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Submission date: 11-Apr-2023 04:52PM (UTC+0900)
Submission ID: 2061391222
File name: jurnal_1_internasional.pdf (457.03K)
Word count: 3725
Character count: 19442

EurAsian Journal of BioSciences
Eurasia J Biosci 14, 6255-6260 (2020)

Distribution and habitat-specific attributes of *Sararanga sinuosa* Hemsl., in a low land tropical forest in Indonesian New Guinea

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Abstract
Palm species have existed for a long time in the New Guinea forests that are known to include exceptionally varied habitat characteristic. *Sararanga sinuosa* is a palm-like dioecious tree that is classified as a shrub and distributed exclusively along the northern part of the Indonesian New Guinea. To contribute to the long-term preservation of floral diversity on the island of Papua, the objective of this study was to determine the specific habitats where *S. sinuosa* is found in and the ideal environmental attributes for the growth of this species. Four sample plots were established to determine the distribution of this species and to understand its ecological and environmental attributes governing its occurrence, including mean temperature, humidity, soil nutrient content, association with other plant species, and preferred landscapes. The result showed that this species, in general, tended to grow at lower altitudes (< 140 m asl), in areas with a mean temperature and humidity of 30.11 °C and 74.55%, respectively. It was found to be most abundant in plot I (24 plants), where the plants showed at mean diameter and height of 22.58 cm and 13.55 m, respectively, and were found at altitudes around 40.33 m asl, on slopes ranging between 10° and 30°. However, there was no significant difference in their abundance between the four study plots.

Keywords: palm, low land, tropical forest, tree association, ecological attribute

Lekitoo K, Peday HFZ, Panambe N, Cabuy RL (2020) Distribution and habitat-specific attributes of *Sararanga sinuosa* Hemsl., in a low land tropical forest in Indonesian New Guinea. Eurasia J Biosci 14: 6255-6260.

INTRODUCTION

High and very dense biodiversity have provided a unique prestige to the Indonesian New Guinea. Timber as a main forest product has contributed significantly towards Indonesia's income since several decades. Wood and its derivative components were taken over times to fulfil some basic needs on the Island. Forests on the island of Papua have existed for long and were found to be the source of livelihood and home to almost 200 tribes in addition to providing multiple tangible services to hundreds of native people (Cabuy et al. 2012, Marwa et al. 2013). Over time, the continued dependency of the island communities on the forest has made forests indispensable to these people, and has become an important part of their lifestyle and culture.

Papua is home to diverse forest types, which are disturbed according to the geography and environment of the land, covering areas from the coast to the alpine mountains in the middle part of the island and show a high floral and faunal diversity. It is important to note that even morphological changes to forest vegetation as a part of natural adaptability contributes to enhancing the diversity of the area, and should be conserved.

Papua, with a total area of 416000 km^2, is a unique region surrounded by a huge expanse of biodiversity-rich tropical rain forest along the equatorial line. Such diversity has made this region one of the almost complete ecosystem types in the world. The island is predicted to contain approximately 20000 to 30000 floral species representing 202 families. In addition, the Papua Island holds many endemics, including approximately 124 endemic floral families, and it is likely that there are more unidentified species. These make the island quite unique (Lekitoo et al. 2017).

Sararanga sinuosa Hemsl., belongs to the Pandanaceae plant family and is endemic to the Island.

Received: October 2019
Accepted: March 2020
Printed: December 2020

Due to the similarity in the shape of its fruit to grapes, it is commonly called '*Anggur papua*' in Bahasa, the word "*Anggur*" meaning grape. The genus *Sararanga* has been described from the Pacific Island and New Guinea, and the name was initially generated based on a Malayo-Polynesian word (Stone 1961). The plant is visually seen as a palm-like dioecious tree and classified as a shrub and distributed along the northern part of Indonesian New Guinea. To contribute to the long-term preservation of floral diversity on the island of Papua, the objective of this study was to determine the specific habitats where *S. sinuosa* is found in and the ideal environmental attributes for the plant to grow.

MATERIAL AND METHODS

Study Area

This study was conducted in the Depapre sub-district, a part of the administrative district of Jayapura, situated in the north of Papua Island, during the summer of 2013. Specifically, this study focused on Tablasupa village, which is considered as an area with a high potential for the existence of *S. sinuosa* in the low-land northern coastal area of the Indonesian New Guinea. Geographically, the area lies between 139°–140°E and 2°–3°S with annual temperatures between 23.7 °C and 24.7 °C and humidity between 75% and 79% (BPS 2017). The forest covers approximately 1.3 million hectares, which consist of production forests, protected forests, limited production forests, convertible production forests, tourism forests, nature reserve forests, and forest for other uses (Aenunaim et al. 2018). The relief of the landscape includes a relatively narrow plain which gently slopes and becomes hilly in some parts close to the Cyclop Mountains. The study area experiences a tropical rainy climate indicated by an average yearly rainfall of over 1000 mm/year.

