PAPER NAME

Short Communication: Population structure and habitat characteristics of Goniothalamus macrophyllu

AUTHOR

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WORD COUNT

4858 Words

CHARACTER COUNT

26484 Characters

PAGE COUNT

6 Pages

FILE SIZE

486.2KB

SUBMISSION DATE

Mar 21, 2023 4:24 PM GMT+7

REPORT DATE

Mar 21, 2023 4:25 PM GMT+7

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BIODIVERSITAS
Volume 21, Number 3, March 2020
Pages: 1130-1135

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d210337

Short Communication: Population structure and habitat characteristics of *Goniothalamus macrophyllus* in Bukit Pembarisan forest, West Java, Indonesia

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Manuscript received: 14 January 2019. Revision accepted: 19 February 2020.

Abstract. *Adhya I, Widodo P, Kusmana C, Sudiana E, Widhiono I, Supartono T. 2020. Short Communication: Population structure and habitat characteristics of* Goniothalamus macrophyllus *in Bukit Pembarisan forest, West Java, Indonesia. Biodiversitas 21: 1130-1135.* *Goniothalamus macrophyllus* (Blume) Hook.f. & Thomson is a forest species with important medicinal value and widely used by many local communities. Excessive harvesting of this species has led to population decline and may lead to extinction. The aims of this research was to investigate population structure, habitat characteristics and environmental factors affecting local densities of *G. macrophyllus* in Bukit Pembarisan forest, Kuningan District, West Java, Indonesia. Purposive sampling was conducted at 17 locations from November 2017 to March 2018. The result showed that the population structure in the study area was dominated by seedlings (95% of the total number of individuals), followed by saplings (4%) and poles (0.1%). Seedlings, saplings, and poles were found growing across a wide elevational range (432-1,273 m asl.), at temperatures of 19-25°C, relative humidity of 80-90%, and soil pH of 4.61-6.46. The multiple regression analysis showed that soil nitrogen and soil pH affected seedling density, whereas soil clay content affected pole density. Our findings indicate that *G. macrophyllus* preferred acidic soils with high nitrogen and high clay content. We, therefore, recommend that future conservation efforts include the maintenance of existing poles, a prohibition on bark harvesting, and encouraging use of the leaves, rather than bark, for medicinal applications among consumers of *G. macrophyllus*.

Keywords: Plant conservation, population density, soil characteristics

INTRODUCTION

The genus *Goniothalamus* (Annonaceae family) comprises 50-130 species distributed from Southeast Asia and Malaysia to the northern tropical regions of Australia (Jessup 1986; Saunders 2003; Nakkhuntod et al 2009; Tang et al 2013). Goniothalamus spread in lowland forests and sub-tropical Southeast Asia: western Malesia, Kalimantan (Mat-Salleh 2001; Turner and Saunders 2008), Sumatra (Saunders 2002), Peninsular Malaysia/ Thailand, south of Isthmus of Kra (Saunders 2003; Saunders and Chalermglin 2008), and southern India and Sri Langka (Huber 1985: Mitra 1997). Of these, *Goniothalamus macrophyllus* (Blume) Hook.f. & Thomson is a shrub or a small tree up to 8 m in height. In Southeast Asia, *G. macrophyllus* is primarily distributed in peninsular Thailand and Malaysia, as well as Borneo, Sumatra, and Java in Indonesia. Its habitat is primary and secondary dry or wet disturbed forests with loamy clay or sandy soils over granite, and it is found at elevations of 0-1300 m. *G. macrophyllus* is the most widespread species of the genus and is characterized by a medium-sized stem and tapered leaf tips. The leaves are 40-55 cm in length and 7-15 cm in width and are highly aromatic, as are the stems. This species is used widely by humans for medicinal purposes. Applications include the use of its leaves as a natural insecticide (van Valkenburg and Bunyapraphatsara 2002), Alabsi, et al. (2013) suggested that the natural extract of *G. macrophyllus* has anti-cancer properties against tumor cells, and an antidote for snake bites in the Serampas area of Jambi, Indonesia (Hariyadi and Ticktin 2012). Traditional healers in Patthalung Province, Thailand, use this species to treat flatulence, general fatigue, and body pain (Maneenoon et al. 2015). It is also used for anti-aging purposes (Ong et al. 2012) and as a treatment for typhoid fever (Setyowati and Wardah 2010). Pounded leaves and bark are used to treat skin complaints (Chong et al. 2012), and essential oil produced from the twigs and roots has shown strong antimicrobial properties against intermediately vancomycin-resistant *Staphylococcus aureus*, *Staphylococcus epidermidis*, and *Candida albicans* (Humeirah et al. 2010).

