GROWTH RATE OF RED JABON AND TEAK TREES FROM PLANTATION FOREST

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ABSTRACT

*Red jabon (*Anthocephallus macrophyllus *Roxb. Havil) and teak (*Tectona grandis *Linn. f) is fast- and slow-growing tree species that are widely planted in Indonesia. Both species have high adaptability to grow in various types of soils. The development of red jabon and teak plantation forests and the utilization of their wood produced require knowledge of their growth rates. The information on the growth rate is important because it is closely related to forest sustainability. Climatic elements such as rainfall, rainy day, temperature, humidity, and duration of irradiation are important factors in tree growth. The purpose of this study was to study the growth rate i.e. the annual increment of red jabon and teak trees and their relationship with climatic elements. Observations were made for one year, namely 2021. This study used descriptive analysis to describe the growth rate; while Pearson's correlation was used to evaluate the relationship between the growth rate and climate elements. The results showed that the diameter increment of the red jabon tree per year was 2.21 cm, while for teak was 0.34 cm per year. A significant relationship between the growth rate of the jabon tree and climatic elements can be seen in rainfall, rainy days, and humidity; while temperature and duration of irradiation did not have a significant correlation. In teak trees, a significant relationship was seen only on a rainy day and humidity; while rainfall, temperature and irradiation time are not significantly correlated.*

Keywords: climatic elements, growth rate, Pearson's correlation, red jabon, teak

INTRODUCTION

Red jabon *(Anthocephallus macrophyllus* Roxb. Havil*)* and teak *(Tectona grandis* Linn. f*)* are woody plants representing a fast- and a slow-growing tree species, respectively. These two species have high adaptability to grow in various types of soils. In Indonesia, jabon from natural- and plantation forest areas consists of red- (*A. macrophyllus*) and white (*A. cadamba*) jabon [1] [2]. Both jabon are currently starting to be glimpsed by the community and wood industry players because they grow fast, i.e. within 5 years the tree trunk can reach 25–30 cm in diameter; while the conventional teak only reaches 2–4 cm for the same period. Although it grows slowly, the demand for such kind of teak wood tends to increase because it is a strong, decorative, stable, and durable period [3][4].

The need for wood as a raw material for various timber industries in Indonesia continues to increase every year. Therefore, it is not surprising that plantation forest development activities are increasingly carried out. The development of plantation forests and the utilization of their wood produced require knowledge of growth rate. The growth rate is important to know because it is closely related to forest sustainability. The growth rate of tropical trees is usually measured by changes in dimensions, based on trunk circumference or diameter [5]. Diameter is one of the tree dimensions that is most often used as a growth parameter. Diameter is often used to predict growth rates [6]. Growth is a biological phenomenon in the form of increasing dimensions per unit of time. Growth involves the activity, development, and differentiation of cells, tissues, or organs [7]. Growth is heavily influenced by factors where it grows, such as stand density, age, climatic elements (temperature, precipitation, wind speed, and humidity), and soil (physical properties, chemical composition, and soil microbiological components) [8]. Environmental changes will change the rate of growth of trees and forests. Growing trees and forests respond to environmental changes in multiple ways simultaneously, for example, by changes in radial increment, growth height, and stand density [9]. Tree growth is part of the equation for the carbon stored in forests or available for use as a carbon biomass fuel or for substitution of concrete and steel [10]. The future evolution of forest biomass is highly dependent on the response to tree longevity and growth rates [11]. Different stand densities will affect the growth of each tree species over time [6]. The growth pattern throughout the generations is typically characterized by a growth function called the sigmoid curve (shape like the letter S) which consists of 4 phases, namely an exponential phase, an increasing linear phase, a decreasing linear phase, and a steady phase (physiological maturation). To reduce bias, it can be used to calculate the growth rate using the average annual increment [12].

Climatic is one of the important factors that determine plant growth [13] . With accumulated evidence of climatic change and its potential effects, forest management efforts will benefit from integrating climatic mitigation and adaptation options in conservation and management plans [14][15]. Climatic factors will determine the variety of forest plants, which are also related to atmospheric conditions determined by sunlight, temperature, wind, and humidity. A shift towards unfavourable conditions for juvenile regeneration and growth could alter the composition and resilience of forests and future activities. The relationship between growth and climate differs according to life stage and location [16] [17] . The implications of climatic change for tree growth are not limited to specific locations but can reach global changes in the carbon cycle. At the local scale, trees and forest stands have a marked influence on climate, so it is possible to determine the microclimatic. This effect depends on local climatic characteristics and stands type. All climatic parameters must be considered especially temperature, light, and water. Considering the interaction of forest cover (climatic and species' ecophysiological potential) is the basis for sustainable forest management [18] [19] . Understanding how trees respond to climatic conditions is critical for evaluating, modelling, and predicting the functioning of forest ecosystems against current and future climatic variability [20][21].

