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HEIGHT AND DIAMETER MEASUREMENT OF *Eucalyptus urophylla* IN BATUR MOUNTAIN NATURE TOURIST FOREST, INDONESIA

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Abstract*. Batur Forest is a volcanic area that was an ex-volcanic eruption. Efforts to rehabilitate forests with critical land were by planting Eucalyptus urophylla. The aim of the study was to examine the adaptation of Eucalyptus urophylla species in critical areas of former volcanic eruptions that were dominated by hard rocks. The research was done for a year (2019-2020). The method used was a species test with a permanent block plot design from 4 age levels, 1 year, 5 years, 10 years, and 15 years. The study results showed growth of 1.02 cm in diameter and 1.10 m in height (1 year), 6.50 cm in diameter and 11.00 m in height (5 years), 13.25 cm in diameter and 18.40 m in height (10 years), and a diameter of 20.48 cm and a height of 23.00 m (15 years). Eucalyptus urophylla experienced the best tree diameter growth after 10 years old and on the contrary experienced a decrease in height. The Eucalyptus urophylla level of adaptation and suitability of volcanic soils with low fertility and rocky soil is a recommendation to increase the quantity of this species of planting. So that the forest succession from rocky thickets to tree vegetation is faster than natural processes. Eucalyptus urophylla species is one of the flora that makes up the savanna forest ecosystem and volcanic critical land in eastern Indonesia.*
Keywords: *adaptation; eucalyptus urophylla; volcanic land; Batur mountain nature tourist forest (status of fores*)

1. Introduction

The ex-eruption of Batur mountain is one of the most important parts of forest and land rehabilitation efforts in Bangli Regency, Bali Province. The first documented eruption was in 1804 and the latest was in 2000. From 1804 to 2005, Mount Batur had erupted 26 time. The former eruption of Batur mountain leaves distinctive biophysical characteristics which causes the study of the characteristics of the land after the eruption of Batur mountain needed in order to formulate a strategy for forest and land rehabilitation. The characteristics of the land studied include climate, physiology and geology, soil, hydrology, and also the vegetation and land cover. The results of the study indicate that the research location climate type is E (slightly dry) with 1750.9 mm annual average rainfall (Nandini and Narendra, 2011). Physiologically, the research location is a landform of volcanic origin which is dominated by a lava field with geology composed of ignimbrite, basalt, volcanic breccia and andesite rocks. Soil fertility is very low and the hydrological potential is in the form of springs around Lake Batur (Astawa, 2011). The dominant vegetation species are *Pinus merkusii* and *Eucalyptus urophylla* S.T. Blake (Susanti *et al*., 2021, Wirabuana *et al*., 2021).

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Eucalyptus urophylla S.T.Blake is an endemic plant species that has a very important role in Bali and Nusa Tenggara. In general, the main flora species that make up the savanna are in dry land and mountainous areas. This tree species has the potential and economic value to be used for essential oils, wood, building materials, pulp raw materials and bee feed. The leaves of this plant are efficacious as antibacterial, antiviral, analgesic, and anti-infective. *Eucalyptus urophylla* essential oil contains paecymene (76%), alpha-pinene (7%) and gamma terpenene (4%), which are used as disinfectants for perfume and soap (Alencar, 2002; Miguel, 2016; Pinheiro, 2019; X. Zhao, 2017).

Besides its high productivity, *Eucallyptus urophylla* has the advantages of being able to grow on less fertile soil types on critical land, resistant to surface fires because it has a lignotube and relatively thick skin, as a pioneer plant, the suitability of the place to grow is wide enough, can grow in dry climates, able to reproduce vegetatively, resistant to pests and diseases, and good for the growth of grass/ understorey (Komara *et al*., 2016; Zanuncio, 2013). Its causes the ampupu wood to be one of the wood species that has the potential to be developed as a future economic wood whose needs are increasing and also for land rehabilitation.

The aim of the study was to examine the adaptation of *Eucalyptus urophylla* species in critical areas of former volcanic eruptions dominated by hard rocks (Alencar, 2019) (Marimpan *et al*, 2022).

2. Methods

Batur Forest (8°14'52.0"S 115°23'12.2"E) is a volcanic area that was ex-volcanic eruption. Rehabilitate forests efforts on critical land by planting *Eucalyptus urophylla*. This research was conducted from 2019-2020. The method used is species test with permanent block plot design from 4 age levels, 1 year, 5 years, 10 years and 15 years. The research was conducted in Bali, the research location was at the Batur mountain, Kintamani Bali (Figure 1).

