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IDENTIFY THE EFFECT OF ALTITUDE ON THE MORPHOLOGY OF SUGAR PALM PLANTS

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ABSTRACT

Indonesia needs to diversify cane sugar into brown sugar to reduce imports of cane sugar. Excessive consumption of cane sugar is one of the causes of the increase in diabetes mellitus sufferers. The sugar palm plant as a producer of brown sugar has the potential to be developed as a substitute for cane sugar. Identification of sugar palm plants is carried out to determine genetic diversity. High genetic diversity also has high adaptability. This research aims to determine differences in the morphological characteristics of sugar palm plants based on different altitudes and identify the level of uniformity of morphological characteristics in sugar palm plants. The results of these observations are used as initial data to determine the parent tree that will be used as propagation material. The research was conducted in North Lintau Buo District, Tanah Datar Regency, West Sumatra from September to October 2024. Sampling locations were taken based on different altitudes with three plant samples per altitude until nine plant accessions were obtained. The research results showed that the quantitative and qualitative characters of sugar palm plants had relatively narrow phenotypic variability values. The kinship analysis of sugar palm plants has a level of similarity with a coefficient value of 10.13 – 80.39%. The closest relationship distance is shown in accession 8 and accession 9, with a similarity level of 80.39%. Meanwhile, accession 4 has a distant relationship with accessions 1, 3, 2, 7, 8, 9, 6, and 5 with a similarity level of only 10.13%. PCA analysis shows that accession 4 is different from other accessions based on the characteristics of bark color, frond shape, petiole shape, and build leaflets.

Keyword: *cluster, dendogram, Principal component Analysis (PCA)*

ABSTRAK

[IDENTIFIKASI PENGARUH KETINGGIAN TERHADAP MORFOLOGI TANAMAN AREN]. Indonesia membutuhkan diversifikasi gula tebu menjadi gula merah untuk mengurangi impor gula tebu. Konsumsi gula tebu yang berlebihan merupakan salah satu penyebab meningkatnya penderita diabetes melitus. Tanaman aren sebagai penghasil gula merah berpotensi untuk dikembangkan sebagai pengganti gula tebu. Identifikasi tanaman aren dilakukan untuk mengetahui keanekaragaman genetik. Keanekaragaman genetik yang tinggi memiliki kemampuan daya adaptasi yang tinggi pula. Penelitian ini bertujuan untuk mengetahui perbedaan karakter morfologi tanaman aren berdasarkan ketinggian tempat yang berbeda dan mengidentifikasi tingkat keseragaman karakter morfologi pada tanaman aren. Hasil pengamatan ini sebagai data awal untuk menentukan pohon induk yang akan dijadikan sebagai bahan perbanyakan. Penelitian dilaksanakan di Kecamatan Lintau Buo Utara, Kabupaten Tanah Datar, Sumatera Barat pada bulan September sampai Oktober 2024. Lokasi pengambilan sampel diambil berdasarkan ketinggian tempat yang berbeda dengan tiga sampel tanaman per ketinggian tempat hingga diperoleh sembilan aksesi tanaman. Hasil penelitian diperoleh bahwa karakter kuantitatif dan kualitatif tanaman aren memiliki nilai variabilitas fenotifik yang tergolong sempit. Analisis kekerabatan tanaman aren memiliki tingkat kemiripan (*similarity*) dengan nilai koefisien 10,13 – 80,39%. Jarak hubungan terdekat ditunjukkan pada aksesi 8 dan aksesi 9 dengan tingkat kemiripan sebesar 80,39%. Sedangkan aksesi 4 memiliki hubungan kekerabatan yang jauh dengan aksesi 1, 3, 2, 7, 8, 9, 6, dan 5 dengan tingkat kemiripan hanya 10,13%. Berdasarkan analisis PCA diketahui bahwa aksesi 4 memiliki perbedaan dengan aksesi lainnya berdasarkan karakter warna kulit, bentuk pelepah, bentuk tangkai daun, dan bangun anak daun.

