Agro Bali : Agricultural Journal
Vol. 8 No. 1: 56-63, March 2025
e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i1.1981

The Influence of Altitude Toward Vegetative and Generative Growth of Sugar Palm (*Arenga pinnata*)

Difa Adiba Akbar♥, Endang Yuniastuti, and Supriyono Supriyono
Agronomy Study Progam, Faculty of Agriculture, Universitas Sebelas Maret, Surakarta, Indonesia
♥Corresponding author email: difaadiba@gmail.com

Article history: submitted: August 5, 2024; accepted: February 24, 2025; available online: March 28, 2025

Abstract. Sugar palm is a member of the palm family that offers many benefits. Palm sugar is produced from the male flower, while the fruit is produced from the female flower. The potential of this resource has not been fully realized because most of it is sourced from the wild. This research aims to determine the differences in the growth of palms based on altitude. The research was conducted from October 2023 to March 2024 in Sleman, Kulon Progo, and Purworejo regions. Treatment of altitude is divided into three, namely lowlands (0-400 masl), medium (401-700 masl), and highlands (>700 masl). The parameters used in this research were plant height, stem, number of leaves, leaf width and length, number of productive and unproductive leaves, number of bunches, number of female and male flowers, and number and weight of fruits. Data on vegetative growth were analyzed using ANOVA, and then LSD for further and data on generative growth used the Kruskal Wallis test with a significance level of 95%. The result showed a significant difference between vegetative growth and altitude except for the number of productive leaves and generative growth; there was only a significant difference in the number of male flowers.

Keywords: altitude; growth; palm, productive leaves, unproductive leaves

INTRODUCTION

Sugar palm is known as a plant that has many benefits in agriculture. This plant is often used to extract its sap and fruits. The sap produced from male flowers is processed into palm sugar or fermented drinks. Male flowers are tapped because they produce more and better sap than female flowers (Long & Zainal, 2022). Sugar palms have different characteristics and content from other sugars. The sucrose content of palm sugar is higher (84%) compared to cane sugar (20%) and beet sugar (17%) (Warismayati et al., 2020). Sugar palm fruit, better known as kolang-kaling, is processed into food. Sugar palm also has potential in terms of medicine because the roots, fruits, and seeds of sugar palm contain antioxidant compounds that are useful for the health of the human body (Eliah et al., 2022). Another benefit is that the stem contains starch that can be extracted into flour.

One of the factors that influences growth is altitude. Sugar palm can grow at an altitude of 0-1400 meters above sea level and is often found in areas that are close to water sources (Azhar et al., 2022). The growth of the stem can reach a height of more than 20 meters with a diameter of around 50 cm. Altitude has an impact on macroclimate, including temperature, humidity, and intensity of sunlight. Climate change is an essential factor in cultivation to minimize crop yield reduction (Wijayani et al., 2022). Air humidity increases as the altitude increases. Temperature decreases as the altitude becomes lower. This is because the higher the altitude, the faster the radiation rate. The amount of sunlight received affects photosynthesis. The adequacy of these factors impacts optimal plant growth. Differences in altitude also affect the type of soil. Not all plant species can grow optimally on all types of soil.

Sugar palm utilized by farmers mostly comes from nature or grows wild. Its utilization cannot be maximised because the population is still small and has not been widely cultivated. One factor is the lack of information related to the cultivation or existence of sugar palm. Another factor is that the growth of sugar palm in each location is different and has an effect on production. This research aims to determine the differences in sugar palm growth based on altitude.

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i1.1981

METHODS

This research was carried out from October 2023 to March 2024 in Sleman, Kulon Progo, and Purworejo areas. The area was divided into three locations based on altitude: lowlands (0-400masl), medium (401-700 masl), and highlands (>700masl). The materials and tools used: Sugar palm, GPS, clinometer, thermohygrometer, lux meter, and soil tester. Five sugar palm samples were taken in the research on each altitude, and there are 15 in total. The criteria for the sugar palm used as a sample has a sufficient level of age maturity. Barlina et al., (2020) said that sugar palm is ready for production in around 6-12 years. Each sample in the altitude was given a symbol or code: R (Lowlands), S (Mediumlands), and T (Highlands).