Banggai Regency is a location where many woody plants including red jabon and teak are planted and grow in the same location in plantation forests. The location of the plantation forest is approximately 20 km from the city centre. Like other areas in Indonesia, Banggai plantation forests are also affected by global warming. So many impacts are caused by global warming, including climatic change. Climatic change is caused by human behaviour that is not environmentally friendly, namely humans who continuously use fossil fuels such as coal, oil, and natural gas. Climatic change is characterized by changes in the rhythm, intensity, and frequency of rainfall. In addition, high forest degradation is one of the causes [22]. This change had a significant impact on the world forests and the forestry sector [23]. Forests are a gift that can be a solution to climatic change because forests can absorb carbon dioxide from the atmosphere. If forests are continuously degraded, it will increase the amount of carbon in the atmosphere which in turn causes climatic change. Indonesia as a tropical country has a wealth of forest resources that are very diverse with various types of local native plants that need to be protected and preserved. Forests throughout Indonesia have a major influence on the wheels of life, both from the ecological, social, and economic aspects. Well-managed forests have the potential for timber and energy production [24].

Up-to-date information on the growth rate of trees in the era of global warming and its relationship to climate is an important part of disseminating the latest information in the field of forestry and the environment. Based on this, this paper study discusses the growth rate or the increment of red jabon and teak trees and their relationship with climatic factors.

METHODOLOGY

Study Site and growth rate measurement

The research material used is red jabon and teak trees that grow side by side in a plantation forest plot in Bunga Village, North Luwuk District, Banggai Regency, Central Sulawesi Province, Indonesia (Figure 1). Observation plots measuring 20 × 20 m each. The spacing for red jabon stands is 3 m × 3 m and teak stands are 2 m × 3 m. The location is at coordinates 00°52'26.23" South Latitude and 122°54'04.19" East Longitude, with an altitude of 304 meters above sea level. The monthly growth rate was measured at diameter at breast height.

Climatic

Climatic data for 10 years (2012–2021) was obtained from the Meteorology, Climatology and Geophysical Agency (BMKG) of the Bubung Luwuk Meteorological Station, Banggai Regency, Central Sulawesi Province. The climatic data used consists of rainfall, rainy days, temperature, humidity, and duration of irradiation.

Data analysis

The data analysis used is descriptive analysis and Pearson correlation analysis. The descriptive analysis describes the growth rate of red jabon and teak trees based on the average value while the Pearson correlation analysis was to compare the diameter increment with climatic components. Statistical calculations were carried out with the help of Microsoft Excel and SPSS for Windows software which was presented in the form of tables and graphs.

