# CHARACTERIZATION OF PHYSIOLOGICAL CHARACTERISTICS IN SUGAR PALM (Arenga pinnata (WURMB) MERR.) AND THE RELATIONSHIP WITH BRIX VALUE AND ELEVATION

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# CHARACTERIZATION OF PHYSIOLOGICAL CHARACTERISTICS IN SUGAR PALM (*Arenga pinnata* (WURMB) MERR.) AND THE RELATIONSHIP WITH BRIX VALUE AND ELEVATION

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**ABSTRACT**

**Sugar palm is a multipurpose tree species, which provides livelihoods for local people and food for other biotas in the landscape. This type of palm is known as the "tree of life" because all parts of the tree can be utilized and have a high economic value. The potential sugar produced is closely related to the characteristics and physiological activities of the plants. Characterization of stomata, trichomes, and chlorophyll showed specific characteristics that correlated with one another, and with Brix content and elevation. Significant correlations were shown in several stomata, trichomes, and chlorophyll parameters. From the three physiological characteristics, stomata and chlorophyll characteristics were significantly affecting Brix content and elevation. The width of the left stomata significantly correlated with elevation (0.4335), while the left tip chlorophyll was significantly correlated with Brix content (-0.44462). Overall, we concluded that some chlorophyll characteristics could be physiological indicators that specifically affect crop yields through environmental interaction in various weather conditions and elevations. In contrast, stomata characteristics can be used to improve the quality and quantity of plants in specific environmental conditions. However, more information on the physiological characteristics of a sugar palm tree is needed to modify physiological characteristics that can enhance growth and optimize crop yields in the future.**

**Keywords:** *Arenga pinnata* (Wurmb) merr.; elevation; stomata; chlorophyll; trichomes.

## INTRODUCTION

Sugar palm is an annual plant that is developed as a non-timber forest product. It has a high economic value as Brix content in the sap, and as an alternative sugar-producing product [1], it can also be used as bioethanol [2] and biofuel [3]. A palm tree is widely used by various ethnic groups, especially in North Sulawesi, Southeast Sulawesi, North Sumatra, West Java, Central Java, East Java, East Kalimantan, and West Kalimantan [1]. However, the productivity of sugar palm is relatively low, because the plant breeding method still uses conventional cultivation, and the availability of superior variety is still very limited. Superior varieties that have received permission from the Ministry of Agriculture are the Akel Tumoung variety [4] in Tomohon and Kutim Dwarf Sugar Palm (Aren Genja Kutim) variety [5] in East Kutai.

Physiological characteristics such as stomata, trichomes, and chlorophyll are closely related to the physiological activities of plants. Stomata and trichomes are found in leaf epidermal cells called epidermal appendices [6]. The functions are as a protector from mechanical damage, plant adaptation method to drought, water preservation, gas exchange in leaf , and to absorbs water from roots. Measurement of various physiological characters such as stomata and trichomes is an approach to study the defensive mechanism in plants against environmental factors [7]. Stomata are specified cells which able to respond to environmental signals, endogenous signals, and to change shape to enable the exchange of gas and water [8]. Structural characteristics of stomata are rarely adapted to changes that occur as a result of increased osmotic potential and turgor pressure, which is an adaptation to the environment [9]. However, plants stomata will be open or closed when facing conditions such as drought or water shortage [10]. Closed stomata used as an attempt by plants to reduce the rate of transpiration [6]. Whereas Trichomes with forms of bulge in the epidermis can reduce evaporation, reduce animal or human disorders, and continue stimulation [11].

A leaf is a place where the photosynthesis process in plants occurs. Chlorophyll is a green pigment in plants, algae, and photosynthetic bacteria. This pigment acts as a photosynthetic organ that has an electron acceptor pigment that supports photosynthesis in plants by absorbing and converting light energy into chemical energy [12]. Chlorophyll can accommodate the light absorbed by other pigments through photosynthesis, that is why it is called a photosynthetic reaction center pigment. The energy is used in reducing water to oxygen by producing electrons, formed ATP, and NADPH compounds, which will facilitate the binding of CO2 to carbohydrate [13]. The photosynthesis process produces carbohydrates that are converted into proteins, fats, nucleic acids, and other organic molecules [14]. Chlorophyll in plants consists of chlorophyll a ($C_{55}H_{77}O_5N_4Mg$) with dark green color and chlorophyll b ($C_{55}H_{70}O_6N_4Mg$) with light green color. The spectrophotometer of chlorophyll-a has maximum absorption at 665 nm, while chlorophyll b has a 652 nm absorption [15]. Chlorophyll content shows the physiological status of plants [13], which is closely related to the rate of photosynthesis and can be used as an indicator to evaluate metabolic imbalances between photosynthesis and production during water shortage condition [16]. The chlorophyll content in plants varies, depending on the ability of the leaf to absorb solar energy and its environmental conditions.

