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Morphophysiological analyses on Teak (*Tectona grandis* Linn. f.) from three provenances

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Abstract. High genetic diversity in teak species causes problems in identifying the individuals. To identify the characteristics of the individuals, an identification system using morphophysiological analyses for Teak is needed. This study was aimed to identify the morphological and physiological differences between three different teak provenances, i.e., Cepu, Sidrap, and Bau-bau provenances. The research was carried out by observing morphological characteristics, i.e., leaf characteristics (color, shape, venation pattern, margin, base, tip, and surface texture) and tree characteristics (height and diameter), and physiological characteristics (leaf area, chlorophyll content, and leaf water content). There were five leaf colors observed in the analysis (green- brownish, green-yellowish, green, dark green, and green with yellow spots). Leaf shapes were divided into two shape types, i.e., widened ellipse and inverted oval. Flat leaf margin, tapered leaf tip, and base, rough surface texture, pinnate venation pattern were observed on all evaluated leaves. Height and diameter of trees were higher in Bau-bau provenance than other provenances. Leaf area was affected by provenance but not leaf position in provenance. Chlorophyll content was affected by both provenance and leaf position, whereas water content was only affected by leaf position in provenance.

1. Introduction

Teak has a significant contribution in supplying raw wood materials. It has not only high wood quality and economic value but also superior characteristics that already well known. Due to producing durable and strong wood quality, many parties (government, private sectors, community, and industry) have been cultivating this species [1]

Hundreds of teak species that having various traits (superior and inferior) have been distributed in Indonesians' regions. The high number of teak species becomes the restriction in distinguishing among teak individuals. For identifying each teak genotype, both skill and experience are needed. Therefore, an identification method for teak needs to be developed. Stem, leaf, fruit, and flower are commonly used for morphological identification [2], while physiological identification uses chlorophyll content, the conductivity of stomata, the diameter of the stem, plant height, and number of leaves [3]

The phenotype is a character (structural, biochemical, physiological or behavioral character) that can be observed on an organism that controlled by genotype, environment, and interaction between them. The definition of phenotype encompasses a number of phases in gene expression of an organism. In the organism level, the phenotype is determined by genotype and environment and widely known in the form of P = G + E. Phenotypic observation can be applied with only a simple observation (such as, flower color) up to complex observation that requires specific method and tools. Nonetheless, as gene expression of a genotype is gradual from molecular to individual levels, the correlation between phenotypes often detects in the different phases. Phenotype, particularly quantitative trait, is controlled by multiple genes [4]

Very high genetic diversity was previously reported in Teak (*Tectona grandis* Linn. f.) stands from different provenances in Southeast Sulawesi that collected from genetic resource area of Sulawesi BPTH based on Microsatellite marker [5] Equivalent to that finding, she assumed that in those populations the diversity of phenotype was also high. The correlation between high genetic diversity and phenotype of teak has not been previously studied, though, it is crucial for teak breeding strategy.

This study was aimed to identify the morphological and physiological characteristics of teak from East Java (Cepu), South Sulawesi (Sidrap), and Southeast Sulawesi (Bau-bau). Such information would be beneficial to complement the genetic data owned by Sulawesi BPTH for developing the genetic resource area of Sulawesi BPTH.

2. Material and Method

Plant materials were randomly collected with 30 repeat units from three different teak provenances, i.e., East Java (Cepu), South Sulawesi (Sidrap), and Southeast Sulawesi (Bau-bau) at genetic resource area of Sulawesi Forest Seed/Seedling office (BPTH), Gowa district, South Sulawesi, Indonesia. Some tools that used to facilitate the sample collection were GPS, laser distance meter (LDM), tape measure, chlorophyll meter (SPAD 502), envelope, marker, label, newsprint, cardboard, stick, oven, digital weight scale, millimeter block paper, characteristic table, tally sheet, and stationery.

2.1. Sample collection

The samples that used in the experiment were leaves from teak progeny populations. Thirty individuals were randomly selected from each provenance, and a total of observed individuals was 90 individuals/samples. Three leaves from each were cut at top, middle, and base of the tree using a scissor and stored them in the envelope with provenance code on it.