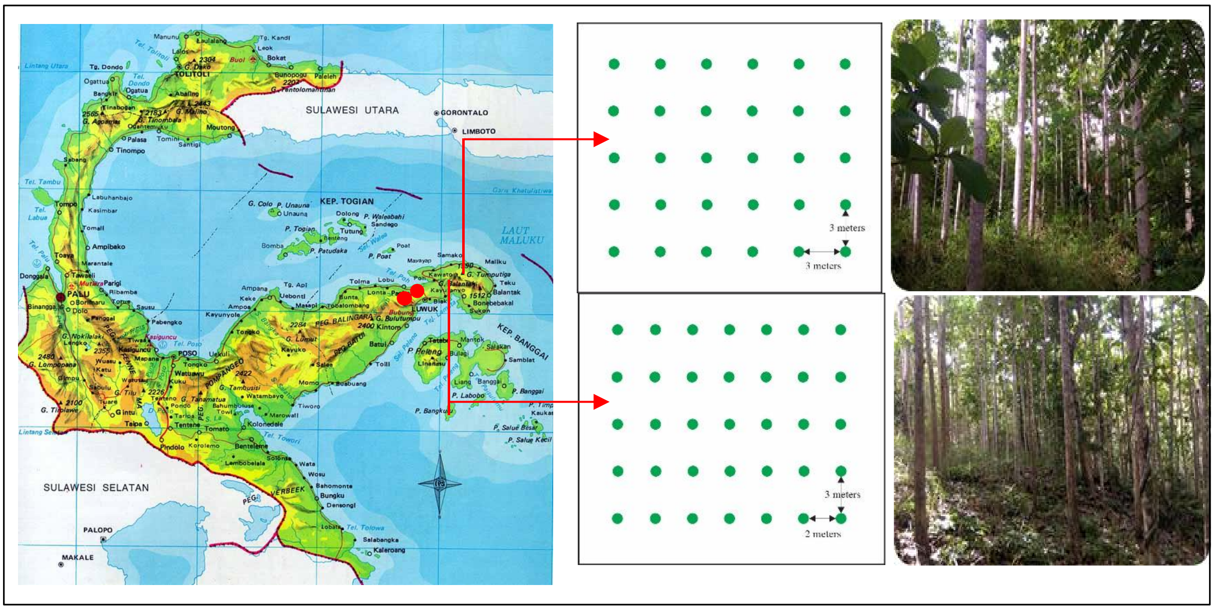

Figure 1. Map of Central Sulawesi; plot and stand of red jabon and teak trees

RESULT DAN DISCUSSION

Climatic Condition

Based on climatic data from the Meteorology and Geophysical Agency of Luwuk station, it is known that for 10 years (2012–2021) the amount of rainfall ranged from 1,004.4–1,848 mm; the average rainy day is 10.33–16 days; temperature in the range of 27.7–28.7 °C; humidity 73.5–77.8%; and 143–416 hours of irradiation. The climate in Banggai Regency for 10 years shows a varied trend. This situation shows that the Banggai Regency, which is the central zone of Indonesia, is also experiencing the impact of climatic change due to global warming. Below is a graph of climatic elements (Figure 2) in the form of rainfall, rainy days, temperature, humidity, and duration of irradiation for 10 years (2012–2021).

