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Ecological Study of Citrus Plants (*Citrus* SPP.) in The Gunung Leuser National Park Area Southeast Aceh

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Abstract

Citrus is one of the strategic horticultural commodities with high economic and genetic value, yet its ecological basis in natural habitats remains understudied, particularly in conservation areas. This study aimed to assess the ecological conditions of wild-growing citrus plants (*Citrus* spp.) in the Gunung Leuser National Park (TNGL). A descriptive exploratory method was employed, combining field surveys with direct observations and quantitative measurements of environmental variables, including air and soil temperature, humidity, light intensity, rainfall, and elevation. The results indicate that citrus plants can grow at air temperatures of 18–31.6 °C, soil temperatures of 22–23 °C, air humidity of 79.4–80.3%, light intensity of 27.6–2871 lux, annual rainfall of 2,500–4,000 mm, and altitudes of 350–400 m above sea level. These conditions reflect a humid tropical ecosystem favorable for wild citrus growth. The findings demonstrate the citrus plant's adaptability to shaded, moist environments, and its potential as a source of valuable local germplasm. This study provides a scientific basis for the conservation, management, and further development of adaptive citrus varieties suited to tropical forest conditions.

Keywords: Adaptive, Forest, Germplasm, Microclimate, TNGL

1. Introduction

Citrus plants (*Citrus* spp.) are one of the most strategically important groups of horticultural plants, both economically and ecologically. In addition to being consumed as a fruit rich in vitamins and nutrients, citrus also plays a crucial role as a source of genetic material in plant breeding activities. Wild citrus species growing in the wild harbor significant genetic diversity, which can be utilized to develop superior varieties that are more adaptive to climate change, resistant to diseases, and have high productivity (Volk *et al*., 2023).

Previous studies have also shown that the genetic diversity of wild citrus is crucial to the plant's ability to adapt to abiotic and biotic stresses, making its conservation a strategic step in the management of horticultural genetic resources (McCouch *et al*., 2014). Therefore, the conservation of wild citrus should be a top priority to ensure the sustainable use of citrus plant genetic resources in the future.

Several citrus species are known to have natural distributions in tropical and subtropical regions, including in conservation areas such as Gunung Leuser National Park (TNGL). TNGL is one of the largest and oldest conservation areas in Indonesia, known as a habitat for various endemic and rare species. This area is not only important in terms of fauna but also harbors high floral biodiversity, including wild citrus groups that have not been extensively studied scientifically (Wu *et al*., 2021). With its diverse ecosystems, ranging from lowlands to mountainous areas, TNGL provides complex ecological conditions that allow citrus species to grow and adapt naturally to environmental variations. Conservation studies indicate that tropical forest habitats like TNGL have great potential in protecting the genetic diversity of plants that are strategically valuable for future agriculture and plant breeding (Volk *et al*., 2023).

The ecological diversity of Gunung Leuser National Park (TNGL), such as variations in temperature, humidity, light intensity, rainfall, and altitude, are important factors influencing the growth and distribution of wild citrus species (*Citrus* spp). The complex interaction between abiotic and biotic factors in this area creates a unique

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habitat that supports the natural survival of various citrus varieties. Research on these ecological parameters is crucial for understanding the habitat preferences and adaptive capacity of citrus in their natural environment (Vincent *et al*., 2020). These findings are not only beneficial for in situ conservation strategies but also provide a scientific basis for developing more adaptive local citrus cultivation practices tailored to the specific conditions of a particular region (Volk *et al*., 2023).

Although Gunung Leuser National Park (TNGL) has significant potential as a natural habitat for citrus plants (*Citrus* spp), documented scientific information on the ecological aspects and habitat characteristics of this species is still very limited. The lack of specific data on environmental parameters such as temperature, humidity, light intensity, and elevation that support the growth of wild citrus creates a significant knowledge gap. This makes it difficult to develop evidence-based conservation and domestication strategies (Curk *et al*., 2022; Malik *et al*., 2013; Roose *et al*., 2015). However, a comprehensive understanding of the relationship between ecological conditions and the adaptation of citrus plants in their natural habitat is crucial to ensuring the sustainability of conservation and the sustainable use of local genetic resources.

Previous studies have discussed the vegetation ecology of TNGL in general. Reported high plant diversity in this area, with dominance of species from the families Dipterocarpaceae, Myrtaceae, and Achariaceae (Susilowati *et al*., 2020). In that study, 693 trees were recorded in a 0.5-hectare observation plot, indicating low disturbance levels and the presence of large trees, suggesting relatively stable forest conditions. Highlighted the vegetation structure and floristic composition of trees, particularly Scaphium macropodum, and identified the negative impacts of illegal activities on the forest ecosystem (Susanti *et al*., 2021). Both studies emphasize the importance of ecological understanding in conservation efforts, but have not specifically examined the relationship between microenvironmental parameters and the growth of wild horticultural species such as citrus. Therefore, this study aims to address this gap by directly examining the ecological parameters influencing the growth of wild citrus in TNGL as a basis for the management and conservation of local genetic resources.

