

DISTRIBUTION, GROWTH HABIT AND MORPHOLOGICAL CHARACTERISTICS OF *PIPER BORNEENSE* N.E.BR. VARIETIES IN SARAWAK, MALAYSIA



 Philip Lepun¹⁺
 Tunung Robin²
 Ribka Alan³

¹Faculty of Agriculture and Forestry Science, Universiti Putra Malaysia Bintulu Sarawak Campus, Bintulu, Sarawak, Malaysia.

¹Email: philip@upm.edu.my

²Institut EkoSains Borneo, Universiti Putra Malaysia Bintulu Sarawak Campus, Bintulu, Sarawak, Malaysia.

²Email: tunungrobin@upm.edu.my

³Faculty of Humanities, Management and Science, Universiti Putra Malaysia Bintulu Sarawak Campus, Bintulu, Sarawak, Malaysia.

³Email: ribka@upm.edu.my



(+ Corresponding author)

ABSTRACT

Article History

Received: 2 June 2022

Revised: 12 July 2022

Accepted: 28 July 2022

Published: 17 August 2022

Keywords

Piperaceae

Piper borneense

Distribution

Plant diversity

Environmental factors

Edible food

Morphological.

Preserving and documenting ethnobotanical knowledge and plant use practices by ethnic groups is an urgent responsibility. This study aims to determine and document the ecological requirements and the distribution of *Piper borneense* varieties, their growth habits, and their morphological characteristics. This study was conducted in Belaga, Tatau and Bintulu, Sarawak, Malaysia. The plant samples were collected, Global Positioning System (GPS) readings and ecological conditions were recorded, and plant samples were analysed. Three different varieties were identified, and variety 1 was found to be widespread in the study area. The distribution of *Piper* species variety was greatly influenced by human activities and natural factors, while the growth habit was greatly influenced by soil's organic substrate, light intensity and soil moisture. Changes to forest environment area need to be monitored so that the growth of wild piper community and its growth habits are easily understood for sustainable forest management.

Contribution/ Originality: The current study contributes to the documentation of *Piper borneense* varieties' distribution, growth habit, and morphological characteristics in Sarawak, Malaysia. Information on the growth and natural needs of this plant needs to be understood for it to be grown to meet food needs and become an economic resource in the future.

1. INTRODUCTION

Tropical rainforests of Borneo, the third largest island in the world have undergone a very drastic transformation of agricultural development over the past two decades that lead to plant habitat destruction and the decreasing of species diversity and loss of genetic diversity. The conversion of forests to commercial plantations, excessive deforestation, which can lead to forest land degradation, results in a permanent reduction of native species [1] and the threat of extinction of plant species increases dramatically [2]. As a result of changes to the forest upper structures and forest soil profile, its' environmental condition and microclimatic also influence the understory plant structural and functional component of forests ecosystem features [3]. These changes to the forest structural and forest soils have caused the important roles of forest soil carrying capacity in providing water, nutrition and

support for forest plants to be decreasingly impressed. As the condition of the forest soil profile has changed, then the plants growth and its' distribution patterns in the forest have also changed in term of existence and ability to compete with others. In local communities, traditional knowledge of forests and the diversity of changing plant species will erode generational knowledge of forests that have become traditional norms and practices [4]. Traditional information data for the forest plant biodiversity and distribution in Borneo is still relatively difficult to access freely and easily by the public due to the constraints of good information data management [5].

Preserving the forest biodiversity, knowledge of ethnic groups related to plant use practices and cultures several ethnobotany studies in Borneo, documenting different plant species and preserving the knowledge of indigenous people from various communities is very necessary [6]. Information about knowledge, practices and cultural traditions in local community need to be passed down from generation to maintain the culture and practices [7]. The dissemination of knowledge that has been a traditional practice since time immemorial is often related to land use, plants biodiversity and ecosystem functioning [8]. The knowledge possessed from the past clearly serves as a good guide to help life as well as fight most of the dangerous infections that pose a serious threat to human [9] and animal health. Also, the culture and traditional skills [10] in sourcing foods, traditional medicine, fragrances and seasonings [11] to survive with the various plant species found in the surrounding area need to be fully documented.

There are many subordinate plant species in Borneo that are poorly understood in many aspects resulting in their conservation priorities being given less emphasis. The lack of important information about plant distribution, habitat and ecological needs contributes to high levels of extinction risk for plant species [12] in many parts of the world, necessitating our efforts to provide comprehensive records. The high number of ethnicities with different lifestyles using forest plants as a source of wild vegetables from the forest areas in Borneo is quite diverse and need to be fully studied by plant and anthropology researchers. The use of wild plants as a source of food and other purposes in the living traditions of local communities requires complete documentation through various research methods [6, 13, 14]. There is a declining tendency about knowledge related to food plant types among indigenous communities in forest areas in Borneo [15]. Similarly for plants that contribute to forest fruit resources, there are many more species with economic potential of lesser-known native fruit tree species often neglected in Borneo forests which have great potential to be promoted, domesticated and commercialized [16].