Although studies on the physiological characteristics of sugar palm plants have been carried out [11], analysis of chlorophyll content of leaf position using a spectrophotometer [15], and analysis of chlorophyll content in various positions of palm leaves and saplings [12], but the study on the correlation between physiological characteristics with Brix content and elevation has not been conducted. Therefore, it is necessary to conduct this study to identify specific physiological characteristics and the correlation with environmental response and plant yield.

## MATERIALS AND METHODS

### Experimental Site and Study Period

The sugar palm samples were collected from two locations, the Bonto-bonto Village in Maros Regency (5°7'43,089" S -119°-46'-45,209" W) and the Bonto Sinala Village in Sinjai Regency (5°18' 49,199" S - 83°54'17,111" W) in South Sulawesi, Indonesia. This research was conducted from

March to June 2019 for field activities and from June to August 2019 for laboratory analysis. Stomata and Trichomes were analyzed at the Forest and Environmental Research Institute (*Balai Penelitian Tanaman Hutan dan Lingkungan Hidup*) in Sudiang, South Sulawesi, Indonesia. While, the chlorophyll analysis was carried out in the Laboratory of Fisheries at Universitas Hasanuddin, South Sulawesi, Indonesia.

**Sampling Plants and Parameters**

Twenty-five sugar palm trees were randomly selected from each location. The criteria of sampling trees are productive trees that are in the tapping process period (for measurement of palm sugar content (Brix)). Sugar content was measured by using a refractometer with a scale of % Brix [17]. Plant samples used to determine stomata and chlorophyll were green leaf samples, which taken from the left and right leaflets of the tree. The measurement of stomata parameters was using the replica method [18]. The parameters measured were the number of stomata, stomata length, and stomata and trichomes width [11]. The chlorophyll was testing by using a UV-Vis spectrophotometer, with base chlorophyll, middle chlorophyll, and tip chlorophyll, chlorophyll a, chlorophyll b and total chlorophyll as the parameters [15]. Also, the height of each sample tree was measured.

**Data Analysis**

Data were analyzed using the Swantat application, free software developed from the R programming language using a shiny dashboard [19]. Correlation analysis using bivariate analysis with Pearson test method and plot correlation.

## RESULTS

**Correlation of Stomata and Trichomes Physiological Characteristics**

**Physiological characteristics of chlorophyll**

The correlation analysis indicated positive correlations between the number of right stomata and the number of left stomata (0.4427*), and the width between right and left stomata, which was 0.469* (Table 1). Then, the positive correlation between the left base chlorophyll and the middle left chlorophyll with a value of 0.53**. The correlation between the chlorophyll b and the total chlorophyll (0.76**) showed a very significant value, whereas the correlation of chlorophyll a with the total chlorophyll showed a positive correlation, 0.41* (Table 2).

**Relationship of Stomata and Trichomes Physiological Parameters with Brix Content and Elevation**

The physiological characteristics of stomata and trichomes were generally negatively correlated with Brix content. However, only the number of right stomata and left stomata showed a positive correlation. Whereas, the stomata correlation with elevation on the width of the left stomata parameter showed a positive correlation, 0.4335 *.

**Table 1. Pearson correlation of stomata and trichomes physiological characteristics**

| Parameter | nls | nrs | lls | rsl | lsw | rsw | ntl | ntr |
|---|---|---|---|---|---|---|---|---|
| The number of left stomata (nls) | 1 | 0.4427 | -0.0187 | 0.001594 | 0.469 | 0.2239 | 0.211 | 0.3073 |
| The number of right stomata (nrs) | 0.4427* | 1 | -0.1294 | 0.2089 | 0.1872 | -0.0366 | -0.05998 | 0.01902 |
| Length of left stomata (lls) | -0.0187 | -0.1294 | 1 | 0.06492 | -0.1008 | -0.0652 | -0.1447 | 0.1597 |
| Right stomata length (rsl) | 0.001594 | 0.2089 | 0.06492 | 1 | -0.04267 | 0.206 | 0 | -0.07778 |
| Left stomata width (lsw) | 0.469* | 0.1872 | -0.1008 | -0.04267 | 1 | 0.3314 | -0.05372 | 0.03107 |
| Right stomata width (rsw) | 0.2239 | -0.0366 | -0.0652 | 0.206 | 0.3314 | 1 | 0.1486 | 0.1632 |
| The number of trichoms left (ntl) | 0.211 | -0.05998 | -0.1447 | 0 | -0.05372 | 0.1486 | 1 | 0.2026 |
| The number of right trichomes (ntr) | 0.3073 | 0.01902 | 0.1597 | -0.07778 | 0.03107 | 0.1632 | 0.2026 | 1 |