The *Eucalyptus urophylla* S.T. Blake research scopes consists of independent variables and dependent variables. The independent variable is the variable that estimated to be the cause of the emergence or change of the dependent variable, while the dependent variable is the variable that occurs or appears/changes due to the influence caused by the independent variable. The independent variable was the age of the plants arranged in a permanent block plot design consisting of 4 age levels, 1 year, 5 years, 10 years and 15 years. While the dependent variables are: plant height and stem diameter.

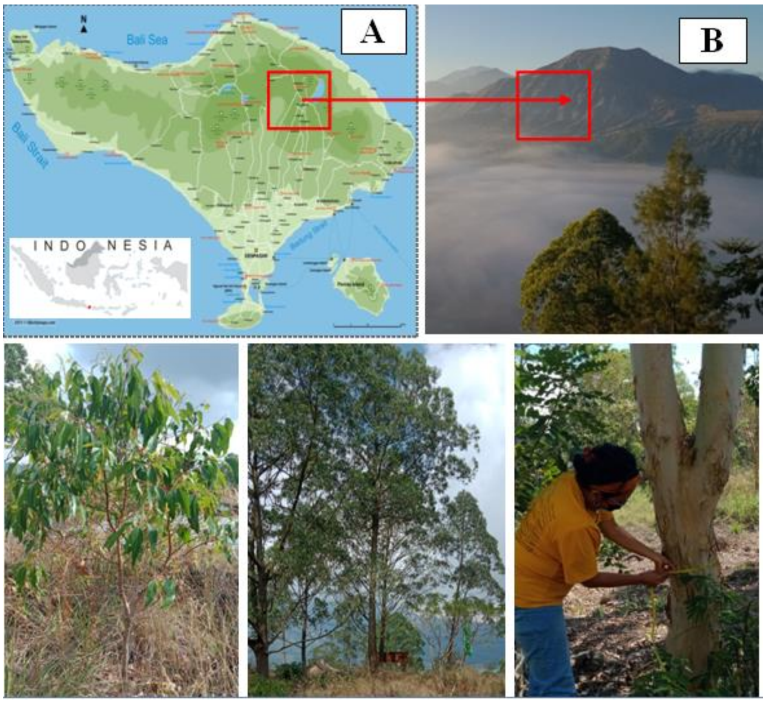

Figure 1. A. The research location in Bali Province. B. Batur mountain, Kintamani Bali

3. Results and Discussion

3.1. Plant height (m) and Growth of stem diameter (cm)

The *Eucalyptus urophylla* height growth at 1 year old had no significant difference. The difference is indicated by the plant height between 0,6-1,6 cm (Table 1). *Eucalyptus urophylla* height measurement is done once a month. *Eucalyptus urophylla* plant height growth was best treated at 5-10 years old. *Eucalyptus urophylla* species produces a good response to plant height growth due to climate and rainfall (Elli *et al*, 2017). Based on the data, the average growth rate of 10 years old has the best response to *Eucalyptus urophylla* (average 1.32 m per year) compared to 1 year old and 15 years old has the lowest average growth score of 1.01 m.

Table 1. The Average height of *Eucalyptus urophylla* plant (m)

Plot	1 year old	5 year old	10 year old	15 year old
1	0.8 d	6.5 cd	14.0 b	20 ab
2	1.5 cd	6.2 cd	13.2 c	19 ab
3	1.1 d	5.9 cd	12.9 c	22 a
4	0.9 d	7.1 c	14.0 b	22 a
5	1.4 cd	6.1 cd	13.0 c	21 a
6	0.9 d	6.5 cd	12.0 c	20 ab
7	1.6 cd	7.2 c	15.0 ab	18 ab
8	0.8 d	5.8 cd	12.5 c	20 ab
9	1.1 d	6.3 cd	12.5 c	22 a
10	0.8 d	6.2 cd	13.2 c	21 a
11	0.5 d	6.3 cd	13.1 c	20 ab
12	1.1 d	8.1 c	13.0 c	19 ab
13	1.0 d	6.5 cd	13.5 c	20 ab
14	0.9 d	6.0 cd	12.9 c	22 a
15	0.9 d	7.2 c	14.0 b	19 ab

Numbers followed by the same letter are not significantly different in Duncan's 5% multiple-distance test

The results showed that *Eucalyptus urophylla* experienced an increase in diameter growth. The diameter of *Eucalyptus urophylla* plants experienced slow growth at the beginning of the year when compared to *Eucalyptus urophylla* in the 15th year. The diameter at the beginning of the year shows a non-significant difference. The difference in *Eucalyptus urophylla* is indicated by the plant diameter producing a height between 0.8-1.7 cm (Table 2).