The richness of plant species and populations in tropical rainforests is relatively dependent on the type of ecology and habitat in the forest area and is always influenced by internal and external variables [17]. The role and changes that contribute to the richness of plant dynamics are environmental and biotic factors of the forest, soil structure [18] and the ability of plant propagation within its area over a period. Next the wealth and distribution of plants in forests has a very important impact due to land use by humans [19] because land use practices are highly related to soil structure and disruption to drainage which ultimately inhibits the regeneration process of plant species in certain forests.

According to Sayok and Teucher [15], tropical rainforests in Sarawak have an important source of fruits and vegetables for local communities because of their unique dietary variations and importance to food security for most ethnic households whose lives are in rural areas. *Piper* a genus in the Piperaceae is often taken by rural residents from the forest as a source of vegetables and are often categorized as weeds in soil development. *Piper* species are slender trees, often twisted and shrubs to strong climbers and terrestrial or epiphytic herbs always dominate secondary forests with the availability of nutrients, moisture and light in forest ecosystems. Creeper habit as ground floor plants found to grow well on forest floors under severe light regimes and different microclimate conditions [20]. Vegetables from natural forest that are usually found to grow allied with these plants and also are commonly used by local community are such as from family of Pteridaceae, Zingiberaceae, Graminae and Arecaceae.

In Sarawak, *Piper borneense* is a species used as a leafy vegetable because of its very fragrant aroma and the very soft texture of its leaves, fruits and stems when cooked especially by the Orang Ulu group living in Sungai Asap,

Belaga, Sarawak [21]. However, this plant which is one of the favorite vegetables of the Orang Ulu community is increasingly difficult to find due to over harvesting and changes in its growth environment due to high forest degradation [22]. In this study, researchers will determine the distribution, growth habits and morphological characteristics of *P. borneense* varieties used by the locals in Sungai Asap in Belaga, Sarawak. The ecological determinants and growth habits of these rare species in these natural forests are still poorly understood and explored although they have economic potential for future cultivation purposes. Findings from this study can contribute as a guide and new information for taxonomic review as well as provide information to facilitate future searches of this plant to meet the checklist for tropical Asian Piperaceae [23]. Information documenting ethnic knowledge related to food plants [24] will help raise awareness in the use of plants as well as the preservation of small plants that may one day make a significant contribution to human life.

2. METHODS

2.1. Study Site

The study on *P. borneense* distribution and ecological were conducted around Sg. Asap, Belaga, Bintulu, Tatau and Selangau area in Sarawak, Malaysia. Samples collection for this study were made from 1st Jun 2020 to 5th September 2020. The selection of this study area was based on the accessibility of the place and its appropriate ecology for the growth of the *Piper* plant species sought. The growth area of *P. borneense* studied were on oil palm plantations edge forest and secondary forests that have been explored for the past 10 years and have a small light penetration space [20]. The focus on this area was based on the local experience of most suitable area for this species to grow in large populations and the existence of this plant species that is often used as an important ingredient and flavor in daily needs [25]. Most of the locations of the plant collection sites are classified as secondary forest and the categories are based on the frequent existence.

2.2. Data Collection

The Global Positioning System (GPS) was recorded for every area. For every plant sample found in the natural forest, the pictures were taken for record and the evaluation on reproductive parts was identified and measured such as the flowering and fruiting stage, colour, over-mature, diseased, or otherwise not normal are avoided. The forest environment condition such as forest type, ecology features and forest covered were also determined. The availability of plant growth in forest areas depends on the soil structure and drainage even though the forest may be disturbed in the recent forest [26]. All samples collected from the forest were turned into specimen vouchers or specimen herbarium through a drying process and stored at the Agronomy Laboratory, Universiti Putra Malaysia Bintulu Sarawak Campus. The process of research and measurement of the morphological characteristics of *P. borneense* was also performed for the leaves, inflorescences and berries with two research methods involving the evaluation of qualitative and quantitative properties for the leaf shape, leaf arrangement, leaf width, leaf length, trichome length, spike colour, spike length, peduncle colour, berry shape, berry diameter, pedicle length and pedicle.

3. RESULTS AND DISCUSSIONS

3.1. *Piper Borneense* Distribution

Forests that are frequently disturbed by humans and natural processes, encourage the growth of ever-changing plant species. The lush forests along the river are very important as a place for searching food plants by the rural community. Among plant species gathered were wild peppers species that have a unique flavour and used as leafy green vegetables among Orang Ulu community in Sarawak such as *Piper umbellatum*, *P. borneense*, *P. auritifolium* and *P. rueckeri* [21]. From this study, *Piper borneense* which are usually called Tung Burong Baleng by the Kenyah Badeng and Daun Baleng by the Kenyah Lebu' Kulit were identified in three different varieties based on morphological characteristics and its' growth habit. This edible plant species from the jungle were found to grow on a fertile and high organic material substrate as long there is light available penetrating to the forest floor [15].