2.2. Morphophysiological observation

Bromophenol The morphological (leaf and stem) characters observed on the evaluated teak individuals were leaf color, leaf shape, leaf tip, leaf middle, leaf base, leaf margin, leaf surface texture, leaf venation, and tree height and diameter. The physiological observations included leaf area, chlorophyll content, and leaf water content.

Leaf area was measured using a gravimetric method by drawing a leaf sample on millimeter block paper. The paper must be larger than the measured leaf, and the measurement was conducted by count the block number inside the drawing.

Leaf chlorophyll was calculated using chlorophyll meter (SPAD-502). The measurement was carried out on a leaf from three leaf positions (top, middle, and base on the tree) without touching the midrib and then calculated the mean of the data. Leaf chlorophyll was counted using formula, $Y = 0.0007x – 0.0059$, where Y= chlorophyll content and x= data measured by chlorophyll meter Water content analysis was conducted using oven method (SNI 01-2891-1992 point 5). Leaf was weighted for determining the wet weight and then dried it using the oven at 60°C for 48 hours. Leaf was then weighted for measuring the dry weight. Water content was calculated using formula, water content (%) = ((wet weight – dry weight) / wet weight) x 100%.

2.3. Data analysis

Qualitative parameters (leaf color, leaf shape, leaf tip, leaf middle, leaf base, leaf margin, leaf surface texture, and leaf venation) were analyzed using the descriptive method, whilst, quantitative parameters (tree height and diameter) was performed using a single factor of Complete Randomized Design (CRD) consisting three treatments (East Java (Cepu), South Sulawesi (Sidrap), and Southeast Sulawesi (Baubau) provenances) with 30 replications. Meanwhile, Leaf area, Leaf chlorophyll, and water content were in Complete Randomized Design (CRD) with Nested pattern consisted of two factors with 30 replications. The first factor was provenances and the second one was leaf position at the tree (top, middle, and base). Quantitative data were analyzed using F test and followed by post-hoc HSD (Honestly Significant Difference) (when F test p-value < 0.05). Data were analyzed using R statistics (R core team).

3. Results

3.1. Leaf color and shape

Leaf colors showed on the evaluated provenances were green-brownish, green-yellowish, green, dark green, and green with yellow spots. Leaf shapes were divided into two, widened ellipse and inverted oval (table 1 and 2).

Table 1. Leaf color of teak from East Java (Cepu), South Sulawesi (Sidrap), and Southeast Sulawesi (Bau-bau) provenances

No.	Provenance	Location	Leaf color	Code of tree
1	East Java (Cepu)	Top	Green-brownish	P27, P28, P29, P30
			Green-yellowish	P6, P8, P13, P20
			Green	P2, P4, P7, P9, P10, P11, P12, P14, P15, P16, P17, P18, P21, P22, P23, P24, P25, P26
			Dark green	P1, P3, P5, P19
		Middle	Green	P2, P6, P7, P8, P10, P12, P13, P14, P16, P17, P20, P22, P23, P24, P26, P27, P28, P29, P30
			Dark green	P1, P3, P5, P19
			Green with yellow spots	P4, P9, P11, P15, P18, P21, P25
		Base	Green	P2, P8, P12, P14, P22, P26, P27
			Dark green	P1, P3, P5, P13, P16, P17, P19, P28, P29, P30
			Green with yellow spots	P4, P6, P7, P9, P10, P11, P15, P18, P20, P21, P23, P24, P25
2	South Sulawesi (Sidrap)	Top	Green-brownish	P26, P27, P28 P29, P30
			Green-yellowish	P17, P23, P24
			Green	P1, P8, P9, P10, P11, P12, P13, P15, P16, P18, P19, P20, P22, P25
			Dark green	P4, P5, P6, P14, P21
			Green with yellow spots	P2, P3, P7
		Middle	Green-yellowish	P7, P26, P29, P30
			Green	P1, P2, P8, P16, P24, P27, P28
			Dark green	P4, P6, P9, P12, P13, P15, P18, P19, P21, P22, P25
			Green with yellow spots	P3, P5, P10, P11, P14, P17, P20, P23