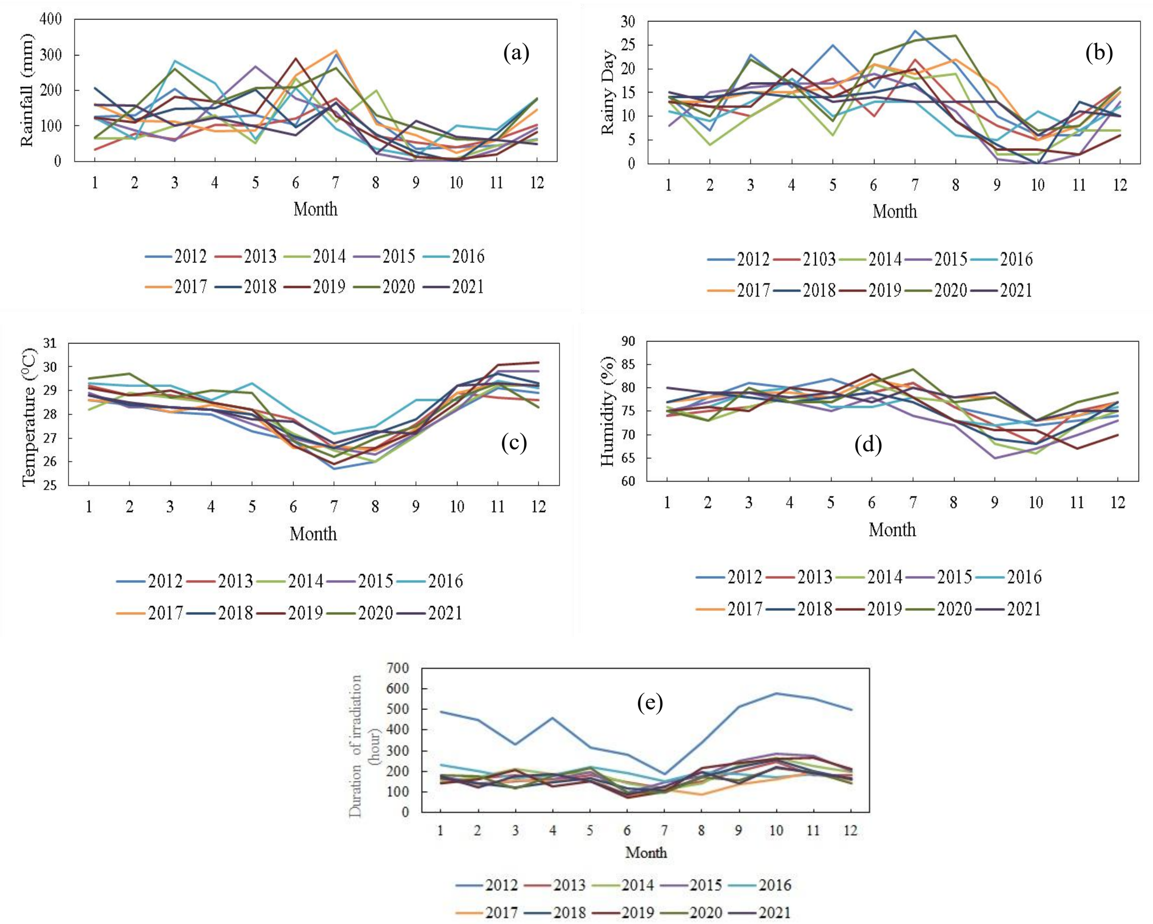

Figure 2. Climatic graph of the last 10 years at Banggai Regency: rainfall (a), rainy days (b), temperature (c), humidity (d), and duration of irradiation (e).

Jabon trees grow in wet to dry climatic with an average annual temperature of 21–26 °C with annual rainfall between 1,500–5,000 mm or more. Jabon can withstand the dry season for up to 3 months without experiencing much damage. Meanwhile, teak plants like rainfall between 1,200–2,500 mm per year with 3–5 dry months or rainfall of less than 50 mm per month. The temperature ranges from 19–36 °C which is a normal temperature for the tropics [25][26]. Understanding how climate affects tree species' growth is very important, to improve the prediction of forest dynamics to climatic change. Long-term climatic averages (average climatics) drive variations in species growth rates. The sensitivity of tree growth to climatic is likely to vary widely between species [27] . Based on Table 1, it is known that during the 2021 period, the amount of rainfall was 1,194.6 mm, 12.92 rainy days, temperature 28.19 °C, humidity 77.67%, and duration of irradiation 162.2 hours.

Table 1. Meteorological data of the site, Bubung Luwuk Meteorological Station, Banggai Regency, Central Sulawesi.

Rainfall (mm)		Rainy Days (day)		Temperature (° C)		Humidity (%)		Duration of irradiation (hour)	
Year	Value	Year	Value	Year	Value	Year	Value	Year	Value
2020	1.848	2020	16	2016	28,68	2017	77,75	2012	415
2017	1.525,3	2012	15,58	2020	28,31	2021	77,67	2015	188,8
2016	1.465	2017	14,38	2019	28,24	2020	77,58	2016	187,6
2018	1.439	2021	12,92	2018	28,22	2012	77	2014	187,3
2012	1.412	2013	12,67	2021	28,19	2013	75,75	2019	179,5
2019	1.317,5	2018	11,58	2013	28,19	2016	75,67	2013	172,7
2021	1.194,6	2015	11,25	2017	28,02	2018	75,33	2018	165,7
2015	1.165,4	2019	11	2015	28,02	2019	74,83	2021	162,2
2014	1.070,8	2016	10,67	2014	28	2014	74,75	2020	162,2
2013	1.004,4	2014	10,33	2012	27,7	2015	73,5	2017	142,8

Source: Bubung Luwuk Meteorological Station, 2022.

Growth Rate and Increment

The growth rate of red jabon and teak trees at the same location shows a very striking difference (Figure 3a). This difference may be influenced by the condition of the species and climatic factors. The red jabon tree is known as a fast-growing species, while the teak is a slow-growing species. The growth rate varies according to tree size. The increase in growth indicates the abundance of a species [28]. The growth rate of the red jabon tree continues to show a sigmoidal growth trend starting from January to December 2021. Unlike the case with teak trees, the sigmoidal growth trend begins to appear in April and then from July to December. The downward trend is seen in February–March and May–June. This decrease is caused by the natural exfoliation of teak bark, the cause of which is unknown.

The increment in diameter of the red jabon in 2021 is 2.21 cm, while the teak is 0.34 cm (Figure 3b). The increments in that year were relatively low compared to 2013 to 2018, as stated [29] that the diameter increment per year for red jabon varies, namely 4.9 cm (2013); 3.75 cm (2014); 2.71 cm (2015); 2.79 cm (2016); 2.53 cm (2017) and 2.93 cm (2018); while for teak they are 0.57 cm (2013); 0.59 cm (2014); 0.65 cm (2015); 0.98 cm (2016); 0.45 cm (2017) and 0.4 cm (2018). At the beginning of the growing season, the formation of new cells takes place rapidly and this rate then decreases during the growing season.