The methods used were survey and observation. The survey was conducted to discover the existence of sugar palms growing well. Variables observed included plant height, stem circumference, number of leaves, leaf width and light, number of productive and unproductive leaves, number of bunches, number of female and male flowers, and number and weight of fruits. Data on vegetative growth were analysed using ANOVA and then LSD for further and data on generative growth used the Kruskal Wallis test with a significance level of 95%

RESULTS AND DISCUSSION

The result showed differences in the growth of palm sugar at each altitude. Differences in altitude affect the vegetative and generative growth of sugar palm. Vegetative growth includes plant height, stem circumference, number of leaves, leaf width and light, and productive and unproductive leaves.

The result in **Table 1** shows that the average plant height and stem circumference of mediumland showed significant differences in the growth between lowland and highland. The highest value is owned by the sugar palm in the mediumland, which is 13,85 meters and 124,6 centimeters. This indicates that at an altitude of 400-700 meters above sea level, sugar palm stem growth is more optimal than in the low and highlands. Based on the **Table 1**, the higher stem growth will be followed by increased stem circumference. According to Samal et al., (2020), height and diameter growth are influenced by how plants interact with the environment, obtain nutrients, and place to grow.

Table 1. Average growth of sugar palm stems based on altitude

Altitude	Plant height (m)	Stem circumference (cm)
Low	11.48 a	112 a
Medium	13.85 b	124.60 b
High	11.08 a	106.60 a

Note: The number followed by the same letter in the same column show that there is no significant difference

Stems have the function of storing food reserves such as starch and sugar from photosynthesis. Stem growth can be used as one of the factors that determine whether plants grow well or not. The height of sugar palm is directly proportional to productivity; the higher the growth, the higher the productivity. It is inversely proportional to stem circumference because growth will be centered on the stem, and flower growth will be inhibited.

Based on **Figure 1**, palm stem growth increases in medium land and then decreases in highland. Sugar palm samples with the highest plant height and stem circumference were also found in the medium, in S4 with a height of 15.8 m and S3 with a stem circumference of 1.28.

The results showed significant differences in all leaf growth except for the growth of productive leaves. **Table 2** shows the highest number of paired leaflets owned by palm sugar in the lowland, with a value of 104 sheets. The number of paired leaflets in the lowland and highland did not significantly differ. Nurmayulis et al., (2021) said the

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i1.1981

number of leaves will affect growth because the leaves are a place for photosynthesis.

The average length and width of the highest leaflets are found in the mediumland with values 147,2 cm and 7,16 cm. This average has significant differences between lowland and highland. The growth of leaflet length is also followed by an increase in leaflet width. Productive leaves owned by sugar palms in the mediumland have the highest average value of 11, but in the ANOVA test, there is no difference in each altitude.

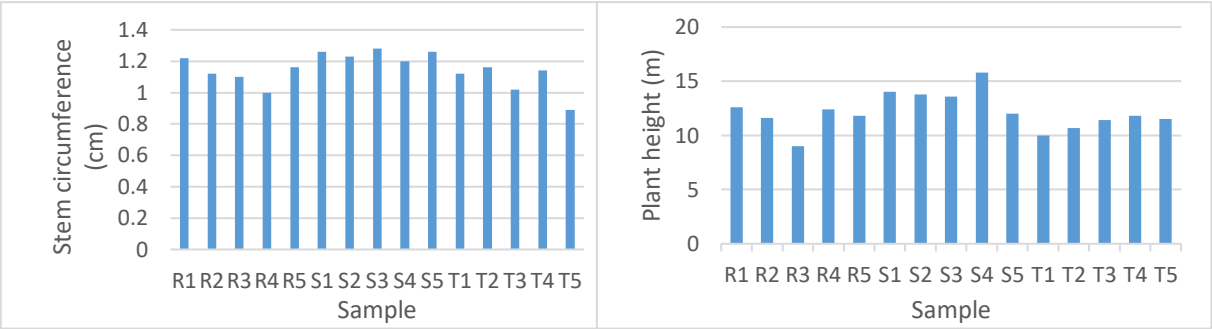

Figure 1. Growth of sugar palm stem in each sample.