Kata kunci: *dendogram, klaster, Principal Component Analysis (PCA)*

INTRODUCTION

Aren (*Arenga pinnata* Merr.) grows naturally and develops from the feces of civets that eat aren fruit, causing it to grow irregularly. Aren plants positively effect on the environment and the community's economy. Aren plants can be used as disaster mitigation to prevent floods, landslides, and reduce the impact of drought during the dry season. In addition, aren plants can improve the community's economy because they have multiple functions (Idris *et al*., 2021). The organs of the aren plants that are utilized by the community economically are sap which can be used as drinks and brown sugar, fruit is used as sugar palm fruit, and fiber is used as roofing and brooms.In general, people are more interested in processing sap into brown sugar.

The need for brown sugar is increasing along with the increase in diabetes mellitus sufferers. According to the International Diabetes Federation (IDF), the number of diabetes mellitus sufferers in Indonesia increases every year with the number of sufferers reaching 19.5 million people in 2021 and in 2045 it is estimated that it will reach 28.6 million people (DitjenP2P, 2024). One of the causes of diabetes mellitus is excessive consumption of cane sugar. According to Gani *et al*., (2023), excessive consumption of cane sugar can increase the percentage of diabetes mellitus three times greater. Granulated sugar contains a greater glycemic index, namely 58, compared to brown sugar, which is only 35. This value shows that palm sugar produces glucose slowly so that it does not burden the pancreas (Aprilia and Lironika, 2022). BPS (2024) shows Indonesia imports 5.069.455,2 tons of sugar for 2.881.115,5 US$ in 2023. Indonesia needs to diversify cane sugar into brown sugar to reduce cane sugar imports to reduce diabetes sufferers.

West Sumatra is one of the provinces that produce sugar palms in Indonesia. Data from the West Sumatra BPS in 2024 shows that West Sumatra has a sugar palm plantation area of 1409.19 ha with a brown sugar production of 1608.19 tons and a productivity of 1.54 tons/ha. The area and production of sugar palm in 2023 increased by 1.1% and 2%, respectively, compared to 2022. This shows that the increase in the planting area affects the increase in sugar palm production. Tanah Datar Regency is the largest sugar palm producer in West Sumatra with a planting area of 385 ha, brown sugar production of 555.35 tons, and productivity of 1.44 tons/ha (Deswaty *et al*., 2024). Compared to 2022, the area of sugar palm and brown sugar production in Tanah Datar Regency did not increase. If sugar palm farmers in Tanah Datar Regency do not expand and develop sugar palm plants, then the production will decrease in the future because the plants are old. Based on the potential of the environment that is suitable for sugar palm plants in Tanah Datar Regency, it is necessary to carry out land intensification to increase sugar palm plant production.

Based on this background, it is necessary to identify sugar palm plants in Tanah Datar Regency to determine the diversity of sugar palm plants. Genetic diversity can be seen in the morphological characteristics of plants. Factors that influence plant morphological characters are genetic and environmental. If the diversity of plant morphological characters is predominantly influenced by genetic factors, then the influence of environmental factors will not have a significant influence. However, if environmental factors dominate the diversity of morphological characters, then genetic factors will have an insignificant influence (Weihan *et al*., 2020). Plants that have high genetic diversity also have high adaptability. High genetic diversity is needed to produce superior varieties through plant breeding.

This research was carried out by observing the adaptability of sugar palm plants to the growing environment based on differences in altitude through the morphological characteristics of sugar palm plants. The altitudes of places are grouped into three, namely, heights > 700 m above sea level are classified as highlands, heights of 400 – 700 m above sea level are classified as mediumlands, and heights of 0 – 400 m above sea level are classified as lowlands (Rinaldi *et al*., 2022). The morphological characteristics of sugar palm plants in North Lintau Buo District, Tanah Datar Regency, West Sumatra Province are unknown. Observing the morphological characteristics of sugar palm plants aims to determine the factors that most influence the growth of sugar palm plants, whether genetic factors or environmental factors. This can be used as initial data to determine the parent tree used as propagation material. This research aims to determine differences in the morphological characteristics of sugar palm plants based on different altitudes and identify the level of uniformity of morphological characteristics of its plants.