According to the local community, this wild pepper species is an indicator that the soil in those areas is very fertile, humid and cool. Based on their experience, if these wild peppers were found growing in the area, that area is normally wet and fertile. This area is good for paddy planting and could get an excellent paddy harvest yield especially when the burning process of the area occurs perfectly. This clearly shows that *P. borneense* distribution has always been affected by human and light mechanisms whereby plants respond to environmental changes in a forest environment. This study also found that this plant species grows well and very fertile when there are other plant species that could retain water on the plant body growth associated with the same area. The fertility of the area with small variations in light conditions and the differential ability of the species to maximize light interception [20] may have a large impact on growth in promoting its excellent growth characteristics by self-maintaining population in natural [13]. Area of plants that are exposed to the light were found to grow in big population, bigger and soft stem, shining leaves and inflorescences, leaf surface was also more hairy, adventitious roots grown faster from the node and the colour were also more bright Figure 1.



Figure 1. Female inflorescence of *P. borneense* var. 1 with cylindrical, greenish when young and whitish while mature.

Differences between the three types are shown in Figure 2. *Piper borneense* is relatively unique in distribution, growth habit and characteristics properties. The results showed, the variety 1 mostly grow on riverside areas and dead tree trunks that have abundant humus with good sunlight reception, while the variety 2 were found to grow on mineral soils which is slightly more sheltered from sunlight, and the variety 3 were commonly found on rocky areas or rock crevices that are slightly damp and with less lighting. Yet the characteristics of these three varieties have not yet been explained in a detailed taxonomy. However, these three varieties have significant differences and have very close growth relationships with each other. The differences between these three varieties can be seen

from the nature of the stems whether woody or succulent, node and internode length, the spike and berry colours. The growth of all varieties has its uniqueness due to its ability to live according to very special environmental conditions in the fragmented forest. In terms of distribution, all three varieties were found in the district of Belaga especially in Sungai Asap Belaga area. From the collection throughout Sarawak, only *P. borneense* var.1 was found distributed on all districts [Table 1](#).



Figure 2. Growth and mature infructescence of *P. borneense*: A. var. 1, B. var. 2 and C. var. 3.

Table 1. *Piper borneense* varieties, growth habit and distribution in Sarawak

Local Name	<i>Piper borneense</i> variety	Growth habit	Location of Distribution
Tung Burong or Baleng	<i>Piper borneense</i> var 1	Perennial erect herb or small shrub with decumbent branches; dioecious; woolly and glabrescent; nodes swollen.	Sg. Basai Selangau Sg. Sebaya Selangau Taman Negara Bukit Kana Tatau Sg. Senunuk Tatau Sg. Kelebuk Tatau Sg. Penyurai Sibiyu Bintulu Sg. Sekubong Sibiyu Bintulu Sg. Selidik Asap Belaga Ladang SOP 1 Sepakau Belaga Sg. Paran SOP 3 Sepakau Belaga Sg Iban Hulu Linau Sg. Ta Hulu Sg. Danum Belaga Jln Kem Hulu Sg Danum Belaga Sg. Buroi Danum Belaga Sg Cak Danum Belaga Sg. Adem Danum Belaga Hulu Sg. Asap Belaga
Tung Burong	<i>Piper borneense</i> var 2	Perennial erect herb with decumbent branches; dioecious; woolly and glabrescent; nodes swollen.	Sg. Selidik Asap Belaga Lusong Laku Hulu Sg Linau Belaga. Sg. Penyuan Belaga
Tung Burong	<i>Piper borneense</i> var 3	Perennial erect herb or small shrub with decumbent branches; dioecious; woolly and glabrescent; nodes swollen.	Sg. Paran SOP 3 Sepakau Belaga

Piper borneense was widely found distributed in almost all areas that have been visited during this study in Sarawak [Figure 3](#) especially at the edge forest of oil palm plantation. The species was found in 20 locations in Sarawak mostly along stream sides area of Selangau, Tatau, Belaga and Bintulu district. This is parallel to [Gardner \[27\]](#) that some *Piper* species can be found in secondary growth along stream sides, on former garden sites and

around the ubiquitous plantations. Based on the collections the *P. borneense* variety 1 which is called Tung Burong Baleng or Baleng by the Kenyah was found widely spread in the suitable environment in Sarawak. Most samples of this variety were found at stream side areas that are often disturbed by natural and human activities. The local people's knowledge and experiences on distribution, growth habits and environmental requirements were very helpful in the collection of plants samples from the forests. The involvement of local communities in aspects of plant distribution research and ecological assessment of their environment was necessary as they are more skilled and experienced in the use and search [21].