Balunas and Kinghorn (2005) reported that the increases in the medicinal uses of this species have increased its risk of extirpation or extinction in the wild. Many medicinal plant species are threatened with extinction from overharvesting and habitat destruction, and 20% of wild medicinal plant resources have already been lost due to overconsumption and anthropogenic activities (Zerabruk and Yirga 2012). Intrinsic biological factors and habitat loss are the major causes of plant endangerment in Indonesia, followed by overexploitation and natural factors (Budiharta et al. 2011). Raw materials have been harvested from *G. macrophyllus* for centuries by many indigenous groups, in particular, its bark is highly valued due to its chemical composition and unusual structure. However, the process of harvesting the bark can cause tree death, leading to population decline.

Natural regeneration of tree species is crucial to maintain its population and forest stand composition over space and time (Henle et al. 2004). Forest managers and ecologists must understand the processes driving forest species regeneration (Slik et al. 2003) because floristic and structural compositions vary among communities and intra- or inter-species competition may relate to changes in regeneration opportunity for a given species (Barker and Kirkpatrick 1994). Studies of the population dynamics of tree seedlings in different forest stands have demonstrated that growth and survival are influenced by a variety of microclimatic and edaphic factors (Scholl and Taylor 2006).

Several regional taxonomic studies of Goniothalamus have been published for western Malesia, include-ing Peninsular Malaysia (Sinclair 1955), Java (Backer and Bakhuizen van den Brink 1963), and Borneo (Mat-Salleh 2001), and within the Gunung Lumut Protected Forest of East Kalimantan (Slik et al. 2007). Research has been conducted to reveal the growth rates of seedlings, saplings, and poles of this species in the Masigit Mountain Kareumbi Forest, Sumedang District, West Java (Suwandhi 2009). We expand this existing knowledge by investigating population structure of the species, habitat preference, and environmental factors that influence local density of *G. macrophyllus* in Bukit Pembarisan forest, Kuningan District, West Java. The results of this study can serve as baseline information in developing conservation approaches.

MATERIALS AND METHODS

Study period and area

This research was conducted from September 2017 to March 2018 in specially protected forest Bukit Pembarisan in Kuningan District, West Java, Indonesia (Figure 1). The forest is located at 108°23′-108°47′E, 6°47′-7°12′S and includes nine villages: Pinara, Gunung Manik, Subang, Bagawat, Jatisari, Legokherang, Bungurberes, Mandapajaya, and Jabranti. The study area has type B and C climates (Schmidt and Ferguson 1952) with an average rainfall of 2,000-4,000 mm/year. During the study period, monthly average temperatures ranged from 18°C to 22°C.