MATERIALS AND METHODS

This research was conducted in North Lintau Buo District , Tanah Datar Regency, West Sumatra from September to October 2024. Sampling locations

were taken based on different altitudes, namely high (T), medium (S), and low (R). Three plant samples were taken from each height to obtain nine plant accessions, namely 1026 m above sea level (Accession 1), 1016 m above sea level (Accession 2), 1011 m above sea level (Accession 3), 700 m above sea level (Accession 4), 672 m above sea level (Accession 4). Accession 5), 620 m above sea level (Accession 6), 427 m above sea level (Accession 7), 427 m above sea level (Accession 8), and 427 m above sea level (Accession 9). Plant sampling locations can be seen in Figure 1.

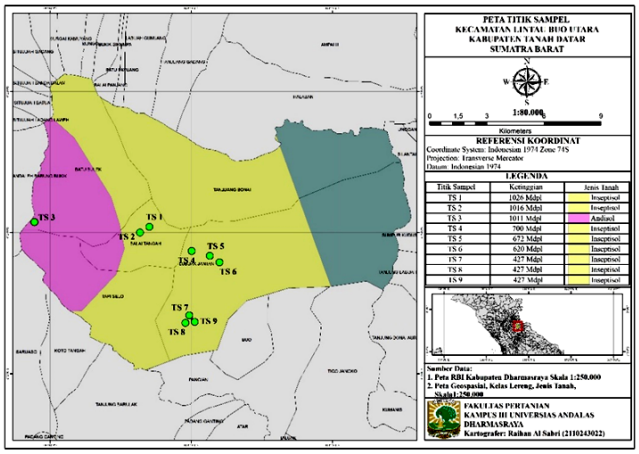

Figure 1. Sample points for sugar palm plants in North-Lintau Buo District

The research method used was a survey with a purposive sampling technique. The criteria for selected sugar palm plant samples are plants that are already producing and are > 5 years old. The materials and tools used were nine samples of sugar palm plants, clinometer, GPS, ladder, plastic, tape measure, knife, ruler, scale and caliper. Observations were made on 20 qualitative and 15 quantitative characters, including stems, leaves, palm fibers, fruit, and seeds. The qualitative and quantitative character data obtained was analyzed for genetic diversity by first converting it into binary data, scoring each variable based on established criteria (Saputri, 2011). Genetic diversity was analyzed using the formula (Steel & Torrie, 1995) :

$$S^2 = \frac{\sum(xi - x)^2}{n - 1}$$

Description:
S^2= Diversity
xi = the value of the-i observation
x = the average value of observation
n = number of observations

According to assessment criteria, phenotypic variability was determined (Pinaria *et al*., 1995). The phenotypic variance is comprehensive if value of S^2 > 2 SD and the phenotypic variance is narrow if value of S^2 < 2 SD. The formula for SD (standard deviation) :

$$SD = \sqrt{s^2}$$

Descrition:
SD = standard deviation
S^2 = diversity

The qualitative and quantitative character data obtained were analyzed by Principal Component Analysis (PCA) to determine variables with different characters based on altitude. Qualitative and quantitative character data were cluster analyzed to determine the genetic similarity or uniformity between sugar palm plant accessions. The analysis results are displayed in table and dendrogram form. Data were analyzed using Minitab-16 software.

RESULTS AND DISCUSSION

Morphological characteristics of sugar palm plants

A simple technique that can be used to determine genetic variation within species is to observe morphological differences. Phenotypic characters are divided into two, namely qualitative characters and quantitative characters. Qualitative characters are obtained by observing plant morphology while quantitative characters are obtained by observing plant agronomy (Saniaty *et al*., 2016) .