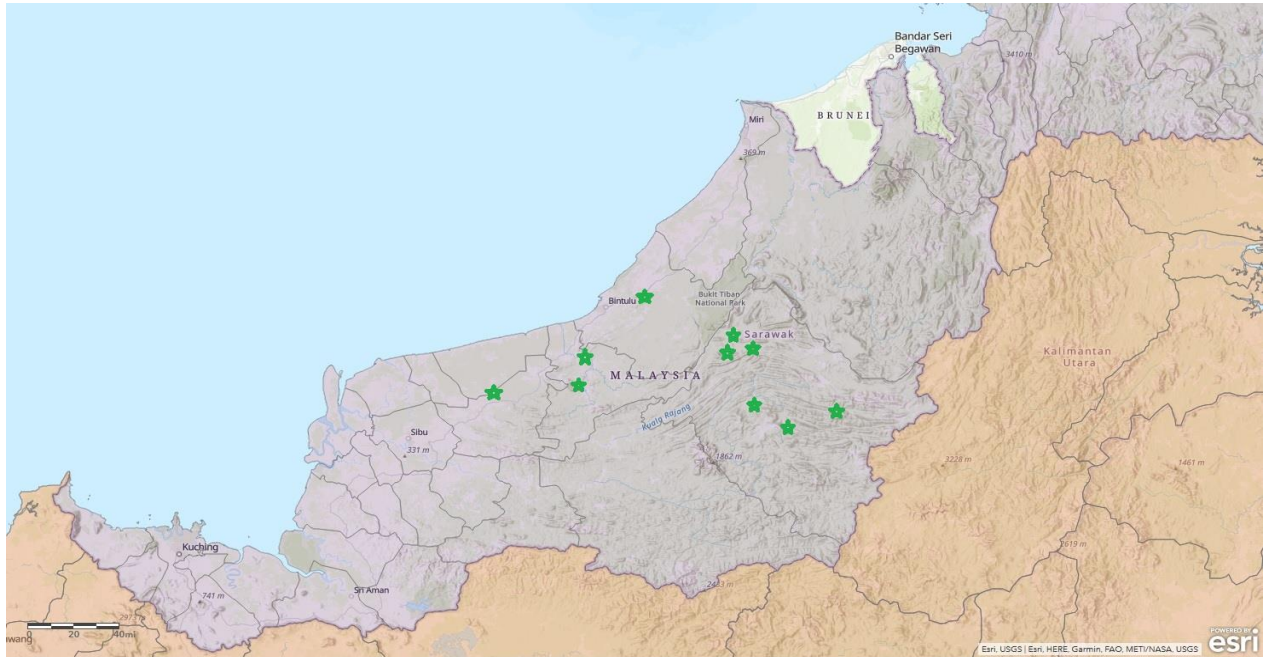


Figure 3. Location and distribution of *P. borneense* in Sarawak.

3.2. Growth Habit and Environment Requirement

The results of this study showed that this wild pepper was suitable for growth on the forest edge of oil palm plantations with the slightly disturbed soil from heavy machinery during planting process preparation. Disturbed forest soil areas of wild pepper are always loose, slightly sheltered, high habitat humidity with a moderate light penetration rate to the forest floor on forest understorey microclimate [28]. In Sg. Asap forest, Belaga Sarawak, *P. borneense* grow on four different locations such as high substrate and muddy soil (2) on or near dead trunks, (3) mineral soil and steep hill and (4) rocky riverbank area. *P. borneense* varieties found in the study area could adapt and grow according to the habitat for them to survive in different areas. Adaptation is a special feature on a particular part of this plant that allows the plant to live in a particular place or habitat. In the case of forest environment that undergoes sudden changes in a short time, it will cause the original plant to make a natural selection including undergoing adaptive mutations [29] for the purpose of its adaptation in the new environment. Many *P. borneense* adapted to grow on tropical forests with shallow roots so that they can utilize the remaining organic matter from plants and animals that decompose on the forest floor quickly and easily. Besides, the broader leaves of *P. borneense* allow it to absorb more sunlight for food production through photosynthesis in the forest gap.

The growth nature of *P. borneense* indeed requires fertile soil areas and contains high substrate. For variety 1 which lives in moist soil areas on the banks of creeks, its growth nature was very fertile with very large population, dense green leaves and large stems with marked succulent nature. However, the population that grows in areas of dead and rocky logs, the nature of the shrub will be more pronounced, erect with longer internodes and larger nodes. The growth of these forest peppers will be very fertile and be in very large clusters around soils that have black soil of high moisture with a thick substrate as reported on dead stems [27]. Its abundant presence was also

closely related to the growth of other plant species assimilated with it such as *Begonia* spp., *Curculigo* spp., Zingiberaceae and Araceae family species. For this wild pepper that grows in fertile soil and gets good sunlight, the colour of the leaves will be a little yellowish compared to the slightly dim green. The growth of variety 1 shows uniqueness if living in different ecological areas. If variety 1 grow on a higher humidity area with a little rickshaw soil, it will have soft stems, thick and large leaves. However, if it grows in mineral soils or slightly rocky area, then the nature of the stems will be harder or become shrubby features and the leaves are thinner and small.

The growth of *P. borneense* variety 2 was found on abandoned area of agricultural and logging activities areas. It was found to grow in mineral soil on gentle and slope associated with many climbers and creepers species. The forest floor of where this variety 2 grow was on thin layer of litter. The common plant species found to grow with this variety were *Curculigo latifolia*, *Alpinia* spp., *Etingera elatior* and *Costus speciosa*. The growth of this variety 2 was more herbaceous with its soft stems and leaves that bend to the ground. The leaves lamina was always hollow due to insect attack and was always found grow in single stems.

The growth of *P. borneense* variety 3 live in areas of mineral soils or rocky soils, the stems are slightly harder or higher in woody nature. The growth characteristic of variety 3 has a short internode with slightly swollen nodes. The leaves were seen to be hairier with slightly wavy leaves margin and there were some leaves found to be asymmetric leaf basal. This variety was found to grow with Ginger, *Clidemia hirta* and several species from Araceae such as *Schismatoglottis* sp. *Homalomena* sp. and *Begonia* species. The comparison for *P. borneense* varieties plants, habitat descriptions and environmental conditions are described in [Table 2](#).