**Table 2. Pearson correlation of chlorophyll physiological characteristics**

| Parameter | lbc | lmc | cle | rbc | rmc | cre | cl_a | cl_b | ttl_clr |
|---|---|---|---|---|---|---|---|---|---|
| Left base chlorophyll (lbc) | 1 | 0.53 | 0.18 | 0.11 | -0.095 | 0.03 | -0.028 | 0.31 | 0.27 |
| Left middle chlorophyll (lmc) | 0.53** | 1 | 0.29 | 0.11 | 0.24 | -0.23 | -0.1 | 0.31 | 0.23 |
| Chlorophyll left end (cle) | 0.18 | 0.29 | 1 | 0.1 | 0.42 | 0.02 | -0.11 | 0.31 | 0.22 |
| Right base chlorophyyl (rbc) | 0.11 | 0.11 | 0.1 | 1 | 0.22 | 0.006 | -0.02 | 0.32 | -0.004 |
| Right middle chlorophyll (rmc) | -0.095 | 0.24 | 0.42 | 0.22 | 1 | 0.09 | -0.11 | 0.01 | -0.006 |
| Chlorophyll rightend (cre) | 0.03 | -0.23 | 0.022 | 0.006 | 0.009 | 1 | -0.02 | 0.07 | 0.09 |
| Chlorophyll a (cl a) | -0.028 | -0.1 | -0.11 | -0.02 | -0.11 | -0.02 | 1 | 0.12 | 0.41* |
| Chlorophyll b (cl b) | 0.31 | 0.31 | 0.32 | 0.01 | 0.07 | 0.12 | -0.27 | 1 | 0.76 |
| Total chlorophyll (ttl cl) | 0.27 | 0.23 | 0.22 | -0.004 | -0.006 | 0.09 | 0.41* | 0.76** | 1 |

**Table 3. Relationship of stomata and trichomes physiological parameters with brix content and elevation**

| Parameter | nls | nrs | lls | rsl | lsw | rsw | ntl | ntr |
|---|---|---|---|---|---|---|---|---|
| Sucrosa content | 0.06568 | 0.1767 | -0.000154 | -0.05381 | -0.1062 | -0.03151 | -0.1668 | -0.1072 |
| Elevation | 0.2554 | 0.2473 | -0.2049 | -0.1019 | 0.4335* | 0.08714 | -0.04642 | 0.09903 |

**Table 4. Relationship of chlorophyll physiological parameters with brix content and elevation**

| Parameter chlorophyll | lbc | lmc | cle | rbc | rmc | cre | cl_a | cl_b | ttl_clr |
|---|---|---|---|---|---|---|---|---|---|
| Sucrosa content | -0.136 | -0.1332 | -0.4462* | -0.06396 | -0.07214 | 0.1098 | -0.009066 | -0.01083 | -0.01624 |
| Elevation | -0.09401 | -0.1642 | -0.08176 | -0.1429 | -0.1526 | 0.1431 | 0.06108 | 0.2602 | 0.2865 |

### Relationship of Chlorophyll Physiological Parameters with Brix Content and Elevation

The correlation of chlorophyll with Brix content and elevation generally showed a negative correlation where the left tip chlorophyll parameter significantly influenced the Brix content with a correlation value of -0.44462 *. Whereas, four other chlorophyll parameters including right tip chlorophyll, chlorophyll a, chlorophyll b, and the total chlorophyll showed a positive correlation with elevation, which correlation values were 0.1431, 0, 061, 0.2606, and 0.2865, respectively. An overview of the correlation plot between each physiological character shown in Fig. 1.

The correlation plot (Fig. 1) illustrates the shape and relationship between the physiological characteristics of stomata, trichomes, and chlorophyll. Characters that showed a very significant correlation were the left base chlorophyll parameter with the middle left chlorophyll and the chlorophyll B parameter with the total chlorophyll. Then, parameters with a significant correlation were the width of the left stomata with elevation, the left tip chlorophyll with the middle left chlorophyll, the left tip chlorophyll, and the right tip chlorophyll, number of the left stomata with the middle right chlorophyll, number of the right trichomes with the middle right chlorophyll, number of the left stomata with number of the right stomata, the width of the left stomata with number of the left stomata, length of the right stomata with the chlorophyll b, length of the right stomata with the total chlorophyll. The left chlorophyll parameter showed a negative correlation with Brix content.