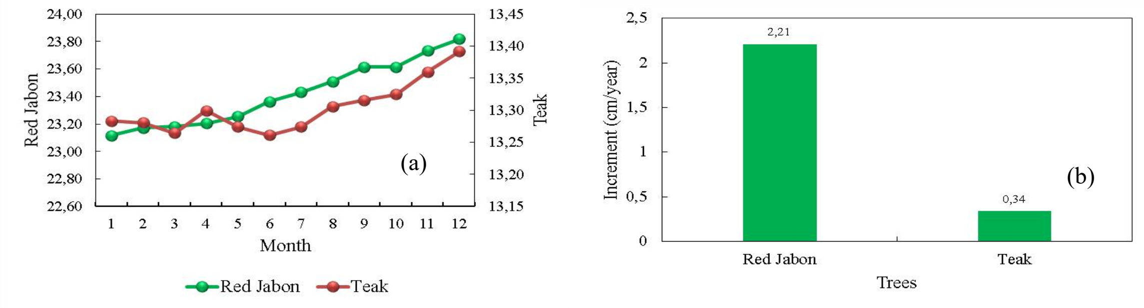

Figure 3. Growth rate (a) and increment (b) per year of red jabon and teak trees

Relationship of Growth Rate with Climatic Elements

The relationship between the growth rate of red jabon and teak trees with climatic elements (rainfall, rainy days, temperature, humidity, and duration of irradiation) shows a different trend every month in the 2021 period, as detailed in Figures 4 and 5. Both figures show that rainfall, rainy day, temperature, humidity, and duration of irradiation fluctuated from January to December 2021. Climatic conditions affect tree growth.