		Base	Green-yellowish	P7
			Green	P2, P16, P24, P26
			Dark green	P3, P8, P13, P19, P21, P22, P27, P28, P29
			Green with yellow spots	P1, P4, P5, P6, P9, P10, P11, P12, P14, P15, P17, P20, P23, P25
3	Southeast Sulawesi (Bau-bau)	Top	Green-brownish	P24, P26, P29, P30
			Green-yellowish	P1, P14, P16, P19, P22, P27
			Green	P6, P7, P9, P10, P11, P13, P15, P17, P18, P20, P21, P23, P25, P28
			Dark green	P2, P3, P4, P5, P8, P12
		Middle	Green-yellowish	P22, P27
			Green	P1, P7, P10, P16, P17, P18, P19, P21, P25, P26, P28, P29, P30
			Dark green	P2, P3, P4, P8, P12
			Greem with yellow spots	P5, P6, P9, P11, P13, P14, P15, P20, P23, P24
		Base	Green	P26, P27, P28 P29, P30
			Green with yellow spots	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10, P11, P12, P13, P14, P15, P16, P17, P18, P19, P20, P21, P22, P23, P24, P25

Table 1 presents most of the leaf color from Cepu, Sidrap, and Bau-bau at the top of the tree were green, it was shown on 18, 14, and 14 leaves of 30 observed leaves, respectively. Stated young leaf color of teak was green-brownish. In contrast to [6], this study observed that leaf color at the top was green as the collected leaves were not from the tip of the tree crown but at the 21st leaf from the tree base. Leaves color from Cepu and Bau-bau located at the middle of the tree were green, 19 and 13 of 30 leaves, respectively. Whereas that of from Sidrap was dark green (11 leaves). These were similar to a previous study [7] that described green as teaks' leaf color.

Most of the leaves that located at the base of the tree from Cepu, Sidrap, and Bau-bau provenances were green with yellow spots (13, 14, and 25 leaves of 30 leaves, respectively). Contrary to [6] study, he informed that the color of adult teaks' leaves was green-greyish. Here, the observed trees already shed their leaves that located at the tree base, and thus it was followed by color changing on the leaf. Water supply is vital in the photosynthesis process. Decreasing water supply will restrict photosynthesis, and consequently, the water keeps evaporating and reduces chlorophyll content in the leaf. Later, the leaf color was changed to yellow-brownish and eventually shed [8].

Younger leaves have greener color than the older ones. It is linked to nutrients which distributed to the leaf. Older leaf tends to receive more nutrients, as consequently having more chlorophyll and darker color than the younger ones [8]. A variation on leaf color indicates a variety of pigment types composed in the leaf. Chlorophyll in the young leaf is in the form of protochlorophyll, and its color changes after protochlorophyll transformation [9].

Table 2. Leaf shape of teak from East Java (Cepu), South Sulawesi (Sidrap), and Southeast Sulawesi (Bau-bau) provenances

No	Provenance	Location	Leaf shape	Figure	Code of tree
1	East Java (Cepu)	Top Middle Base	Widened Ellipse		P1-P30
2	South Sulawesi (Sidrap)	Top Middle Base	Widened Ellipse		P1-P30
3	Southeast Sulawesi (Bau-bau)	Top Middle Base	Widened Ellipse		P1, P2, P3, P9, P10, P11, P12, P13, P14, P15, P17, P18, P19, P20, P21, P22, P23, P25, P30
		Top Middle Base	Inverted oval		P4, P5, P6, P7, P8, P16, P24, P26, P27, P28, P29

Table 2 depicts that leaf shape on all samples from Cepu and Sidrap provenances located at the top, middle, and base of the evaluated trees were widened ellipse, whereas that of from Bau-bau provenance was divided into two groups, widened ellipse (18 trees) and inverted oval (12 trees). These results were supported by Dahana and [10] who stated leaf of teak has either widened ellipse or inverted oval. The variation in leaf shape from Bau-bau provenance is assumed due to the unexpected mixing in plant materials (with other provenances) during planting

3.2. Leaf tip, base, margin, surface texture, and leaf venation

Leaf tip, base, margin, surface texture and venation in all samples on the three provenances at different collecting sample location showed the same morphological characters.