Table 2. Average growth of sugar palm leaves based on altitude

Altitude	Paired leaflets	Length leaflets (cm)	Width leaflets (cm)	Productive leaves	Unproductive leaves
Low	104 a	110.60 a	4.22 a	10 a	7 a
Medium	89 c	147.20 b	7.16 b	11 a	10 bc
High	103 ab	116.90 a	4.60 a	9 a	11 c

Note: Number followed by the same letter in the same column shows that there is no significant difference

Sugar palms in the highlands have the highest number of unproductive leaves, namely 11. The number of unproductive leaves in the highlands is different from that in the lowlands. Growth differences are caused by 2 factors, namely internal and external. According to Elidar (2020), they can be caused by internal factors such as genetics and varieties. This happens because the growth of wild sugar palms is not known from the parent, so genetics and varieties are different for each individual.

Figure 2 shows that the number of leaves did not increase significantly with increasing altitude. Widarawati et al., (2023) said that the increase in the number of leaves was slow, only about 3-6 leaves per year. According to Sari et al., (2021), early growth to have perfectly open leaves takes quite a long time, which is after 98 days after sowing. The highest number of paired leaflets owned by R1, namely 118 sheets.

Figure 3 shows an increase in leaf size in the mediumland and then a decrease again at the highland. The highest leaf length is owned by S1, while the highest width is in S4.

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i1.1981

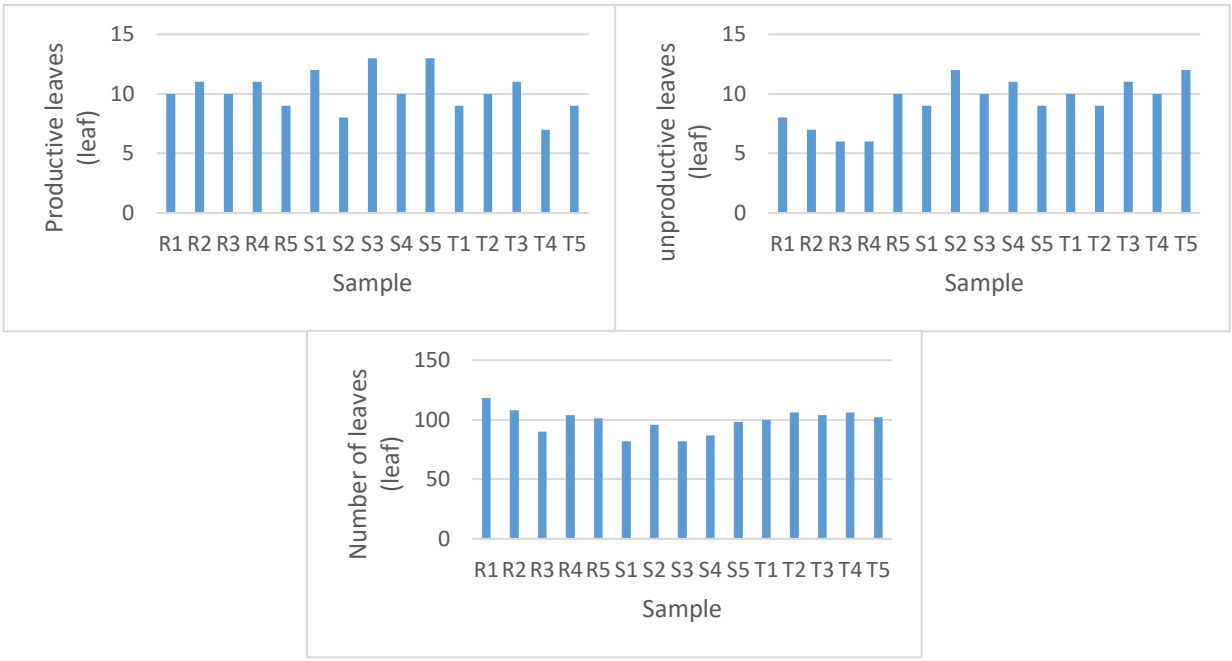

Figure 2. Number of sugar palm leaves in each sample.