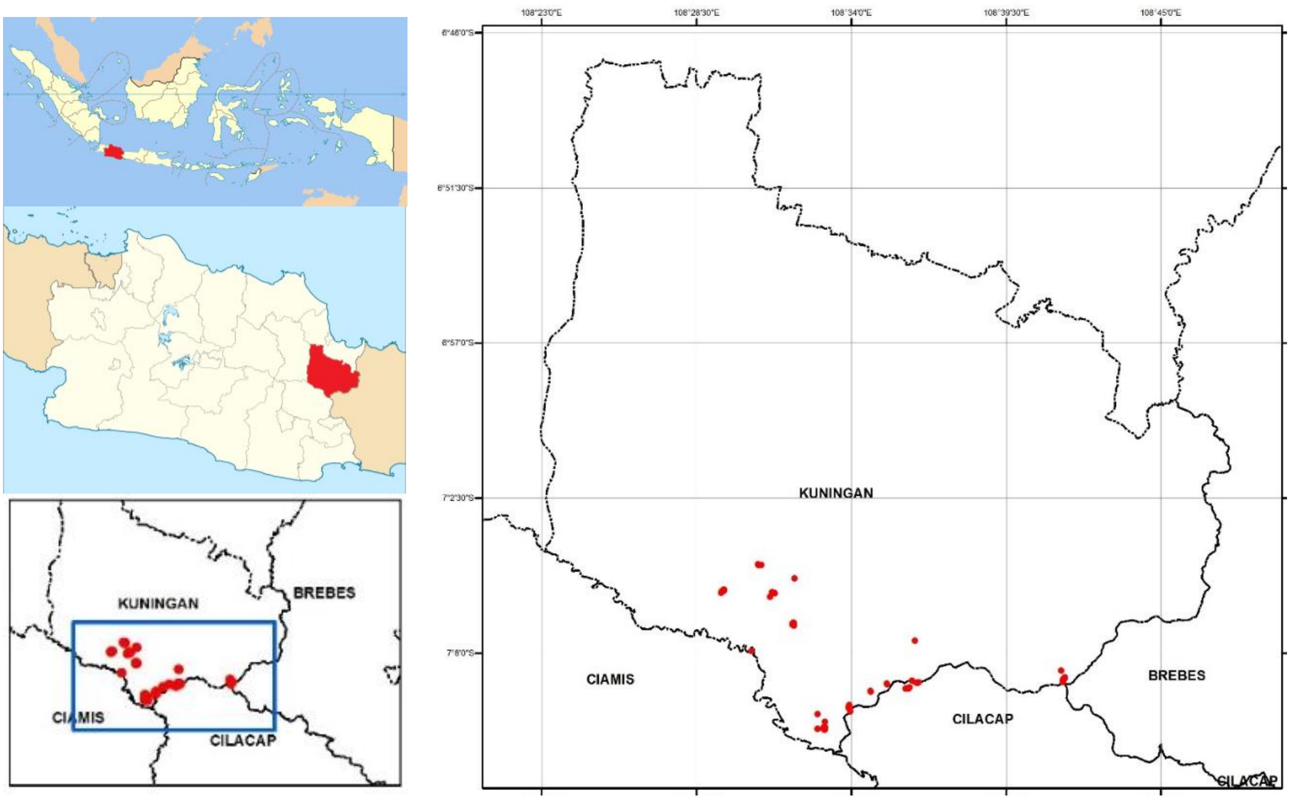


Figure 1. Study area and seventeen sampling sites of *Goniothalamus macrophyllus* in Bukit Pembarisan, Kuningan District, West Java, Indonesia

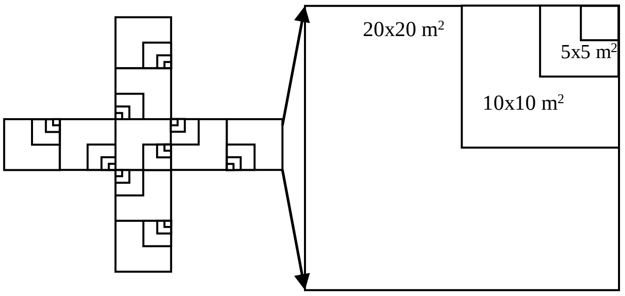


Figure 2. Nested survey plots used to assess *G. macrophyllus* at different growth stages

Sampling procedure

Sampling was conducted at seventeen sites based on the occurrence of *G. macrophyllus* found during the preliminary survey. These sites have altitudes ranging from 432 m asl to 1273 m asl. At each sampling location, nine plots were established, totaling 153 plots across the studied areas. Survey locations were determined using a purposive sampling method and conducted using the distance sampling technique (Burnham et al. 1980). Population structure of *G. macrophyllus* and soil data were taken using nested sample plot. Nine nested sample plots of varying sizes were established around *G. macrophyllus* populations to record individuals at varying growth stages (Kusmana 1997). Plot sizes included 2 × 2 m^2 plots for seedlings (< 1.5 m in height), 5 × 5 m^2 plots for saplings (> 1.5 m in height and < 10 cm in diameter), 10 × 10 m^2 plots for poles (10-19 cm in diameter), and 20 × 20 m^2 plots for trees (> 20 cm in diameter) (Figure 2). The number of individuals of each growth stage at each plot was recorded. Elevation was determined at each site.