3.3. Morphological Characteristics

According to [Suwanphakdee, et al. \[23\]](#), the *Piper* genus can be easily recognized on gross morphological characters, but it is difficult to identify until the species level. The *P. borneense* was first published in Gardeners' Chronicle in 1882 from a sample (K000575316) of Western Borneo. From this study, the species has three varieties although the leaf characteristics are quite difficult to be distinguished but still have different characteristics in some parts of the plant. For these three varieties, the spike is almost the same size, and the length is also almost the same while the pedicel of variety 3 is longer than variety 1 and variety 2. Stems of *P. borneense* are swollen at nodes, with short aerial roots present on lower nodes. Stem internodes were short and generally the internodes length increase when going upward. The branching is vigorously off near the base. The stem of *P. borneense* is succulent with the presence of trichome and light green in colour on the upper part. Meanwhile, the basal is woody and hard with the absence of a trichome. Mostly *P. borneense* showed moderate orthotropic branching or monopodial main stem that climbs over support trees.

Leaves of *P. borneense* are spiral, variable in shape and size; usually cordate, base is deeply cordate and symmetric, the apex is shortly acuminate to round, margin is entire or crenulate and absent of stipules. Besides, non-glandular trichomes are found on both surfaces of leaf but more densely on the adaxial surface, usually straight or rarely slightly curved. Leaf vein 7-13 veined from base with 2 additional major veins arising just below base in *P. borneense*, the venation is campylodromous; disposition of the veins to the apex. Veins are densely pubescent below in *P. borneense*. Petiole grooved adaxially, heart-shaped in cross-section. The epidermal layer is made up of tabular or squarish cells, with dense cytoplasm, and most cells giving rise to non-glandular trichomes. The collenchyma patches are separated from each other by thin-walled parenchyma of few to many cells wide. Vascular bundles collateral, few, arranged in a U-shaped arc in the ground tissue, larger and smaller bundles alternating with each other, and every bundle is positioned opposite to a collenchyma patch; xylem is facing outwards and the phloem facing the center of the petiole.

Table 2. Location, habitat environment and growth habit of *P. borneense* varieties in Sarawak.

Location	<i>Piper borneense</i> variety	Latitudinal and Longitudinal	Environmental condition	Growth habit	Soil pH	Light intensity (W/m ²)	Moisture content (m ³ .m ⁻³)
High substrate and muddy soil	<i>Variety 1</i>	N 02° 56.566' E 113° 52.072'	Edge of forest land on small stream valley that has not disturbed. Grow on along stream sides high nutrients from organic debris helps the healthy and fertile growth. Receive good light rays in the early morning and well sheltered in the afternoon. Colonies of ants that live abundantly in the stands area. Grow associated with <i>Begonia</i> spp., <i>Curculigo</i> spp., and species from Zingiberaceae.	Perennial herb usually 20–30 cm high; dioecious; woolly and glabrescent; nodes swollen. Leaves cordate, long petiole, large and green leaves. with oblong floral bracts when flowering and spatulate bracts when fruiting, erect, catkin-like inflorescences and infructescence. Mature fruit orange and red colour.	6.23 ± 0.09 (6.1-6.4) n=3	1356 ± 2.08 (1353-1360) n=3	0.00 n=3
Near dead trunks	<i>Variety 1</i>	N 03° 09.474' E 113° 92.913'	Logged over forest and oil palm plantation area. Grow on shaded and the ground floor is abundant with fallen leaves. Grow population is small on loosened soil by logging activities with thicker dead plant materials.	Perennial erect herb or small shrub usually 20–115 cm high; dioecious; woolly and glabrescent; nodes swollen. Leaves cordate, long petiole, large and green leaves. with oblong floral bracts when flowering and spatulate bracts when fruiting, erect, catkin-like inflorescences and infructescence. Mature fruit orange and red colour.	6.70 ± 0.08 (6.6-6.8) n=3	388 ± 0.88 (387-390) n=3	0.53±0.14 (0.3-0.8) n=3
Mineral soil and on steep hill	<i>Variety 2</i>	N 02° 56.588' E 113° 51.590'	Abandoned area of agricultural and logging activities areas. Grow on gentle and slope with many climbers and creepers species. Forest floor is thin layer of litter. Grow associated with <i>Curculigo</i> spp., and species from Zingiberaceae.	Perennial erect herb with decumbent branches, 20–45 cm high; dioecious; woolly and glabrescent; nodes swollen and long petiole. Leaves cordate, long petiole, large and green leaves. with oblong floral bracts when flowering and spatulate bracts when fruiting, erect, catkin-like inflorescences and infructescence. Mature fruit yellowish green.	6.60 ± 0.10 (6.4-6.7) n=3	387 ± 2.08 (386-391) n=3	0.00 n=3
Rocky and riverbank	<i>Variety 3</i>	N 03° 09.471' E 113° 92.950'	Extreme growth on the crevices rock filled with organic materials alongside the small stream fresh and clean water. Area of growing also covered with many ferns and tuberous plant such as ginger and Araceae species. Basal stem is woody with many roots that burrow into rock crevices to absorb nutrients from moss and organic debris.	Perennial erect herb or small shrub with decumbent branches, 30–70 cm high; dioecious; woolly and glabrescent; nodes swollen and long petiole. Leaves cordate, long petiole, large and green leaves. with oblong floral bracts when flowering and spatulate bracts when fruiting, erect, catkin-like inflorescences and infructescence. Mature fruit orange.	6.50 ± 0.10 (6.3-6.6) n=3	257 ± 3.79 (250-263) n=3	3.50± 0.29 (3.0-4.0) n=3