Table 2. The average diameter of *Eucalyptus urophylla* plant (cm)

Plot	1 year old	5 year old	10 year old	15 year old
1	1.1 d	9.90 bc	18.0 ab	22 a
2	1.2 d	9.40 bc	21.0 a	21 a
3	0.8 d	10.90 bc	18.1 ab	24 a
4	0.8 d	7.80 b	17.9 ab	20 ab
5	1.5 cd	14.50 b	17.5 ab	24 a
6	1.2 d	17.10 ab	20.0 ab	23 a
7	0.9 d	7.10 cd	19.0 ab	22 a
8	1.5 cd	11.01 bc	16.8 ab	25 a
9	1.0 d	9.90 bc	20.0 ab	23 a
10	1.7 cd	12.90 bc	19.0 ab	19 ab
11	0.9 d	10.10 bc	17.5 ab	26 a
12	0.6 d	15.80 b	21.0 a	23 a
13	1.2 d	10.50 bc	18.0 ab	25 a
14	1.1 d	9.60 bc	15.5 b	24 a
15	1.0 d	9.80 bc	18.0 ab	26 a

Numbers followed by the same letter are not significantly different in Duncan's 5% multiple-distance test

Eucalyptus urophylla diameter measurements were carried out once a month. The diameter growth of *Eucalyptus urophylla* plants best treatment at 5-10 years old. *Eucalyptus urophylla* species produced a good response to the growth of plant diameter due to climate and high rainfall. The best response to *Eucalyptus urophylla* plants at 15 years old (average 2.20 cm per year or 11.09 cm for 5 years) compared to the age of 1 year which had the lowest value of 1.1 cm.

The measurement results showed that there was a systematic range of data for each stand parameter with to the stand age class. The distribution of the average height and diameter data, Table 1 and Table 2. From the data, it can be seen that the growth of the average height and diameter tends to be a logistical and linear pattern. This condition supports the biological principle of stand development where at the beginning of growth tends to be slow and linear in the middle of the cycle age (Franklin *et al*., 2007; Purba *et al*., 2020; Sasmita *et al*., 2019). Until the age of 15 years, growth in height and diameter tended to be linear and there was a significant range of mean differences in growth parameters at each age of the stand. This condition can be caused by differences in the productivity of the growing site or the quality of the plots.

Eucalyptus urophylla plant height from the plot around the lake showed the highest measurement results both at the 1 to 10 years old. This is probably due to roots growth and the compactness of the roots so it is very supportive of growth in the field. Besides, the supporting factor is the genotype uniformity with the parent that been used (Siregar *et al*., 2021). The source of explants is from the cutting garden where the material used is superior material as a result of the plant breeding program. The average plant height of seeds from seed is lower than seedlings from cuttings and tissue culture as the age of the plant increases, the difference in plant height increases because there is a very large variation in growth in plants from seed. There are tall plants but many plants are short so the average height obtained is low. The average height of plants at 15 years old was 20.33 m (Sopacua *et al*., 2021).

In the diameter growth curve of *Eucalyptus urophylla* at the 1-15 years old plant, a sigmoid-shaped diameter growth curve will appear. This explains that the growth of *Eucalyptus urophylla* stands diameter on Batur mountain is in accordance with the ideal growth of organisms where the growth curve is still juvenile. The diameter increment growth of 1 to 5 year old plants showed that the diameter increment at 1 year of planting was the smallest compared to the others. This is thought to be due to the plant's lack of adaptability to its environment. In the statement above, *Eucalyptus urophylla* species still require intensive silvicultural treatment, such as plant maintenance in the form of vertical release until 3 years old. Although changing, the growth trend (increment) from planting 1 to 5 years old was not significantly different or quite stable with an average of 1.80-2.20 cm/year, only 1 year old plants had increments below the average about 1.10 cm/year. If this trend does not change drastically, then at 25 years old, the diameter of *Eucalyptus urophylla* planted by Batur mountain can reach the diameter limit (45 cm up) (Wiranto *et al*., 2008; Xu, 2015).

The results obtained from the source of *Eucalyptus urophylla* seeds will increase if the seeds quality that's used were improved and continues to be developed, along with the silvicultural techniques improvement used in plant cultivation so that the environmental conditions in which plants grow are appropriate so the plants can adapt well. Conservation efforts by vegetative and generative propagation of *Eucalyptus urophylla* forest plants are urgently needed for genetic conservation and increasing accuracy in genetic and non-genetic tests or reducing variation errors (Almeida, 2020; Barbosa, 2017; Desalle & Amato, 2017; Susilowati *et al*., 2021).