Plant identification was done at the Herbarium Bogoriense, Indonesian Institute of Sciences in Bogor, Indonesia. Soil samples were taken from plots at 0–30 cm and 30–45 cm depths using a ground drill. Samples were then composited for each depth and analyzed at the Balitro Bogor Laboratory for physical characteristics (soil texture) and chemical properties (pH, organic carbon [OC], carbon: nitrogen ratio [C/N], total nitrogen (TN), phosphorus [P], potassium [K], calcium [Ca], and magnesium [Mg]).

Data analysis

Data were analyzed using multiple linear regression with a stepwise approach with population density as response variable and environmental factors as predictor variables. Plot data of seedling, sapling, and pole counts were assessed using the following formula (Kusmana 1997):

$$K = \frac{\text{the number of type i tree (s)}}{\text{plot size (ha)}}$$

Where, K is the density of growth stage *i* (seedling, sapling, and pole).

RESULTS AND DISCUSSION

Population structure of *Goniothalamus macrophyllus*

We encountered 46,279 individuals of *G. macrophyllus* across all sampling sites. However, most individuals were seedlings (44,168, equal to 94% of the total population), while saplings accounted for only 4% and poles accounted for only 0,1% (Figure 3), another study in New Medonia found population of *G. dumontetii* is 250 individuals, with a density of 1 individual per 200 m square (Saunder and Munzinger 2007). Other studies have also demonstrated that seedlings are the most common growth stage relative to saplings, poles, and trees for *G. macrophyllus* (Fathia 2016), and this age structure pattern in common in plants. Also, it is important to note the very low proportion of poles relative to seedlings and saplings in which among all sampling sites, poles were only detected at two locations, one at 997 m in elevation and the other at 1,175 m (Table 1). This was likely the result of limiting environmental factors. Laughlin and Clarkson (2018) suggested that death at the seedling stage is likely related to canopy cover.

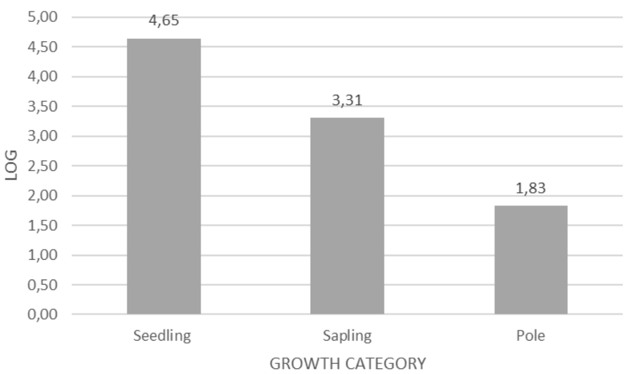
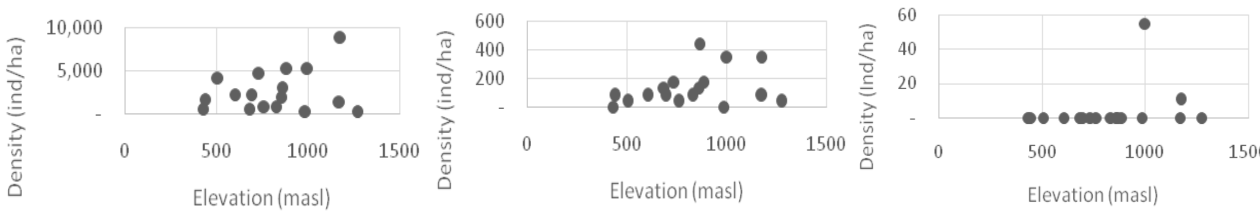


Figure 3. Population of *Goniothalamus macrophyllus* based on growth category



A B C

Figure 4. *Goniothalamus macrophyllus* densities among growth classes along an elevational gradient. A. Seedling, B. Sapling, C. Pole

Goniothalamus macrophyllus population was observed at sites 432–1,273 m in elevation within the study area. This is consistent with the findings of Saunder and Munzinger (2007), who reported population of *G. dumontetii* grows in a level area 500 m, in humid forest over ultramafic soil in New Caledonia. Other studies have also documented this species in low elevation forests (<200 m) (Fiqa et al. 2019; Susiarti et al. 2018). In terms of forest type, *G. macrophyllus* has been reported found in primary and secondary forests in Jambi (Hariyadi and Ticktin 2012). Moreover, Purnomo et al. (2015) found seedlings of *G. macrophyllus* growing in burnt forest areas in East Kalimantan. Based on these results, it can be indicated that *G. macrophyllus* inhabits primary and secondary lowland forests.