The inflorescence is axillary or leaf opposed spikes, orientation erect and usually in false umbels with the pedicels bearing the bracts. The flower is minute, usually bisexual and without perianth. The stamens are two in number, with a superior ovary and three single-celled stigmas. The form of the bract floral is triangular/subpeltate and the margin of the bract floral fimbriate. The fruits of *P. borneense* are usually three-angled fleshy drupe or berries form, with a single seed per fruit. The fruit surface was slightly rough and the position of the fruit to the stem was slightly horizontal. The seeds have a minute embryo, and mealy perisperm. *P. borneense* can flower all year round, depending on the availability of water. Propagation is mostly by the seed which is usually broken by direct sunlight on maturity.

The morphological characteristics observed for *P. borneense* were highlighted for both qualitative and quantitative traits. Whilst many qualitative differences were observed in almost all traits studied, contrasts were most easily recognized in the stem and leaf traits. Besides, the quantitative morphological characteristic of *P. borneense* was also compared among the location or traits. The summary of qualitative data of *P. borneense* found at different locations in Sarawak is shown in Table 3.

Table 3. Summary of *P. borneense* varieties qualitative morphological characteristics assessed for vegetative and reproductive structures at four different locations in Sarawak.

Location / Traits	High substrate and muddy soil	Near the dead trunk	Mineral soil on steep hill	Rocky riverbank area
Stem				
Stem texture	Succulent	Succulent on the upper stem, and woody at the basal	Woody	Succulent on the upper stem, and woody at the basal
Stem colour	Light green	Light green	Dark green	Light green
Stem branching	Orthotropic	Orthotropic	Orthotropic	Orthotropic
Leaf				
Leaf shape	Cordate	Cordate	Cordate	Cordate
Leaf colour of adaxial surfaces	Dark green	Dark green	Dark green	Dark green
Leaf colour of abaxial surfaces	Light green	Light green	Light green	Light green
Leaf apex	Acuminate	Acuminate	Acute/ acuminate	Acuminate
Leaf base	Cordate	Cordate	Cordate	Asymmetric and cordate
Leaf margin	Entire	Entire	Entire	Entire and wavy
Leaf arrangement	Spiral	Spiral	Spiral	Spiral
Trichome colour on adaxial and abaxial surface	White	White	White	White
Type of trichome on adaxial and abaxial surface	Non-grandular	Non-grandular	Non-grandular	Non-grandular
Petiole				
Petiole colour	Light green	Light green	Light green	Light green
Trichome colour on petiole	White	White	White	White
Type of petiole	Grooved	Grooved	Grooved	Grooved
Inflorescence				
Spike colour	Creamy white	Creamy white	Green	Yellowish orange
Spike shape	Oblongoid	Oblongoid	Oblongoid	Oblongoid
Peduncle colour	Light green	Light green	Light green	Light green
Fruits				
Fruit shape	Drupe or berries form	Drupe or berries form	Drupe or berries form	Drupe or berries form
Mature Fruit colour	Orange and red	Orange and yellow	Yellowish green	Orange
Pedicel colour	Light green	Light green	Light green	Light green

4. CONCLUSION

Piper borneense was found growing and distributed widely all over the places in Sarawak. The growth of this wild edible piper was greatly influenced by the environment needs such as soil fertility with a high organic substrate, moderate light intensity and good moisture content. The distribution and environmental determinants of

this species were highly dependent on natural deforestation and human activities such as agriculture and logging. Therefore, information on the growth and natural needs of this plant needs to be understood so that it can be grown to meet food needs and become an economic resource in the future. The urgent need to assess the needs of rare plant species in developing potential plant needs as food crops with a high threat of extinction due to land development needs to be accelerated.

Funding: This research is supported by Geran Putra IPM, Universiti Putra Malaysia (Grant number: 9695800).

Competing Interests: The authors declare that they have no competing interests.

Authors' Contributions: All authors contributed equally to the conception and design of the study.

Acknowledgement: We thank the Chief Executive Officer of Sarawak Biodiversity Council for issuing permit for us to do our plants collection for research and development with the Permit No. SBC-2020RDP-25-PL.