2. Material and Methods

This study was conducted in the Gunung Leuser National Park (TNGL) at coordinates $3^{O}40'59"$N $97^{O}38'50"$E. The location was chosen based on the natural presence of citrus plants (*Citrus* spp.) in previous studies (Assauwab *et al*., 2025) and the accessibility of the area. This study was conducted from May 5, 2025, to June 3, 2025, using an exploratory descriptive approach.

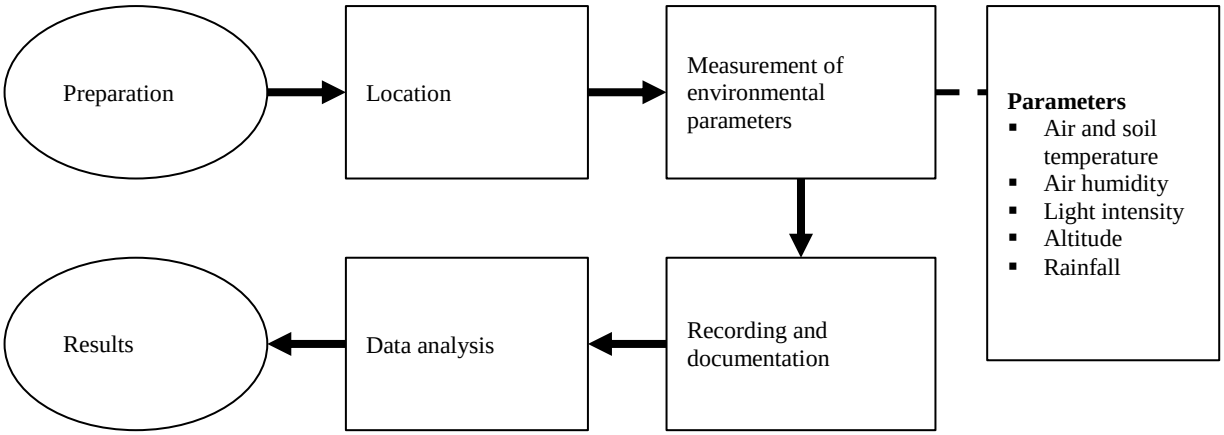

Figure 1. Research flow diagram

Data were collected through direct observation of habitat conditions and morphological characteristics of citrus trees, as well as measurement of environmental parameters. The parameters measured included air and soil temperature, air humidity (BLUR-Intelligent Soil Detector), light intensity (HABOTEST HT603), altitude (Garmin GPSMAP 64S), and rainfall (secondary data from the local BMKG). Measurements were taken at several points around the citrus trees found, in the morning and afternoon. All data were analyzed descriptively by presenting minimum, maximum, and average values to describe the ecological conditions of the citrus habitat.

3. Results and Discussion

3.1. Temperature

Observations show that citrus plants (*Citrus* spp.) are found growing naturally at several points in Gunung Leuser National Park (TNGL), particularly in locations with relatively stable and supportive environmental characteristics. The air temperature at the observation site ranges from 18°C to 31.6°C, while the soil temperature tends to be more constant, ranging from 22°C to 23°C.

The observed temperature range is considered optimal for supporting citrus plant growth, as it falls within the

range that supports important physiological processes such as photosynthesis, respiration, and enzymatic activity within plant tissues. Previous studies have shown that temperatures between 20–30°C are the ideal range for citrus growth, as temperatures that are too low or too high can inhibit metabolic activity and reduce plant productivity (Bueno *et al*., 2012; Curk *et al*., 2022; R. V. Ribeiro *et al*., 2012).

Table 1. Ecological Parameters of Citrus (*Citrus* spp.) Plant Habitats in the GLNP Area

Ecological Parameters	Values	
	Minimum	Maximum
Air Temperature (day and night)	18,0 °C	31,6 °C
Soil Temperature (day)	22,0 °C	23,0 °C
Air Humidity	79,4 %	80,3 %
Light Intensity	27,6 Lux	2.871 Lux
Annual Rainfall	2.500 mm/ year	4.000 mm/ year
Elevation	350 masl	400 masl

Additionally, relatively stable soil temperatures play a crucial role in maintaining optimal root system activity, particularly in water and nutrient uptake. The stability of air and soil temperatures is a key ecological factor enabling oranges to grow and adapt naturally in conservation areas such as Gunung Leuser National Park (Volk *et al*., 2023).