Places to grow from the plots have different variations. Fertility pictures of *Eucalyptus urophylla* are arranged with a growth index of 20-25 with 1.0 m intervals. The growth index of 20-25 shows the distribution of the sample plots based on the age class of the tree. The test results show that there are differences in site index in each *Eucalyptus urophylla* age class. It can be seen that the *Eucalyptus urophylla* growth response to the growth sites as growth media shows a positive relationship between the quality of the growing site with the *Eucalyptus urophylla* plant height and diameter plant that has a very well achievement (Beese & Arnott, 1999; Santana, 2012; Zhao, 2019).

In general, there are indications that the quality of the growing site at the research location is relatively high, which is indicated by the slope of the curve which tends to be sigmoid. Places of growth that have high quality usually caused by the relation between height and age that are in line with the *Eucalyptus urophylla* tree growth form, on the other hand, the site with low quality will tend to form a sloping curve of the relation between age and height. From the data above (Table 1, Table 2), it is clear that tree height is not affected by stand density, because plant growth first forms height and then increases diameter, and in early growth, plants tend to compete with other plants for the need for nutrients in soil, water and light. In line with the competition, the full height of the tree will increase until the maximum height and age is reached.

In addition to the factors of plant species are the rainfall and hydrology condition (Schmidt & Ferguson, 1951). The average monthly rainfall in Batur mountain is 150.50 mm. Wet months occur from November to April. Based on the Schmidt-Ferguson climate classification, the research area belongs to the climate type E (slightly dry) with a value of Q=1.145. This rather dry climate causes a lack of water sources at the research site. Another consequence is that the vegetation that's able to grow in the research location is very limited, that is, only vegetation that is able to survive in limited water sources. From the rain data obtained, annual rainfall from 2019-2020, it rains almost all year round. The largest rainfall occurs in January of 1.580 mm. Air temperature was obtained from temperature recording at the research location which was carried out at five observation points. The results of the temperature analysis showed that the average temperature in the study area was 22°C. The air temperature at the research site is moderate and cool. This condition is influenced, among others, by the location of the research location which is at 900 m above sea level altitude. Air humidity was obtained from the recording of humidity at the research site which was carried out at four observation points. The results of the air humidity analysis showed that the average humidity in the study area was 68%. The air humidity at the research site is moderate. This humidity is very suitable for the development of vegetable crops because it does not cause vegetables to rot quickly due to the growth of fungi which usually thrive in areas with high humidity.

The hydrology parameter analysis is the infiltration capacity to support *Eucalyptus urophylla*. The relationship between height and diameter growth in *Eucalyptus urophylla*, height growth will affect tree diameter. If the optimal height growth, the diameter growth will increase. Subsequent height growth will tend to remain, but the diameter of the tree is getting bigger. Infiltration is the entry of water into the soil (Arsyad, 1989; Purba *et al*., 2019). Infiltration rate is influenced by infiltration capacity and water supply rate. The results of the analysis of the infiltration capacity at the research site conducted at five observation points obtained values from 35 cm/hour to 165 cm/hour with an average of 110 cm/hour. This value can be interpreted that the infiltration capacity at the research site is very fast. This very fast infiltration capacity is usually found in sandy textured soils. This is in accordance with the results of soil analysis at the research site, where the soil texture is sand and loamy sand. The research location is on the slopes of a mountain, but at the research location there are no springs that can be a source of water for the community. Springs are only found around the lake which is not far from the research location. Most of the water supply for the community around the research site is met from lake water, both for bathing, washing, and also for watering their agricultural land. The springs around the lake are also used for various purposes, such as bathing and cooking. The springs emerged from the rock crevices on the edge of the lake. The existing springs are hot springs and cold springs. Hot springs are widely used for public baths which in certain seasons are visited by many tourists, both domestic and foreign.

The cumulative individual and dominant tree vegetation species based on diameter and tree height class formed a sigmoid-shaped growth indicating good forest regeneration capacity. The level of adaptation and suitability of *Eucalyptus urophylla* on volcanic land with low fertility and rocky soil is a recommendation to increase the quantity of this species of planting. So that the forest succession from rocky scrub to tree vegetation is faster than natural processes. *Eucalyptus urophylla* species is one of the flora that makes up the savanna forest ecosystem and volcanic critical land in eastern Indonesia.

4. Conclusions

The distribution of height and diameter of trees on Batur mountain at 1 to 15 years old can indicate the age of the land and the regeneration power of tree vegetation in the future. The 15-year-old Batur mountain area is a natural vegetated forest with accumulated tree diameters spread over 18–26 cm class with an average height of 18–22 meters. The diameter growth between 1.02 cm and height 1.10 m (1 year), diameter 6.50 cm and height 11.00 m (5 years), diameter 13.25 cm and height 18.40 m (10 years), and 20.48 cm in diameter and 23.00 m in height (15 years). *Eucalyptus urophylla* experienced the best tree diameter growth after 10 years old and on the contrary experienced a decrease in height.

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