REFERENCES

- [1] H. F. Aditya, S. Gandaseca, M. L. Rayes, D. S. Karam, C. Prayogo, and G. A. Nugroho, "Characterization, changes in soil properties and vegetation distribution as affected by topography in Ayer Hitam Forest Reserve, Selangor, Peninsular Malaysia," *AGRIVITA, Journal of Agricultural Science*, vol. 42, pp. 548-562, 2020. Available at: <https://doi.org/10.17503/agrivita.v42i3.2617>.
- [2] T. O. Grande, L. Aguiar, and R. B. Machado, "Heating a biodiversity hotspot: Connectivity is more important than remaining habitat," *Landscape Ecology*, vol. 35, pp. 639-657, 2020. Available at: <https://doi.org/10.1007/s10980-020-00968-z>.
- [3] S. Chelli, A. Bricca, M. Cutini, G. Campetella, M. Cervellini, J. L. Tsakalos, and R. Canullo, "Large standard trees and deadwood promote functional divergence in the understory of beech coppice forests," *Forest Ecology and Management*, vol. 494, p. 119324, 2021. Available at: <https://doi.org/10.1016/j.foreco.2021.119324>.
- [4] Y. A. Bofo, O. Saito, S. Kato, C. Kamiyama, K. Takeuchi, and M. Nakahara, "The role of traditional ecological knowledge in ecosystem services management: The case of four rural communities in Northern Ghana," *International Journal of Biodiversity Science, Ecosystem Services & Management*, vol. 12, pp. 24-38, 2016. Available at: <https://doi.org/10.1080/21513732.2015.1124454>.
- [5] J. A. Widians, M. Wati, A. Tejawati, and E. Budiman, "Biodiversity Information system for management of medicinal plants data tropical rainforest Borneo," *International Journal of Engineering & Technology*, vol. 7, pp. 31-36, 2018. Available at: <http://dx.doi.org/10.14419/ijet.v7i4.44.26858>.
- [6] S. B. Adi, Z. I. NAVIA, T. HARMAWAN, and E. MUKHTAR, "Ethnobotany and conservation of indigenous edible fruit plants in South Aceh, Indonesia," *Biodiversitas Journal of Biological Diversity*, vol. 21, pp. Adi1850-1860, 2020. Available at: <https://doi.org/10.13057/biodiv/d210511>.
- [7] M. E. Siahaya, T. R. Hutauruk, H. S. Aponno, J. W. Hatulesila, and A. B. Mardhanie, "Traditional ecological knowledge on shifting cultivation and forest management in East Borneo, Indonesia," *International Journal of Biodiversity Science, Ecosystem Services & Management*, vol. 12, pp. 14-23, 2016. Available at: <https://doi.org/10.1080/21513732.2016.1169559>.
- [8] J. Parrotta, Y. Yeo-Chang, and L. D. Camacho, "Traditional knowledge for sustainable forest management and provision of ecosystem services," *International Journal of Biodiversity Science, Ecosystem Services & Management*, vol. 12, pp. 1-4, 2016. Available at: <https://doi.org/10.1080/21513732.2016.1169580>.
- [9] L. H. Iwamoto, D. B. Vendramini-Costa, P. A. Monteiro, A. L. T. G. Ruiz, I. M. d. O. Sousa, M. A. Foglio, J. E. de Carvalho, and R. A. F. Rodrigues, "Anticancer and anti-inflammatory activities of a standardized dichloromethane extract from Piper umbellatum L. leaves," *Evidence-Based Complementary and Alternative Medicine*, pp. 1-8, 2015. Available at: <https://doi.org/10.1155/2015/948737>.