Table 3. Tip, base, margin, surface texture, and leaf venation of teak from East Java (Cepu), South Sulawesi (Sidrap), and Southeast Sulawesi (Bau-bau)

No	Provenance	Leaf tip	Leaf base	Leaf margin	Leaf surface texture	Leaf venation	Figure	Code of tree
1	East Java (Cepu)	Tapered	Tapered	Flat	Rough	Pinnate		P1-P30
2	South Sulawesi (Sidrap)	Tapered	Tapered	Flat	Rough	Pinnate		P1-P30
3	Southeast Sulawesi (Bau-bau)	Tapered	Tapered	Flat	Rough	Pinnate		P1-P30

Table 3 describes leaf tip and base from all provenances at top, middle, and base of the trees had a tapered tip and base and flat margin. These descriptions were identic [11], [12] who reported that leaf of teak has a tapered tip and base and flat at the leaf margin.

All leaf samples in the evaluated provenances had rough surface texture and pinnate venation. These were supported [12]. They stated that teaks' leaf has pinnate venation and rough surface texture.

3.3. Tree height

Anova of tree height presented that provenance did not affect tree height (Table 4).

Table 4. Anova of tree height

Treatment	Df	Sum Sq	Mean Sq	F Value	Pr(>F)
Provenance	2	12.207	6.1034	3.0512	0.0524
Residuals	87	174.031	2.0004		

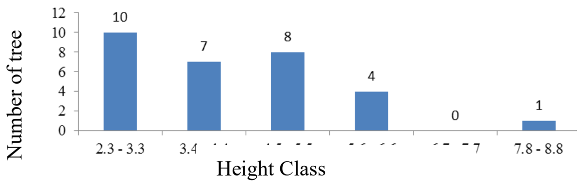

Figure 1. Frequency distribution of tree height in East Java (Cepu) provenance

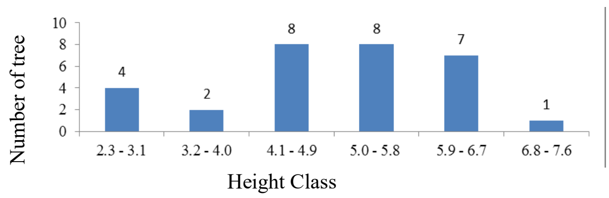

Figure 2. Frequency distribution of tree height in South Sulawesi (Sidrap) provenance

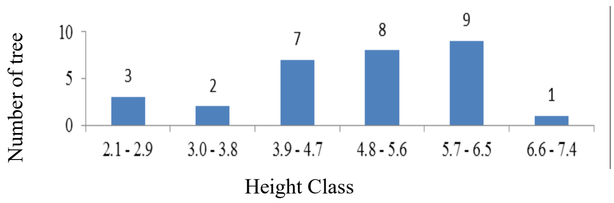

Figure 3. Frequency distribution of tree height in Southeast Sulawesi (Bau-bau) provenance

Figure 1-3 shows the frequency distributions of the tree height. The highest frequency of tree height in Cepu provenance was 2.3 - 4.4 which was the lowest level in the distribution class. While, the highest frequency in Sidrap and Bau-bau provenance were in the class of 4.1 – 5.8 and 3.9 – 4.7, respectively, where both were the moderate class of tree height. Bau-bau provenance had a higher height than other provenances that could be seen by having more individuals number in the higher class.

3.4. Tree diameter

The analysis of variant on tree diameter showed provenance significantly affected tree diameter (table 5).

Table 5. Anova of tree diameter

	Df	Sum Sq	Mean Sq	F Value	Pr(>F)
Provenance	2	60.209	30.1043	18.459	2.079e-07 ***
Residuals	87	141.887	1.6309		

Notes: (*) significant at p value < 0.05

Table 6. HSD test of tree diameter

	Diff	lwr	upr	p adj
Cepu-Baubau	-1.72666667	-2.5129158	-0.9404176	0.0000033
Sidrap-Baubau	0.01666667	-0.7695824	0.8029158	0.9985925
Sidrap-Cepu	1.74333333	0.9570842	2.5295824	0.0000027

Notes: (*) significant at p value < 0.05

Table 6 presents that in tree diameter, Cepu provenance differed from Sidrap and Cepu provenance but Sidrap provenance did not differ from Bau-bau. Variation in diameter growth was influenced by genetic and environment. There are three factors that affect diameter growth, i.e. soil nutrient content, soil humidity, and sunlight [13]. Moreover, the genetic factor is traits that are inheritably controlled so it could not be easily changed in a certain condition of environment. The unchangeable genetical traits are tree morphology, growing speed of tree (fast growing or slow growing species), wood color, etc [14]

One of environment factor influenced in tree diameter is the quality of growing environment. According to [15] growing environment affects variation in wood growth and formation. A good environment will produce trees with rapid growth, and vise versa, due to deficiency of nutrient and low moisture level.