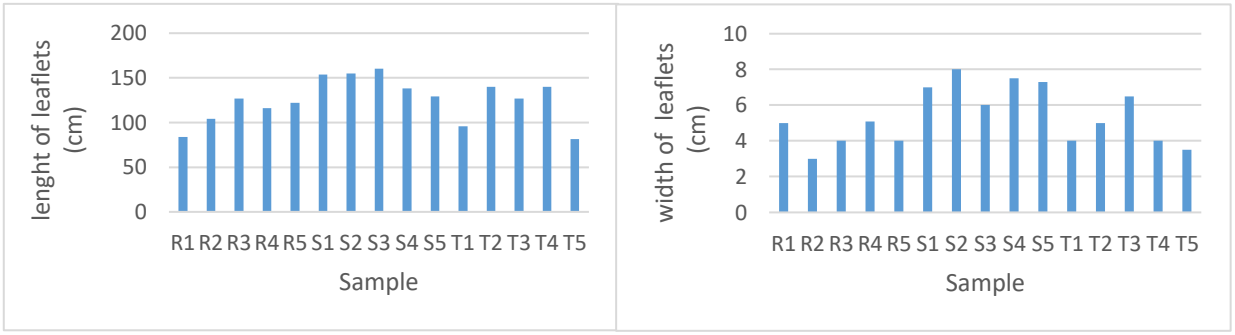

Figure 3. Size of sugar palm leaves in each sample.

Table 3. Average generative growth of sugar palm based on altitude

Altitude	Number of Bunches	Number of Male Flowers	Number of Female Flowers	Number of Fruits	Fruit Weight (g)	Fruit Circumference (cm)
Low	1 a	250 a	102 a	1080 a	4.34 a	2.20 a
Medium	3 a	2501 b	208 a	2153 a	12.71 a	4 a
High	2 a	834 a	100 a	664 a	13.91 a	4.70 a

Note: The number followed by the same letter in the same column shows that there is no significant difference

The result showed that only the growth number of male flowers was significantly different at each altitude (**Table 3**). The highest number of bunches was owned by medium altitude with an average of 3 bunches. According to Hakim et al., (2024) sugar palm bunches have high cellulose content, making them useful as raw materials for paper or boards. The highest average number of male and female flowers are owned by sugar palm in mediumland, 2300 and 208. Sugar palms in the highlands

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i1.1981

have the highest number of fruits at 2153. This follows research by Jacob (2020) Palm sugar grows well at an altitude of 500-700 masl or in mediumland. The highest average fruit weight was found in the mediumland at 13,91 g and fruit circumference at 4,7. This can happen because the number of fruits is low, so the nutrients provided are greater. Another cause is that sugar palm that grows does not come from quality seeds, this is explained by Prayoga et al., (2020) quality seeds will support the further growth of the next sugar palm.

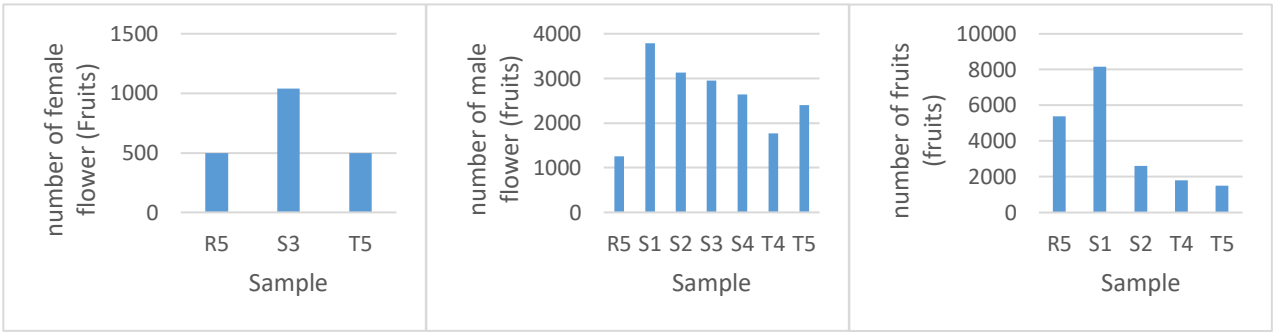

Figure 4. Growth of sugar palm flowers and fruits in each sample.