Plot Design

Sampling was designed purposively to follow the distribution of *S. sinuosa* in both secondary and primary forests in the Depapre sub-district. Four plots (I, II, III, and IV), each measuring 1000 m × 100 m, were established based on the distribution of the study species. The surrounding geographical terrain, the physiological attributes, and ecological conditions of the four plots differed slightly. Continuous strip sampling was undertaken in order to locate all individuals of *S. sinuosa* in the plot. And their characteristics such as fruit production, fruit bearing period, and potential uses of the plant were noted. Further, the diameter and height of the trees were measured in order to determine its dominance and associations. These data were then used to calculate the importance value index (IVI), which is emanated from the relative dominance, relative frequency, and relative density of the species.

Data Collection

Vegetation data

All occurrences of *S. sinuosa* in the four plots were noted. In addition, plant diameter and height were measured for each plant found in the plots. Plant diameter was measured using a diameter tape wrapped around the plant stem, 130 cm from the ground. To measure the total height of a plant, a laser hypsometer (clinometer sunto PM-5) was used. To determine dominance and tree associations, all trees inside the established plots were enumerated, their located noted, and their diameter measured.

Ecological attributes

Temperature and humidity data were collected every day for two weeks by hanging a digital thermohydrometer on a selected tree branch. A clinometer (Sunto PM-5) was used to obtain the slope of the area and an altimeter was used to record the altitude. To understand the potential distribution and ideal growing habitat of the plant soil, nutritional composition was determined, for which, a manual hand-held soil corer was used to collect soil samples at depth of 10 cm from the top. The soil samples then analyze to reveal detailed nutrient compositions in a laboratory, following the Kjeldahl method.

Data Analysis

In the filed, all plant species were identified by a taxonomy expert who had experience with the tropical New Guinea plant species. The identified plants were then enumerated to determine the density per area in each of the sampled plots. An average value for each of the fruit characteristics that were noted directly in the field were calculated and used to generalize these characteristics for the species. An ideal habitat for the growth of the species and their association were determined based on the importance value index. All data were processed using R statistics program 3.5.3. (R Development Core Team 2018).

RESULTS

The results showed that *S.sinuosa* occurred in the lowland forests in the study area at altitudes between 0 and 140 m asl. The number of individuals, their characteristics, and ecological conditions differed slightly between the four sampled plots (**Table 1**). *S. sinuosa* was most abundant in plot I with 24 individuals, while it was least abundant in plot II with only 15 individuals. The highest mean diameter was observed in plot I with 22.58 cm, while the lowest mean diameter recorded was 20.22 cm, which was recorded in plot IV. A difference in the height of the plant was also noted the maximum mean plant height (16.10 m) was found in plot IV, while the minimum mean height (13.55 m) was found in plot I. In conjunction with a latitudinal range of plant distribution, in plot IV, the plant was found to be

Table 1. Plant characteristics, physical attributes, and ecological conditions of *S. sinuosa* in the lowland tropical forest of the Depapre sub-district

Plot	Number of plant	Mean of plant diameter (cm)	Mean of plant height (m)	Mean of temperature (° C)	Mean of humidity (%)	Range of altitude (m asl)	Range of slope (°)
I	24	22.58	13.55	30.85	67.33	0–85 (± 40.33)	10–30 (± 20.46)
II	15	20.93	15.33	30.13	77.86	0–95 (± 50.67)	15–45 (± 32.27)
III	18	21.33	14.67	30.61	68.05	0–115 (± 60.56)	20–70 (± 43.00)
IV	20	20.20	16.10	28.85	84.95	0–140 (± 64.55)	20–75 (± 47.25)
Ave.	19.25	21.26	14.92	30.11	74.55	± 54.03	± 35.75

Fig. 1. Stem, leaves, and fruits of *S. sinuosa* in their habitat in the low-land tropical forest of Depapre

distributed across the widest range of altitudes, ranging from 0 m –140 m asl, while in the other plots, they were found at maximum altitude of 115 m asl. On the other hand, between the four established plots, there were slight variations in the slope at which *S. sinuosa* was found growing, which ranged from 10°–75°. The range of slopes found within plot IV (20°–75°) was found to be widest among the sampled plots, while that within plot I (10°–30°) was the narrowest. Shade cover for *S. sinuosa* to grow was measured, and the mean value ranged from 60% to 85% across the four plots.