3.2. Humidity

The air humidity at the observation site ranged from 79.4% to 80.3%, reflecting the typical microclimate of a humid and stable tropical rainforest. This high humidity plays an important role in maintaining the physiological balance of plants, particularly in maintaining the turgor pressure of cells necessary for the growth of young tissues such as leaves and shoots. Additionally, humid conditions can reduce excessive transpiration rates, allowing plants to allocate energy more efficiently for the formation of reproductive organs like flowers and fruits. For citrus plants, a high-humidity environment strongly supports photosynthesis, respiration, and other metabolic processes (Nazari & Karyadi, 2024; Jifon & Syvertsen, 2003). Such humidity stability is one of the primary ecological factors enabling wild citrus to grow and adapt optimally in the Gunung Leuser National Park area (Volk *et al*., 2023).

For citrus plants, high humidity greatly supports photosynthesis and other metabolic activities, and helps maintain cell turgor pressure, keeping the plants fresh and actively photosynthesizing despite daily temperature fluctuations. This condition is particularly important in both open and protected environments, where changes in daytime and nighttime temperatures can affect the physiological stability of plants. Environments with relatively consistent humidity, such as those found in the Gunung Leuser National Park area, are a key supporting factor in the growth and adaptation of wild oranges (Jifon & Syvertsen, 2003; Volk *et al*., 2023).

3.3. Light Intensity

The light intensity at the observation site showed a very wide variation, ranging from 27.6 to 2,871 lux. This range reflects differences in canopy openness in wild orange habitats, from shaded areas to areas receiving moderate light exposure. This range indicates that wild oranges in the TNGL area have the ability to adapt to low light conditions, which is a common characteristic of tropical rainforests. The ability of citrus plants to continue photosynthesis under limited light conditions demonstrates tolerance to shade and is an important adaptive strategy for maintaining growth and physiological processes in low-light environments (Ribeiro & Machado, 2007; Wang *et al*., 2020). This adaptation is one of the reasons why wild citrus is worthy of conservation as valuable genetic resources in horticultural plant conservation and breeding programs.

Figure 2. Microecology of Wild Orange Growth Sites in TNGL

3.4. Rainfall

Annual rainfall in the study area ranges from 2,500 to 4,000 mm, reflecting a tropical rainforest climate with relatively even rainfall distribution throughout the year. These conditions provide sufficient water supply for citrus plants, both to support physiological processes such as photosynthesis, respiration, and fruit formation, and to support optimal vegetative growth. Rainfall stability also contributes to consistent soil moisture and supports soil microorganism activity, which is important for nutrient cycling and plant health (Nugraha *et al*., 2024; Santos *et al*., 2012). For wild citrus species, high rainfall is an important ecological factor that allows them to survive in natural habitats with low drought risk. The abundance of water also enhances the adaptive potential of wild citrus to wet tropical forest environments such as those found in Gunung Leuser National Park (Volk *et al*., 2023).

3.5. Elevation

The elevation of the observation site, between 350 and 400 meters above sea level (masl), falls within the humid tropical lowland zone. This zone is known as an ideal natural habitat for various citrus species, especially those originating from Southeast Asia, which tend to adapt to environments with high rainfall, warm temperatures, and high humidity. At this elevation, air temperatures are relatively stable and support plant metabolic activities such as photosynthesis and nutrient absorption. Soil in tropical lowlands generally also has a high organic matter content due to forest vegetation decomposition, making it rich in essential nutrients for plants (Islam *et al*., 2020). The suitability of these elevation factors reinforces that wild citrus in TNGL grows under conditions close to its ecological preferences, making it an important source for conservation and breeding programs of local varieties adapted to tropical environments (Volk *et al*., 2023).

Overall, the data indicate that Citrus spp. in TNGL can adapt well to humid, shaded, and high rainfall ecological conditions. Their presence in this conservation area also underscores the importance of TNGL as a natural habitat for tropical plant genetic diversity, including local citrus species with potential as superior seed sources and stress-tolerant varieties.

4. Conclusion

Citrus plants (*Citrus* spp.) grow naturally in the Gunung Leuser National Park area at an air temperature range of 18–31.6°C, soil temperature of 22–23°C, air humidity of 79.4–80.3%, light intensity of 27.6–2871 lux, rainfall of 2,500–4, 000 mm/year, and an elevation of 350–400 m above sea level. These conditions reflect the ideal humid tropical habitat for the growth of wild citrus. The morphological variations found indicate significant genetic diversity that is important for the conservation and utilization of local germplasm. As a follow-up, genetic identification is needed to strengthen the conservation and sustainable utilization of endemic citrus species.

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