3.5 Leaf area

Analysis of leaf area showed that leaf area was significantly affected by provenance (table 7).

Table 7. Anova of leaf area

	Df	Sum Sq	Mean Sq	F Value	Pr(>F)
Provenance	2	269729	134865	4.124	0.0172 *
Provenance (location)	6	337859	56310	1.722	0.116
Residuals	261	8534945	32701		

Notes: (*) significant at p-value < 0.05.

Table 8. HSD test of leaf area on provenances

	diff	lwr	upr	p adj
Cepu-Baubau	45.51556	-18.02684	109.05795	0.2115324
Sidrap-Baubau	-31.48	-95.02239	32.06239	0.4735142
Sidrap-Cepu	-76.99556	-140.53795	-13.45316	0.0128241

Notes: (*) significant at p-value < 0.05

Leaf area between Sidrap and Cepu provenances significantly differed (table 8). It was due to genetic and environmental factors. Environmental factor, such as topography, ecological condition, climate, and land fertility, can influence the physiology of plant [6]. [5] added genetic diversity of teak progeny populations in genetic resource area of Sulawesi BPTH was high. It indicated variation in leaf area between provenances (particularly Sidrap and Cepu) was also high.

3.6 Chlorophyll content

Table 9. Anova of chlorophyll content

	Df	Sum Sq	Mean Sq	F Value	Pr(>F)
Provenance	2	0.000182	9.09E-05	5.058	0.006994 **
Provenance (location)	6	0.000502	8.36E-05	4.652	0.000164 ***
Residuals	261	0.004691	1.80E-05		

Notes: (**) and (***) significant at p-value < 0.05

Table 10. HSD test of chlorophyll content on provenances

	Diff	lwr	upr	p adj
Cepu-Baubau	0.001506667	1.71E-05	0.002996282	0.0467368
Sidrap-Baubau	-0.000398889	-1.89E-03	0.001090726	0.8030904
Sidrap-Cepu	-0.001905556	-3.40E-03	-0.00041594	0.0079134

Notes: (**) and (***) significant at p-value < 0.05

Table 11. HSD test of chlorophyll content on location in provenances

	diff	lwr	upr	p adj
cepu:Base-baubau:Base	0.0039400	0.0005161	0.0073639	0.0112733
sidrap:Base-baubau:Base	0.0007467	-0.0026772	0.0041705	0.9989707
baubau:Middle-baubau:Base	0.0017367	-0.0016872	0.0051605	0.8114331
cepu:Middle-baubau:Base	0.0022367	-0.0011872	0.0056605	0.5145709
sidrap:Middle-baubau:Base	0.0014700	-0.0019539	0.0048939	0.9173122
baubau:Top-baubau:Base	-0.0001933	-0.0036172	0.0032305	1.0000000
cepu:Top-baubau:Base	-0.0001133	-0.0035372	0.0033105	1.0000000
sidrap:Top-baubau:Base	-0.0018700	-0.0052939	0.0015539	0.7409535
sidrap:Base-cepu:Base	-0.0031933	-0.0066172	0.0002305	0.0892834
baubau:Middle-cepu:Base	-0.0022033	-0.0056272	0.0012205	0.5357459
cepu:Middle-cepu:Base	-0.0017033	-0.0051272	0.0017205	0.8273831
sidrap:Middle-cepu:Base	-0.0024700	-0.0058939	0.0009539	0.3726380
baubau:Top-cepu:Base	-0.0041333	-0.0075572	-0.0007095	0.0060599
cepu:Top-cepu:Base	-0.0040533	-0.0074772	-0.0006295	0.0078655
sidrap:Top-cepu:Base	-0.0058100	-0.0092339	-0.0023861	0.0000084