Qualitative character

The qualitative characters of sugar palm plants in North Lintau Buo District can be seen in Table 1. The results of observations of the qualitative characters of sugar palm plants show that the phenotypic variability is relatively narrow in all parameters observed. The stem characteristics of sugar palm plants observed showed that nine accessions had uniform stem surfaces, namely a combination of three different heights. Two color criteria were obtained for the bark color of sugar palm plants, namely grayish brown and dark brown. The bark is grayish brown (8 accessions) and dark brown (1 accession). The dark brown bark is found at medium altitudes, namely 700 m above sea level.

Table 1. Qualitative characteristics of sugar palm plants in North Lintau Buo District

No.	Characteristics	Criteria	Number of accessions	S^2	SD	2 SD	Description
1	Stem surface	Combina-tion	9	0	0	0	Narrow
2	Bark color	Grayish brown	8	1.58	1.27	2.51	Narrow
		Dark brown	1				
3	Frond shape	Faceted	8	0.39	0.63	1.26	Narrow
		Round	1				
4	Frond arrange-ment	Crossed	9	0	0	0	Narrow
5	Frond color	Green	9	0	0	0	Narrow
6	Petiole shape	Faceted	8	0.40	0.63	1.26	Narrow
		Round	1				
7	Petiole color	Green	9	0	0	0	Narrow
8	Build leaflets	Ribbon shaped	8	0.40	0.63	1.26	Narrow
		Elongated	1				
9	Leaflet tip	Split	9	0	0	0	Narrow
10	Base of leaflets	Tapered	9	0	0	0	Narrow
11	Leaflets spines	Parallel or straight spines	9	0	0	0	Narrow
12	Leaflets edge	Scratched/ scratched	6	0.89	0.94	1.89	Narrow
		Flat edged	3				
13	Leaflets surface	Smooth	6	0.89	0.94	1.89	Narrow
		Smooth shiny	3				
14	Leaflets layout	Crossed facing	9	0	0	0	Narrow
15	Leaflets color	Dark Green	9	0	0	0	Narrow
16	Fiber surface	Rough	9	0	0	0	Narrow
17	Palm fiber color	Brownish black	6	0.89	0.94	1.89	Narrow
		Blackish brown	3				
18	Fruit shape	Round	4	0	0	0	Narrow
19	Seed shape	Oval	1	0.75	0.87	1.73	Narrow
		Ovoid	3				
20	Young seed color	White	2	4	2	4	Narrow
		Clear white	2				

The leaf characters of sugar palm plants observed showed that the nine accessions had uniform characters at three different heights. Namely the character of the frond arrangement with the criterion of being crossed, the color of the frond and petiole with the criterion of green, the leaflet tip with the criterion of being split, the base of the leaflet being classified as tapered, the leaflets spines are classified as parallel or straight spines, the layout of leaflets is classified as crossed facing, and the color of the leaflets is classified as dark green.

Two criteria were obtained for the frond shape: faceted (8 accessions) and round (1 accession). The petiole shape also has two criteria: faceted (8 accessions) and round (1 accession). The build leaflets have two criteria: ribbon-shaped (8 accessions) and elongated (1 accession). The difference is that 1 accession of sugar palm plants was found at an altitude of 700 m above sea level,which is classified as a medium altitude.

Two criteria were obtained for the edge of leaflets observed: incised or serrated in 6 accessions and flat edges in 3 accessions. The leaflets edges at medium and high altitudes were various. At an altitude of > 1000 m above sea level, which is classified as high, leaflet edges were obtained with the criteria of being flat-edged (2 accessions) and incised (1 accession). On the other hand, at medium altitudes, namely 400 – 700 m above sea level, the edges of the leaflets were obtained with the criteria of being incised (2 accessions) and having flat edges (1 accession). Meanwhile, leaf edges were obtained with flat-edged criteria (3 accessions) at a relatively low altitude, namely 400 meters above sea level.