- [10] S. A. M. Hayrol, N. Ahmad, S. F. Samsuddin, A. A. Samah, and M. E. Hamdan, "Systematic literature review on adaptation towards climate change impacts among indigenous people in the Asia Pacific regions," *Journal of cleaner production*, vol. 258, p. 120595, 2020. Available at: <https://doi.org/10.1016/j.jclepro.2020.120595>.
- [11] A. Chaveerach, R. Sudmoon, and T. Tanee, "Interdisciplinary researches for potential developments of drugs and natural products," *Asian Pacific Journal of Tropical Biomedicine*, vol. 7, pp. 378-384, 2017. Available at: <https://doi.org/10.1016/j.apjtb.2016.12.019>.
- [12] I. Darbyshire, S. Anderson, A. Asatryan, A. Byfield, M. Cheek, C. Clubbe, Z. Ghrabi, T. Harris, C. D. Heatubun, and J. Kalema, "Important Plant Areas: revised selection criteria for a global approach to plant conservation," *Biodiversity and Conservation*, vol. 26, pp. 1767-1800, 2017. Available at: <https://doi.org/10.1007/s10531-017-1336-6>.
- [13] A. M. Carvalho and A. M. Barata, *The consumption of wild edible plants. In: Ferreira, I.C.F.R., Morales, R., Barros, L. (Eds.), Wild Plants, Mushrooms and Nuts: Functional food properties and applications*. Chichester, UK: John Wiley & Sons, Ltd, 2017.
- [14] A. M. Abbasi, M. A. Khan, and M. Zafar, "Ethno-medicinal assessment of some selected wild edible fruits and vegetables of Lesser-Himalayas, Pakistan," *Pakistan Journal of Botany*, vol. 45, pp. 215-222, 2013.
- [15] A. K. Sayok and U. Teucher, "Loss of food plants knowledge and identity among indigenous peoples in Malaysia," *Journal of Advance Research in Social and Behavioural Sciences*, vol. 11, pp. 174-188, 2018.
- [16] F. A. Muhammad, M. Elias, H. Lamers, U. Shariah, P. Brooke, and H. Mohd Hafizul, "Evaluating the usefulness and ease of use of participatory tools for forestry and livelihoods research in Sarawak, Malaysia," *Forests, Trees and Livelihoods*, vol. 26, pp. 29-46, 2017. Available at: <https://doi.org/10.1080/14728028.2016.1246213>.
- [17] W. Jetz, M. A. McGeoch, R. Guralnick, S. Ferrier, J. Beck, M. J. Costello, M. Fernandez, G. N. Geller, P. Keil, and C. Merow, "Essential biodiversity variables for mapping and monitoring species populations," *Nature Ecology & Evolution*, vol. 3, pp. 539-551, 2019. Available at: <https://doi.org/10.1038/s41559-019-0826-1>.
- [18] M. R. Ramírez-Flores, S. Perez-Limon, M. Li, B. Barrales-Gamez, D. Albinsky, U. Paszkowski, V. Olalde-Portugal, and R. J. Sawers, "The genetic architecture of host response reveals the importance of arbuscular mycorrhizae to maize cultivation," *Elife*, vol. 9, p. e61701, 2020. Available at: <https://doi.org/10.7554/elife.61701>.
- [19] M. Malavasi, R. Santoro, M. Cutini, A. Acosta, and M. L. Carranza, "The impact of human pressure on landscape patterns and plant species richness in Mediterranean coastal dunes," *Plant Biosystems-an International Journal Dealing with All Aspects of Plant Biology*, vol. 150, pp. 73-82, 2016. Available at: <http://dx.doi.org/10.1080/11263504.2014.913730>
- [20] N. Helm, F. Essl, M. Mirtl, and T. Dirnböck, "Multiple environmental changes drive forest floor vegetation in a temperate mountain forest," *Ecology and Evolution*, vol. 7, pp. 2155-2168, 2017. Available at: <https://doi.org/10.1002/ece3.2801>.
- [21] R. Alan, R. Tunung, N. Saupi, and P. Lepun, "Wild pepper species consumed as green leafy vegetables among Orang Ulu groups in Asap-Koyan Belaga, Sarawak," *Food Research*, vol. 6, pp. 161-171, 2021.
- [22] N. K. Abram, E. Meijaard, M. Ancrenaz, R. K. Runting, J. A. Wells, D. Gaveau, A.-S. Pellier, and K. Mengersen, "Spatially explicit perceptions of ecosystem services and land cover change in forested regions of Borneo," *Ecosystem Services*, vol. 7, pp. 116-127, 2014. Available at: <https://doi.org/10.1016/j.ecoser.2013.11.004>.
- [23] C. Suwanphakdee, D. Simpson, T. Hodgkinson, and P. Chantaranonthai, "Typification of piper species (Piperaceae) in Southeast Asia, especially Thailand," *Kew bulletin*, vol. 73, pp. 1-18, 2018. Available at: <https://doi.org/10.1007/s12225-018-9761-6>.
- [24] N. Saupi, P. Lepun, R. Alan, M. H. Zakaria, A. A. Saidin, and N. A. Yusli, "Morphological characterization and nutrient assessment of wild pepper, *Piper umbellatum* L.(Piperaceae) grown in Sarawak, Malaysia," *Journal of Phytology*, vol. 13, pp. 055-063, 2021. Available at: <https://doi.org/10.25081/jp.2021.v13.6995>.

- [25] V. Van Stokkom, A. Blok, O. Van Kooten, C. de Graaf, and M. Stieger, "The role of smell, taste, flavour and texture cues in the identification of vegetables," *Appetite*, vol. 121, pp. 69-76, 2018. Available at: <https://doi.org/10.1016/j.appet.2017.10.039>.
- [26] E. Rabot, M. Wiesmeier, S. Schlüter, and H.-J. Vogel, "Soil structure as an indicator of soil functions: A review," *Geoderma*, vol. 314, pp. 122-137, 2018. Available at: <https://doi.org/10.1016/j.geoderma.2017.11.009>.
- [27] R. O. Gardner, "Piper (Piperaceae) in New Guinea: the non-climbing species," *Blumea-Biodiversity, Evolution and Biogeography of Plants*, vol. 48, pp. 47-68, 2003. Available at: <http://dx.doi.org/10.3767/000651903X686051>.
- [28] B. D. Clinton, "Light, temperature, and soil moisture responses to elevation, evergreen understory, and small canopy gaps in the southern Appalachians," *Forest Ecology and Management*, vol. 186, pp. 243-255, 2003. Available at: [http://dx.doi.org/10.1016/S0378-1127\(03\)00277-9](http://dx.doi.org/10.1016/S0378-1127(03)00277-9).
- [29] V. V. Ashapkin, L. I. Kutueva, N. I. Aleksandrushkina, and B. F. Vanyushin, "Epigenetic mechanisms of plant adaptation to biotic and abiotic stresses," *International Journal of Molecular Sciences*, vol. 21, p. 7457, 2020. Available at: <https://doi.org/10.3390/ijms21207457>.

Views and opinions expressed in this article are the views and opinions of the author(s), Journal of Asian Scientific Research shall not be responsible or answerable for any loss, damage or liability etc. caused in relation to/arising out of the use of the content.