baubau:Middle-sidrap:Base	0.0009900	-0.0024339	0.0044139	0.9925879
cepu:Middle-sidrap:Base	0.0014900	-0.0019339	0.0049139	0.9111443
sidrap:Middle-sidrap:Base	0.0007233	-0.0027005	0.0041472	0.9991828
baubau:Top-sidrap:Base	-0.0009400	-0.0043639	0.0024839	0.9947807
cepu:Top-sidrap:Base	-0.0008600	-0.0042839	0.0025639	0.9971799
sidrap:Top-sidrap:Base	-0.0026167	-0.0060405	0.0008072	0.2935385
cepu:Middle-baubau:Middle	0.0005000	-0.0029239	0.0039239	0.9999486
sidrap:Middle-baubau:Middle	-0.0002667	-0.0036905	0.0031572	0.9999996
baubau:Top-baubau:Middle	-0.0019300	-0.0053539	0.0014939	0.7062757
cepu:Top-baubau:Middle	-0.0018500	-0.0052739	0.0015739	0.7521442
sidrap:Top-baubau:Middle	-0.0036067	-0.0070305	-0.0001828	0.0303747
sidrap:Middle-cepu:Middle	-0.0007667	-0.0041905	0.0026572	0.9987541
baubau:Top-cepu:Middle	-0.0024300	-0.0058539	0.0009939	0.3958084
cepu:Top-cepu:Middle	-0.0023500	-0.0057739	0.0010739	0.4438085
sidrap:Top-cepu:Middle	-0.0041067	-0.0075305	-0.0006828	0.0066143
baubau:Top-sidrap:Middle	-0.0016633	-0.0050872	0.0017605	0.8455460
cepu:Top-sidrap:Middle	-0.0015833	-0.0050072	0.0018405	0.8785193
sidrap:Top-sidrap:Middle	-0.0033400	-0.0067639	0.0000839	0.0621394
cepu:Top-baubau:Top	0.0000800	-0.0033439	0.0035039	1.0000000
sidrap:Top-baubau:Top	-0.0016767	-0.0051005	0.0017472	0.8396128
sidrap:Top-cepu:Top	-0.0017567	-0.0051805	0.0016672	0.8015215

Chlorophyll content in evaluated leaves was affected by provenance and location in provenance (table 9). According to [16] chlorophyll content can be measured by greenness level of the leaf: the greener of a leaf, the higher chlorophyll content in it. Observation on leaf collecting location depicted that leaves at the base of the tree had higher chlorophyll content that other locations as consequently the chlorophyll content was indeed affected by provenance and location in provenance. The post-hoc test also showed chlorophyll content from Cepu provenance differed from Sidrap and Bau-bau provenance. Whereas, that of from Sidrap provenance did not differ from Bau-bau provenance. The previous study [5] in the same populations stated the high genetic diversity could influence chlorophyll content containing in leaves so that the chlorophyll contents were different between provenances.

3.7 Water Content

The analysis on water content showed it was not affected by provenance, but by leaf collecting position in provenance (table 12). Post-hoc HSD test is presented in table 13.

Table 12. Anova of leaf water content

	Df	Sum Sq	Mean Sq	F Value	Pr(>F)
Provenance	2	0.068	3.38E-02	2.786	0.0635.
Provenance (location)	6	1.691	2.82E-01	23.235	<2e-16 ***
Residuals	261	0.004691	1.80E-05		