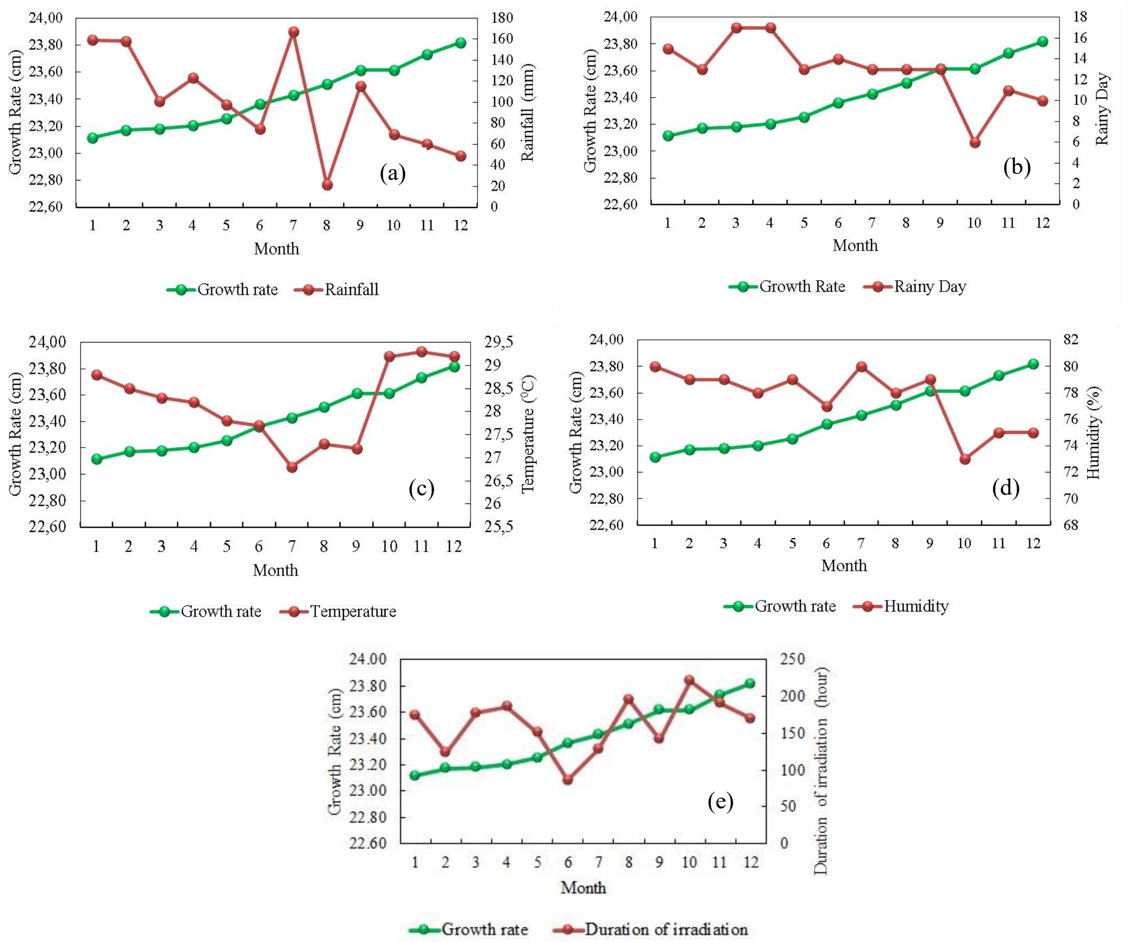

Figure 4. Graph of the relationship between red jabon growth rate and climatic: rainfall (a), rainy day (b), temperature (c), humidity (d), duration of irradiation (e).

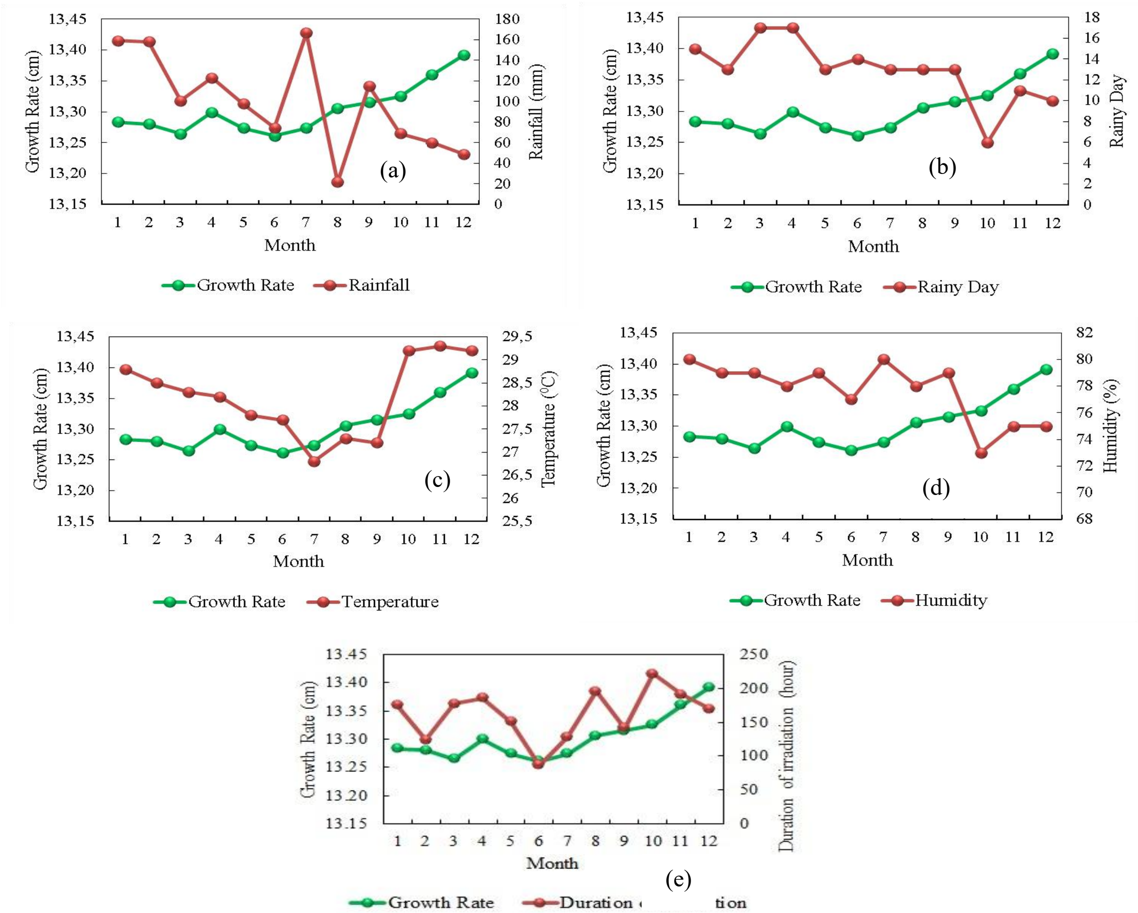

Figure 5. Graph of the relationship between teak growth rate and climatic: rainfall (a), rainy day (b), temperature (c), humidity (d), duration of irradiation (e).