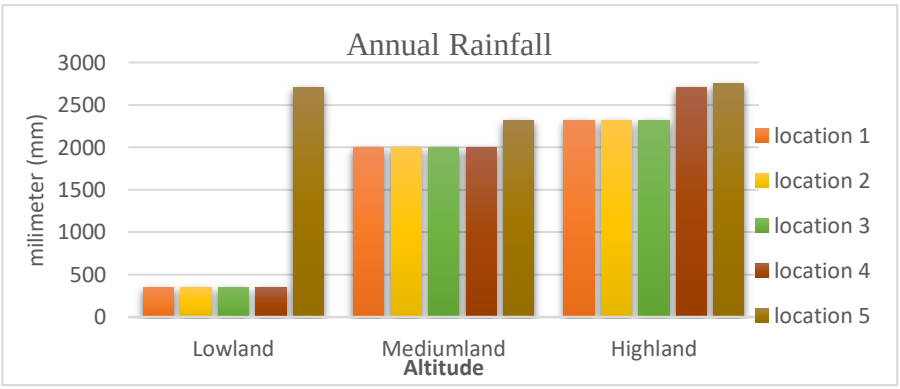

Figure 5. Annual rainfall at the research location

Based on **Figure 4**, the growth of female flowers was only found in samples R5, and S3 flowers were only found in samples R5, S3, and T5. Male flower was found in sample R5, S1, S2, S3, S4, T4 and T5. Fruits found on sugar palms amounted to 5 out of 15 samples at R5, S1, S2, T4, and T5. There is only one sugar palm in Lowland that has fruits and flowers. Sugar palm that grows in the lowlands is less optimal, conveyed by Pranoto et al., (2022) that sugar palms can grow in the lowlands but do not provide optimal results. Another factor is due to lack of maintenance; according to Fatmona et al. (2024), at the age of 7 years, the sugar palm can be produced, but if it is not maintained, the production may be lacking.

Annual rainfall is one of the main factors for measuring the climate of an area, affecting ecosystems and plant growth. Rainfall affects the type of vegetation that can grow because each plant has different water needs. Duryat et al., (2024) state that places with annual rainfall of 1750-3000 mm have potential for sugar palm cultivation. **Figure 5** shows that the highest annual rainfall in location 5 is in low land at 2482,6 mm. Harahap et al., (2021) said rainfall is one of the main factors affecting the growth and production of palm annually.

e-ISSN 2655-853X
https://doi.org/10.37637/ab.v8i1.1981

Table 4. Average environmental conditions based on altitude

Altitude	Air temperature (℃)	Light intensity (lux)	Air humidity	Type of soil	Soil Temperature (℃)	pH	Soil humidity
Low	26.1	668.75	33%	Latosol and Regosol	27.5	7	Dry
Medium	26	3749	38%	Latosol	25.5	6.3	Normal
High	25.4	62515	41%	Latosol	25.8	6.3	Normal

Differences in altitude also affect surrounding environmental conditions, such as microclimate. **Table 4** shows the highest average temperature in the lowlands, at 26,1℃. Optimal temperature conditions in sugar palms are around 25℃, although temperatures exceed usual. The highlands have the highest average light intensity and air humidity of 62515 lux and 41%. Lawendatu et al. (2020) said the light requirements of each plant are different depending on its type. Nirawati et al (2020) found that the higher the light intensity under tree stands, the lower the sugar content (brix). The difference in humidity result at each height follows the research result by Witno et al. (2022) that altitude affects growth; the higher the altitude, the higher the humidity.

There are two types of soil at the research location: latosol and regosol, but almost all locations have latosol soil. The condition of volcanic soil on the slopes of the mountains is an ideal place for sugar palms. According to Pribadi et al. (2022), the growth of sugar palms is suitable in diverse agroclimatic conditions, such as mountainous areas with high rainfall. The highest average soil temperature is in the lowlands, which is 27,5^{o}C. pH of the soil found in the location ranges between 6-7, which means that soil conditions are neutral. Soil moisture in the lowlands is dry, while the medium and highlands are standard.

CONCLUSION

The altitude of the place affects the vegetative and generative growth of sugar palms. Stem and leaf growth of sugar palms decreased significantly with altitude except for the number of productive leaves. The generative growth of sugar palms only had a significant difference in the number of male flowers. Optimal growth was shown in sugar palms at medium altitudes.

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