Notes: (**) and (***) significant at p-value < 0.05

Table 13. HSD test of water content

	diff	**lwr**	**upr**	**p adj**
cepu:Base-baubau:Base	0.1170000	0.0280411	0.2059589	0.0016942
sidrap:Base-baubau:Base	-0.0086667	-0.0976255	0.0802922	0.9999978
baubau:Middle-baubau:Base	0.1023333	0.0133745	0.1912922	0.0113221
cepu:Middle-baubau:Base	0.1010000	0.0120411	0.1899589	0.0132757
sidrap:Middle-baubau:Base	0.1050000	0.0160411	0.1939589	0.0081775
baubau:Top-baubau:Base	0.1916667	0.1027078	0.2806255	0.0000000
cepu:Top-baubau:Base	0.1920000	0.1030411	0.2809589	0.0000000
sidrap:Top-baubau:Base	0.2486667	0.1597078	0.3376255	0.0000000
sidrap:Base-cepu:Base	-0.1256667	-0.2146255	-0.0367078	0.0004895
baubau:Middle-cepu:Base	-0.0146667	-0.1036255	0.0742922	0.9998707
cepu:Middle-cepu:Base	-0.0160000	-0.1049589	0.0729589	0.9997512
sidrap:Middle-cepu:Base	-0.0120000	-0.1009589	0.0769589	0.9999721
baubau:Top-cepu:Base	0.0746667	-0.0142922	0.1636255	0.1811774
cepu:Top-cepu:Base	0.0750000	-0.0139589	0.1639589	0.1764997
sidrap:Top-cepu:Base	0.1316667	0.0427078	0.2206255	0.0001976
baubau:Middle-sidrap:Base	0.1110000	0.0220411	0.1999589	0.0038047
cepu:Middle-sidrap:Base	0.1096667	0.0207078	0.1986255	0.0045273
sidrap:Middle-sidrap:Base	0.1136667	0.0247078	0.2026255	0.0026696
baubau:Top-sidrap:Base	0.2003333	0.1113745	0.2892922	0.0000000
cepu:Top-sidrap:Base	0.2006667	0.1117078	0.2896255	0.0000000
sidrap:Top-sidrap:Base	0.2573333	0.1683745	0.3462922	0.0000000
cepu:Middle-baubau:Middle	-0.0013333	-0.0902922	0.0876255	1.0000000
sidrap:Middle-baubau:Middle	0.0026667	-0.0862922	0.0916255	1.0000000
baubau:Top-baubau:Middle	0.0893333	0.0003745	0.1782922	0.0481317
cepu:Top-baubau:Middle	0.0896667	0.0007078	0.1786255	0.0465192
sidrap:Top-baubau:Middle	0.1463333	0.0573745	0.2352922	0.0000184
sidrap:Middle-cepu:Middle	0.0040000	-0.0849589	0.0929589	1.0000000
baubau:Top-cepu:Middle	0.0906667	0.0017078	0.1796255	0.0419569
cepu:Top-cepu:Middle	0.0910000	0.0020411	0.1799589	0.0405245
sidrap:Top-cepu:Middle	0.1476667	0.0587078	0.2366255	0.0000147
baubau:Top-sidrap:Middle	0.0866667	-0.0022922	0.1756255	0.0628334
cepu:Top-sidrap:Middle	0.0870000	-0.0019589	0.1759589	0.0608105
sidrap:Top-sidrap:Middle	0.1436667	0.0547078	0.2326255	0.0000288
cepu:Top-baubau:Top	0.0003333	-0.0886255	0.0892922	1.0000000
sidrap:Top-baubau:Top	0.0570000	-0.0319589	0.1459589	0.5418012
sidrap:Top-cepu:Top	0.0566667	-0.0322922	0.1456255	0.5499762

Notes: (**) and (***) significant at p-value < 0.05

Increasing age in the plant will lead to decreasing optimal condition even death of the organ or organism. The final development until losing the function of the cell is defined by maturation. Maturation is experienced by all cells at different time. [16] declared leaf age can be used to determine water content in the leaf. Teak's leaf at base of the tree is older than at the top. Those leaves begin to reduce chlorophyll production and nutrient distribution, and eventually only carotenoid and anthocyanin left. This situation will induce color-changing on leaves to orange, yellow-reddish, or purple. Leaves located at base of the tree will be shed thus the leaf weight becomes lighter and affects the water content.

4. Discussion
Morphological analysis in Cepu, Sidrap, and Bau-bau provenances on leaf color were divided into five, green-brownish, green-yellowish, green, dark green, and green with yellow spots. Most of leaf shapes were widened ellipse, except on some leaves in Bau-bau provenances that having inverted oval. All observed leaf samples had flat margin, tapered tip and base, rough texture, and pinnate venation. Tree height and diameter were higher in Bau-bau provenance than other provenances. Physiological analysis on leaf area was affected by provenance but not by leaf collecting position. Chlorophyll content was affected by both provenance and collecting position. Meanwhile, water content was not affected by provenance, but by collecting position

5. Conclusion
1. Freshness indicator of mango fruit can be produced by utilizing bacterial cellulose from *Acetobakter xilinum* which then soaked with bromophenol blue solution.
2. Profile of colour change on the freshness indicator of mango arummanis showed the change of colour from dark blue indicating fresh fruit, light blue is firm and green colour indicates the fruit has been rotten

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