## DISCUSSION

The characterization of chlorophyll content on sugar palm showed a significant correlation on several parameters tested. The middle left chlorophyll parameter was positively correlated with the left base chlorophyll. However, the result was in line with research conducted by [15] stated that the left leaves had higher chlorophyll content compared to right leaves because the left leaves received more sunlight than any other positions. Thus, the chlorophyll concentration was higher. Then, the results showed that chlorophyll b had a positive correlation with the total chlorophyll, meaning that an increase in chlorophyll b content, causing an increase in chlorophyll a / b ratio as well. This condition illustrates the adaptation of

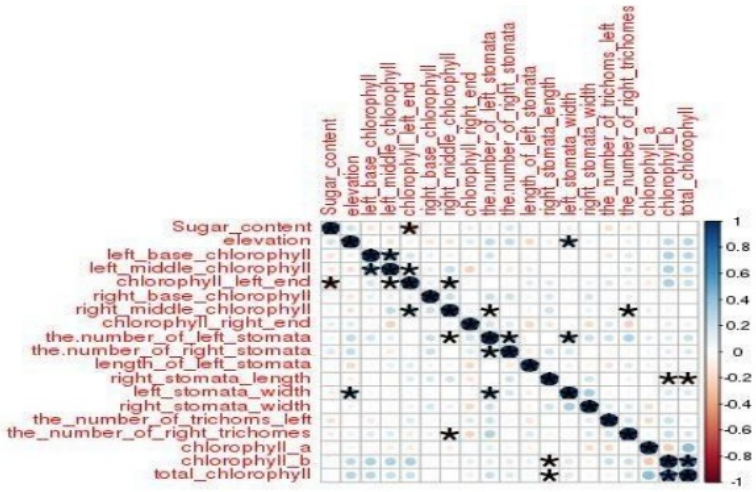


**Fig. 1. Plot correlation of physiological characteristics of stomata, trichomes and chlorophyll**

Note. *significance, blue color shows a positive correlation, and red color shows a negative correlation

plants to low radiation [20], which able to have positive impacts on the effectiveness of solar energy absorption in the shade of trees. The left tip of chlorophyll was negatively correlated with the Brix content, meaning that an increase in chlorophyll content of tip position, causing a decrease in the quality of the Brix content. Chlorophyll content can be used as an indicator when plants are experiencing water shortages [14].

A significant relationship with positive correlations to the characteristics of stomata detected in the correlation between the width of the left stomata with elevation. It indicated that an increase in elevation would cause an increase in the width of the left stomata. This was in line with research by [21] showed that differences in elevation of sugar palm plants influence the physiological process of growth and maximum yield of palm sap. The length of the right stomata with chlorophyll b and length of the right stomata with the total chlorophyll showed a positive correlation. The stomata and chlorophyll characteristics have a significant and mutually supporting relationship in the metabolism process. Morphophysiological characteristics are essential for supporting genes detection correlated with superior characters and providing genetic diversity information [22].

Change of plant metabolism during the development process able to sustains plants that respond to their environment [23]. A significant relationship was also found in trichomes with right middle chlorophyll like Teak [24] and mahogany trees [25]. This relationship showed a response to humid environmental conditions as an effort to maintain the physiological activities of plants to be optimal.

## CONCLUSION

The characteristics of stomata, trichomes, and chlorophyll described the physiological characteristics related to plant growth and productivity. The result of the parameter test on the number of left stomata showed a positive correlation with the number of right stomata, and the width of the left stomata, with a significant correlation value. Four chlorophyll parameters showed a very significant positive correlation on the left base chlorophyll with the middle left chlorophyll, the chlorophyll b with the total chlorophyll. While the left tip chlorophyll with the middle left chlorophyll, the left tip chlorophyll with the right middle chlorophyll showed a significant positive correlation. The correlation between three physiological parameters of stomata, trichomes, and chlorophyll with Brix

content and elevation showed a significant positive correlation on the width of the left stomata with elevation. The correlation between the left tip chlorophyll showed a significant negative correlation with Brix content. These physiological characteristics illustrate the sugar palm breeding program in the future and can be used as physiological indicators for growth and productivity of sugar palm germplasm with superior potential.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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