We analyzed the association of different growing stages of the study species with other plant species. Our data showed that *S. sinuosa* is closely associated with *Inocarpus fagifer* (15.10%), *Pometia pinnata* (13.44%), *Intsia bijuga* (11.53%), *Cananga odorata* (10.98%), and *Commersonia bartramia* (9.74%) at the seedling stage. At the sapling stage, it was found to be closely associated with *C. odorata* (25.95%), *P. pinnata* (21.82%), *Palaquium amboinensis* (19.52%), *Canarium indicum* (14.60%), and *I. bijuga* (13.88%). At the adult stage, we found *S. sinuosa* to be closely associated with *P. pinnata* (42.93%), *C. odorata* (41.12%), *I. fagifer* (24.93%), and *Artocarpus altilis* (18.25%).

Constructive semi-structured discussion with local inhabitants revealed that *S. sinuosa* bears fruits for an entire month, annually, and that fruiting occurs when the plant diameter is around 20 cm and the height is ≥ 10 m. Phenology of this species has not been studied previously, and hence, in the absence of a reference for the age at which the plant fruited and the fruiting season, we assumed that only older mature plants that are big in size will bear fruits. The fruits of *S. sinuosa* contain essential nutrients such as fat, protein, fiber, vitamin C, and carbohydrate. However, the fruit is not commonly consumed.

DISCUSSION

S. sinuosa is considered a habitat specialist that grows only in the lowland tropical forests of Papua, especially in the lowland coastal areas ranging from the eastern region of Jayapura (east of West Papua Island) to the upper center of the island in the Waropen District and the Yapen Island (center of West Papua Island). It is a non-woody plant that does not show clustered growth. They reach a maximum height of 20 m and a diameter ranging from 10 cm to 18 cm (Huynh 2001). The main stem tends to grow vertically with no riding root, and flowers usually appear on the edge of the stem and branch or sometimes under leaves with predominantly white and yellow colors. The fruit shape is oval with both edges resembling a crescent shape. The seeds are found inside the fruit, and their size is similar to that of chilli pepper. Although there is a report indicating the occurrence of *S. sinuosa* in some Pacific islands (Stone 1975), due to its restricted distribution and habitat specificity, this species has been categorized as endemic to New Guinea. There is a paucity of published information on the ecological characteristics of *S. sinuosa* habitat and factors restricting the occurrence of this species to the northern part of the Indonesian New Guinea area. Nevertheless, the ecophysiological attributes that have been reported in this study, allows the identification of preferred habitats for this plant.

S. sinuosa was found to be distributed mainly in the lowland areas, indicating this as its suitable habitat

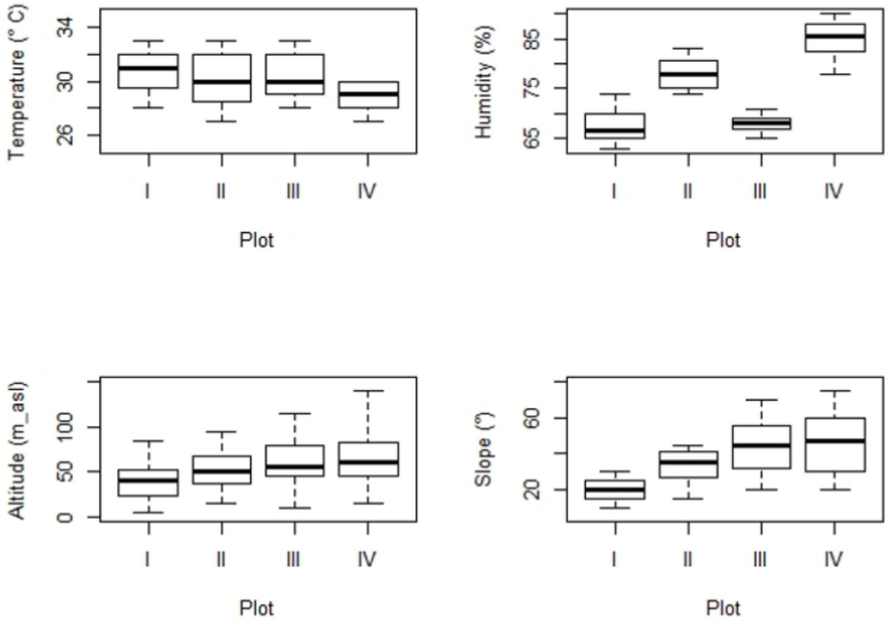

Fig. 2. Ecophysiology of the area surrounding *Sararanga sinuosa* plants in the lowland tropical forest of the Depapre sub-district