Among all sites, the highest density of seedlings was found at 1,175 m in elevation (8,889 individuals [ind]/ha), whereas the highest densities of saplings and poles were found at 864 m (444 ind/ha) and 997 m (56 ind/ha), respectively. The lowest seedling density was observed at 1,273 m (278 ind/ha), and the lowest sapling and pole densities at 506–1,273 m (44 ind/ha) and 1,175 m (11 ind/ha), respectively (Table 1). During the sampling there was no tree stage were found in any sampling locations, however, the observed high densities of seedlings and saplings indicate that the lowland forest of the study site is suitable habitat for the species. The densities of poles and trees were low relative to other studies, but were high in terms of saplings and seedlings. Prasaja (2016) reported the densities of poles and trees of *G. macrophyllus* in Bukit Duabelas Jambi National Park, Indonesia with 215 ind/ha and 5 ind/ha, respectively, while Handayani (2010) reported densities of 1 ind/5 ha, 7 ind/5 ha, and 2 ind/5 ha for seedlings, saplings, and poles, respectively. Elevation affected sapling density ($\lambda 2 = 25.903$, $p = 0.055$), but not pole ($\lambda 2 = 44.310$, $p = 0.000$) or seedling ($f = 0.004$, $p = 1$) density. However, we note that poles were only encountered at two locations.

Habitat characteristics of *Goniothalamus macrophyllus*

Temperature and humidity may strongly affect *G. macrophyllus* growth. *G. macrophyllus* occurred at temperatures of 19-25°C and relative humidity of 80-90%. These values are comparable to those reported by Hanum (1999), who found *G. macrophyllus* in areas with 87.6-97.8% humidity in Ayam Hutan Forest, and by Prasaja (2016), who reported humidity of 80-94% at *G. macrophyllus* locations in Bukit Duabelas Jambi National Park. Lestari and Sulistyadi (2015) reported that *G. macrophyllus* was found in areas with temperatures of 22.5-33°C. In addition, this species is grown at the Bogor Botanical Gardens at temperatures of 25-39°C and humidity of 34-80% (Handayani 2010). Table 2 describes the physical and chemical soil properties at *G. macrophyllus* sites.

Broadly, the results of the soil analysis suggested that this species prefers soils that are relatively acidic, with moderate to high OC, moderate TN, a low to moderate C/N, very low P_2O_5, high to very high Ca, and high Mg and K. Preferred soil textures appear to be sandy loams to sandy clay loams in which in accordance to Hanum (1999) who also reported *G. macrophyllus* growing on sandy clay loams in peninsular Malaysia. In summary, this species appears to grow in slightly acidic soils with sufficient macro- and micro-nutrient concentrations, which are common requirements by most plants for survival. The balance of nitrogen and phosphorus in plant tissues is of particular interest because this elementsplay a pivotal role in many aspects of plant biology and their availability frequently limits plant growth (Vitousek 1982; Chapin et al 1986; Gu Sewell 2004), P is important for strengthening stems and increasing disease resistance (Hardjowigeno 2007), and Mg is important for chlorophyll formation (Hardjowigeno 2007).

Relationship between environmental factors and *Goniothalamus macrophyllus* density

The results of multiple linear regression using a stepwise approach indicated that pole density was affected by soil clay content at the 0-30 cm soil depth ($t = 2.40$, $p = 0.03$, $R^2 = 0.278$), as well as by the clay content at the 30-45 cm soil depth ($t = 2.578$ $p = 0.021$). These results indicate that *G. macrophyllus* likely grows best in soils with a dominant clay content. Soil structure influences plant growth with regard to root distribution and the ability of the soil to absorb water and nutrient (Rampazzo, *et al*., 1998; Pardo, *et al*. 2000). Sandy soil surface disturbances resulted greatly decreased soil resistance to wind erosion (Zhang et al 2006), researchers are studying the role of microbiotic crusts on the structural stability of sandy soils (Belnap and Gardner, 1993; Verrecchia et al.,1995; Issa et al. 2001; Li et al. 2002). Hardjowigeno (2007) also emphasized that sandy soils tend to have lower nutrient concentrations than clay soils.