Based on the Pearson correlation coefficient (Table 2), it can be seen that there is a significant relationship between the growth rate of red jabon and climatic elements, namely rainfall, rainy day, and humidity (while temperature and duration of irradiation are not significantly correlated). Meanwhile, for teak trees, the relationship was significant only on rainy days and humidity (rainfall, temperature, and duration of irradiation were not significantly correlated). The relationship between climate and growth is species-specific, varies, and is inconsistent over time. This may also occur in red jabon and teak stands in the Banggai plantation forest. The following studies provide a comparison.

Table 2. Pearson coefficient of correlation (r), the relationship between growth rate and climate in 2021

Climatic	Growth Rate			
	Red Jabon		Teak	
	r	ρ value	r	ρ value
Rainfall (mm)	- 0,63*	0,27	- 0,53	0,08
Rainy day (day)	- 0,72**	0,01	- 0,59*	0,04
Temperature (^{0} Celcius)	0,21	0,52	0,56	0,06
Humidity (%)	- 0,70*	0,01	- 0,69*	0,01
Duration of irradiation (hour)	0,26	0,42	0,48	0,12

* Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level

Two species, Pinus and Sabina, from the two locations clearly showed differences in growth. Divergent locations show a more stable relationship with climatic factors (usually rainfall). At non-divergent locations, almost all relationships varied in strength or became insignificant. This may be related to increased pressure on some trees due to increased temperatures [30] . During 1984–2000, tree canopy growth in the tropical rainforest of La Selva, Costa Rica, varied > 2-fold. The increase in the annual diameter of trees over 16 years was negatively correlated with the annual mean daily minimum temperature. Variation in tree growth is also negatively correlated with net carbon exchange in the tropics as a whole [31]. Physiological processes and biotic interactions associated with mature trees are highly temperature dependent, from the thermal sensitivity of the plant gametophyte [32] . The growth of Scots pine and Douglas fir is stimulated by increased winter temperatures, particularly January, February, and March temperatures. In contrast, Norway's spruce growth was stimulated by increased rainfall in May, June, and July and increased temperatures in March of the current year. In the future, in warmer climatics with drier summers, Norway's spruce tree growth may be negatively affected [33].

The increase in tree diameter is largely determined by the activity of the cambium network in the tree. The activity of the vascular cambium increases stems or root diameter, improving plant support and transport [34]. Based on research results [35], on the types of Pinus merkusii and Pinus kesiya that grow in northern Thailand, where rainfall and temperature do not significantly affect cambium activity. The significant effect on cambium activity is correlated with groundwater. Also explained that the light availability and tree diameter only explained an average of 12% of the variation in growth rates. The average growth rate range was almost twice as large under high light (20%) as compared to low light (5%). All species grow faster at higher light. Other factors such as soil characteristics, herbivores, or pathogens can contribute greatly to shaping tree growth in the tropics [28].

Climatic plays an important role in cambium activity and wood formation, low temperatures and reduced photoperiod in winter, and high temperatures associated with low water availability in summer limit tree growth [36] . Climatic variations from year to year affect the quantity and quality of wood formed. Biological and physiological aspects of regulating cambium activity in trees are also important. Seasonal cambium activity plays an important role in wood formation and reflects the tree's ability to adapt to its environment. In temperate and cold climatics, the cambium is dormant during winter and is active in spring and summer. Low temperatures and decreased photoperiod in winter trigger the trees to enter a dormant state [37] [38]. The unit heat approach to the biological process of wood formation begins as soon as a certain amount of heat has accumulated over time. The amount of heat determines the onset of cambium activity [39]. Rainfall is strongly correlated with cambium thickness [40], which causes the diameter of the tree to increase in each growth period (1 year).

CONCLUSIONS

The growth rate in diameter of the red jabon tree per year was 2.21 cm, while for the teak tree, it was 0.34 cm per year. A significant relationship between red jabon and climatic elements can be seen in rainfall, rainy days and humidity; while temperature and duration of irradiation did not have a significant correlation. In teak trees, a significant relationship was seen only on rainy days and humidity; while rainfall, temperature and irradiation time are not significantly correlated.

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