.5753tn | 0.3843tn | 0.4961tn | 0.4961tn | 0.0038\* | 0.8250tn | 0.3224tn |
| Plot | 0.6891tn | 0.0583tn | 0.6792tn | 0.6795tn | 0.0273\* | 0.6318 | 0.0267\* |

\*\*= Treatment have significant effect at α=5%; \*= Treatment have significant effect at α=5%; tn= Treatment have no significant effect at α=5%.

**Morphological Variation of *A. scholaris* in HJ and BJ**

The variation in response to environmental conditions indicates that plants adapt to their specific environmental conditions (Jones & Luchsinger, 1987). As a form of adaptation to natural conditions or environmental pressures, plants can exhibit phenotypic plasticity, which is the ability of an individual to modify certain traits during its development (Jones & Wilkins, 1971). Plants provide abundant evidence of environmental changes in their growing habitats, including through leaf organs. Leaves are one of the organs that develop relatively quickly and are considered sensitive. Cox and Moore (1980) state that there is a correlation between climate and leaf characteristics. Leaf size and leaf edges can provide information about plant adaptation processes to average rainfall and temperature.

The variation in response to environmental conditions indicates that plants adapt to their specific environmental conditions (Jones & Luchsinger, 1987). The dendrogram in Figure 2 shows the results of Cluster Analysis for *A. Scholaris*. In a dendrogram in cluster analysis, the closer the distance between two merged clusters indicates the level of similarity or relationship between the clusters. The closer the distance between two merged clusters in a dendrogram, the stronger the relationship between the objects within those clusters. This indicates that the objects in those clusters have a high similarity or a strong association. Two groups were apparent among the seven plots based on cluster analysis of the complete leaf morphology data set. Group 1 consist of HJ2, BJ4, HJ4, and HJ3 plots. HJ2 and HJ4 plots have the most close-distance coefficients in group 1. The second group (Group 2) consists of HJ1 and BJ3. The dendrogram from the Cluster Analysis for *A. scholaris* also indicates the existence of an outlying plot. The outgroup is plot BJ2.



*Figure 2. Dendrogram of CA for A. scholaris (scale using standard deviation)*

**Distribution of Variation in Leaf Morphology of *A. scholaris* across two Landscapes**

Principal Component Analysis was applied to the whole leaf morphology data sets obtained from 61 samples *A. scholaris*. As expected, the first synthetic variable from the analysis method accounted for the highest proportion of the total variance in the data sets, followed by the second synthetic variable (Table 6). The first synthetic variable accounts for 36.2% of the total variance, contributing the most to the *A. scholaris* leaf sample data variation. The first synthetic variable significantly influences leaf morphological variables such as PL, LL, and LW (Table 7). The second synthetic variable accounts for 26.0% of the total variance, significantly impacting the *A. scholaris* leaf sample data variation. The second synthetic variable is influenced by leaf morphological variables such as LS, LWR, and PR (Table 7).

*Table 7. Correlation of all leaf morphology variables of A. scholaris to synthesis variables 1 and 2 using the PCA method*

|  |  |
| --- | --- |
| Variable | *A. scholaris* |
| VS1 | VS2 |
| LL | -0,486 | -0,274 |
| PL | -0,490 | -0,018 |
| LW | -0,485 | -0,088 |
| WP | -0,411 | 0,346 |
| NV | -0,303 | -0,180 |
| LS | -0,087 | 0,660 |
| PR | -0,138 | 0,367  |

VS= Variabel sintesis

Therefore, in the PCA analysis of the *A. scholaris* leaf sample data, leaf morphological variables such as PL, LL, LW, and WP significantly influence the variation in the data. The first and second synthetic variables are able to explain a large portion of the variance in the dataset, with the first synthetic variable contributing the highest. Table 6 shows that for the PCA multivariate analyses, more than 50% of the total variance in the leaf morphology data sets obtained from the two Landscapes was accounted for by synthetic variables 1 and 2 for each tree species *A. scholaris*.

*Table 6. The proportion of the total variance explained by the First and Second Synthetic Variables derived from Principal Component Analysis (PCA) applied to A. Scholaris*

|  |  |
| --- | --- |
| Parameter | Value |
| Synthetic variable 1 | 36.20% |
| Synthetic variable 1 | 26.00% |
| Total | 62.20% |

PCA analyses' scatter diagram and histogram revealed a random distribution of values on the first two synthetic variables. No apparent clustering patterns indicated wide plasticity in leaf morphology in response to the environmental variation. In general, the leaf morphology of *A. scholaris* showed no significant grouping of response to differences in the two Landscapes under study.



**B**

**A**

*Figure 5. Distribution of the First and Second Synthetic Variables formed from PCA analyses applied to the A. scholaris leaf morphology data set. (A) is the distribution values for leaves on the First Synthetic Variable (the X axis) and the Second Synthetic Variable (the Y axis); (B) describes the distribution of values on the First Synthetic Variable*

The similarity of results in the scatter diagrams and histograms produced by PCA for *A. scholaris* revealed a continuous distribution in overall leaf morphology as assessed by the combined data set from seven measured leaf variables without any appearance of a differential response to the different environments in the two Landscapes. Briggs and Walters (1984) have suggested that using metric data derived from morphological characters is often unable to identify differences between species because of the continuous variability arising from the plasticity of organisms in response to the environment.

**CONCLUSIONS**

Based on this study's results, we conclude that the differences between the two Landscapes understudy result in a detectable difference in the morphology of leaves in the number of leaf veins (NV) of *A. scholaris*. Differences between Plots within the Landscapes did show a statistically significant effect on some leaf morphological variables for *A. scholaris*. There is a need to assess the possible impact of differences in soil and microclimate in producing this difference between Plots. The results of PCA analysis applied to the overall leaf morphological variation of *A. scholaris* indicated that there might be some differences between the species in the degree of plasticity in response to the environment.

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