At a soil depth of 30-45 cm, seedling density was affected by TN ($t = 4.28$, $p = 0.01$) and pH ($t = 3.138$, $p = 0.07$). These results suggest that seedlings may perform best in soils with a high N concentration and neutral pH. N is a critical nutrient for plants and a deficiency in this element can limit plant growth and lead to plant death (Hardjowigeno 2007). Nitrogen fertilizer application to cereal has achieved large increases in yields (Raun and Johnson 1999). Therefore adequate N is critical for normal plant growth (Wang et al. 2007; Homer 2008). Boussadia et al. (2010) reported that nitrogen deficiency in olive plants led to a reduction of leaf chlorophyll content and the rate of photosynthesis. Soil pH affects nutrient absorption by plants in which nutrients are more easily absorbed in soils with neutral pH (Hardjowigeno 2007).

In conclusion, *G. macrophyllus* appears to grow in habitats with average temperatures of 19-25°C and high humidity (80-90%), in soils that are slightly acidic, have high to very high Ca, Mg, and K concentrations, low P concentrations, a low C/N, moderate N concentration, and a sandy clay loam texture.

Table 2. Physical and chemical soil properties at two soil depths at *Goniothalamus macrophyllus* sampling locations

Parameter	Soil depth					
	0-30 cm			30-45 cm		
	Range	Mean	Description	Range	Mean	Description
pH	4.61-6.28	5.57	Slightly acidic	4.62-6.46	5.63	Slightly acidic
OC (%)	0.23-8.84	4.07	High	0.20-6.00	2.39	Moderate
TN (%)	0.09-0.80	0.39	Moderate	0.05-0.68	0.25	Moderate
C/N	0.96-15.63	9.58	Low	1.33-46.40	11.24	Moderate
P_2O_5 (mg/100 g)	2.93-11.68	4.29	Very low	2.69-13.94	4.05	Very low
Ca (Cmol(+)/Kg)	1.43-34.22	20.35	Very high	0.60-34.92	16.79	High
Mg (Cmol(+)/Kg)	0.65-11.57	5.84	High	1.18-10.47	5.72	High
K (Cmol(+)/Kg)	0.07-3.13	0.95	High	0.13-2.61	0.68	High
Sand (%)	37.20-80.08	60.74	Sandy loam	17.14-74.71	54.96	Sandy clay loam
Dust (%)	0.00-35.15	11.60		0.00-42.65	16.93	
Clay (%)	14.94-48.98	27.68		15.38-48.23	28.60	

Note: OC: Organic Carbon, TN: Total Nitrogen, C/N: Carbon Nitrogen ratio

Conservation implications

When considering conservation efforts for this species, it is important to give attention to the survival and growth of poles such that they can develop and produce seeds to ensure the sustainability of local populations. Silvertown et al (2006) suggested that high densities of a plant species within a habitat indicate suitable environmental conditions for that species. Various studies in tropical forests have related differences in tree densities to environmental variables such as light intensity (Yamada 2006), topography (Sri-Ngernyuang 2003), edaphic factors (Palmiotto 2006), or a combination of these factors (Davies et al. 2004). Our study indicated that seedling density was affected by TN and pH, and pole density was affected by soil clay content. Our recommendations for future conservation efforts, based on these findings, include the maintenance of existing poles, a prohibition on bark harvesting, and encouraging use of the leaves, rather than bark, for medicinal applications among consumers of *G. macrophyllus*.

ACKNOWLEDGEMENTS

We express our gratitude to the Faculty of Biology at General Sudirman University, Purwokerto, banyumas, Indonesia, the Faculty of Forestry at the Kuningan University, Indonesia the Balitro Soil Laboratory, the Ministry of Agriculture of the Republic of Indonesia in Bogor, Indonesia and Perum Perhutani Regional Division III of West Java and Banten. We also convey our gratitude to Yayan Hendrayana, Agus Yadi Ismail, Alif, and many friends that have been steadfast in surveying and data collection.

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