(Tilman and Lehman 2001). It has been noticed that among the four plots established for this study, the number of *S. sinuosa* individuals was almost the same (not significantly different among plots), and that the individuals were evenly distributed in the area. Soil type and its nutrient composition were underlying factors affecting the ideal growth of the plant. This was indicated by the dominance of podzolic and latosol (Jayapura Land Office 2019) around study site, as well as the high concentration of phosphor and iron, which was likely to have emanated from bleached horizon of the soil due to rain from the Cyclops Mountains that are situated close to the study area. Our results show that the soil where *S. sinuosa* occurred was poor in macro nutrients, insufficient to support the growth of either *S. sinuosa* or any other plant. However, several micronutrients that were found were predicted to be the major key in supplying essential minerals for the plants to grow (Tripathi et al. 2015). Sillanpää (1982) noticed the importance of micronutrients during plant growth, and this has been an important factor in characterizing plant habitats.

Our study showed that this plant was commonly distributed in the low-land old secondary forest habitat with moderate to heavy forest closure (60%–85%) in areas where the slopes were mostly gentle, but also in some steep areas. Moreover, this is a moderately shade-tolerant species that depends partially on the surrounding adult vascular trees for shade during their initial stages of growth and development. It was obvious that the surrounding old trees with their long expanse of canopy will accelerate the lateral and vertical growth of *S. sinuosa* and provide an ideal macro climate for the plant to be productive and bear fruit (Wagner et al. 2011, Lu et al. 2015). Valladares et al. (2016) highlighted the importance of shade factors in forest ecosystems as they can contribute towards forest structure, composition, and dynamics for a number of understorey plants as well as initiate multiple interactions that subsequently increase the chance for vegetation to grow exponentially. In addition, a moderate degree of association was observed around *S. sinuosa* from the seedling stage up to the mature tree, which strengthened the likelihood of a close inter-dependency among the tree species during the growing period. However, there is no strong evidence to support the ultimate conclusion that these tree species are key indicators of the occurrence of *S. sinuosa* in other locations. Certainly, many studies on the ecology of *S. sinuosa* and its habitat are needed to draw any conclusion regarding the suitability of growing habitat.

In addition, the plants tend to grow in different terrains as evidenced by the wide range of slopes (**Fig. 2**) recorded in the areas of occurrence. Also, the structure of the forest is quite dense in these areas, and perhaps does not allow light to penetrate to the understorey plants. These could indicate that this species requires a lower amount of direct sunlight during the day for its daily metabolism and growing in areas that are sloping increases its chance of acquiring the required direct sunlight. This is an obvious adaptability of plants in order to independently strive and grow to obtain light from the sun (Givnish 1988, Fiorucci and Fankhauser 2017). Our results indicate that lower temperatures and higher relative humidity is beneficial for the growth of *S. sinuosa*. However, slope does not influence either of these environmental attributes. Thus, habitats characterized by lower temperature and relatively higher humidity with sufficient direct sunlight available appear to be an ideal habitat for *S. sinuosa* to grow well and bear fruits throughout the year. Higher relative humidity is a requirement for the growth of several *Pandanus* species and is a factor that influences fruiting (Lekitoo et al. 2017).

CONCLUSION

The potential distribution of *S. sinuosa* through its ecological characteristics was assessed by establishing purposive plots for sampling and by undertaking laboratory analyses of soil nutrients and nutritional content of fruit. To understand the ecophysiology of the study species, data on specific abiotic parameters were recorded. Additional perspectives were also obtained through semi-structured interviews with the locals for overall plant usefulness. The results of this study showed that the ecological conditions along the northern tropical low-land forest of Indonesia New Guinea were conductive for the growth and fruiting of *S. sinuosa*. Plant establishment and fruit production are indicators of favorable environments for a species. The absence of this species from other areas of the Papuan mainland implies that habitats in these areas were not favorable for it, and that they are probably habitat specialists. Although this plant does not have any significant commercial prospect, ensuring its survival and growth is important for bolstering the biodiversity richness of the Island.

ACKNOWLEDGEMENTS

We would like to thank the head of the Manokwari Environmental and Forest Research Development Institute for the grant provided for the field study. We thank the local people, living around the study area who provided us with their constant support during the field study. We would also like to thank the University of Gadjah Mada for supporting the laboratory analyses.

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