Two criteria were obtained for the observed leaflets surface: smooth (6 accessions) and shiny smooth (3 accessions). The leaflets surface is also found to vary at medium and high altitudes. The leaflets surface was classified as smooth in 3 accessions observed at an altitude 400 m above sea level. Meanwhile, leaflet surfaces were obtained at medium height with the criteria of being smooth (2 accessions) and shiny smooth (1 accession). On the other hand, at an altitude of > 1000 m above sea level, the leaflets surface was obtained with the criteria of being smooth (1 accession) and shiny smooth (2 accessions).

The palm fiber characteristics observed were that the palm fiber surface was relatively rough in 9 accessions at three different heights. Two criteria were obtained for the observed fiber color: brownish black (6 accessions) and blackish brown (3 accessions). The color of the palm fiber is more dominant, blackish brown at an altitude of > 1000 m above sea level.

The characteristics of palm fruit and seeds were observed in only four accessions of sugar palm plants, namely three accessions at a relatively high altitude and one accession at a medium altitude. Five sugar palm plant accessions were found to have no fruit bunches. This shows that sugar palm plants in the Lintau Buo District grow more at an altitude of > 700 m above sea level. The palm fruit shape characteristics observed were round in the four accessions. The shape of the seeds observed had two criteria: slightly oval (3 accessions) and ovoid (1 accession). The color of the young seeds observed had two criteria: white (2 accessions) and clear white (2 accessions). Sugar palm plants have a variety of seed shapes and seed colors.

Quantitative character

The quantitative characteristics of sugar palm plants in the North Lintau Buo District can be seen in Table 2. The results of observations of the quantitative characteristics of sugar palm plants show that the phenotypic variability is relatively narrow. Four criteria were observed for the trunk circumference characteristics of sugar palm plants: very large (2 accessions), large (3 accessions), medium (2 accessions), and small (2 accessions). This shows that trunk circumference is not influenced by altitude.

Three criteria were obtained for plant height characteristics: very low (7 accessions), low (1 accession), and medium (1 accession). Plant height tends to be lower at an altitude of > 600 m above sea level compared to 400 m above sea level. The height of sugar palm plants in this study was 4.43 – 18.6 m with an average of 8.28 m. According to Fadhilla *et al*. (2023), sugar palm plants with a height of 8 – 12 m are the *Arenga longipes* Mogea species. Meanwhile, according to Wardani *et al*. (2020), sugar palm plants with a height 9 – 18 m are the *Arenga pinatta* species.

The observed frond length was obtained by two criteria: short (8 accessions) and very short (1 accession). This shows that the frond lenght is not influenced by altitude. The observed leaf rachis length was obtained by three criteria: medium (4 accessions), short (4 accessions), and very short (1 accession). The leaf rachis length tends to be more energetic at low altitudes 400 m above sea level. Two criteria were obtained for the observed petiole length leaf: short (6 accessions) and medium (3 accessions). The petiole length stalk is not affected by altitude. Three criteria were obtained for the number of leaflets in one leaf: many (3 accessions), medium (1 accession), and few (5 accessions). The highest number of leaflets in one leaf is found at medium altitudes 600 – 700 m above sea level.

Table 2. Quantitative characteristics of sugar palm plants in North Lintau Buo District

No.	Characteristics	Criteria	Number of accessions	S^2	SD	2 SD	Description
1	Trunk circumference (m)	Small	2	1.13	1.06	2.13	Narrow
		Medium	2				
		Large	3				
		Very large	2				
2	Plant height (m)	Very low	7	0.44	0.66	1.33	Narrow
		Low	1				
		Medium	1				
3	Frond length (m)	Very short	1	0.09	0.31	0.62	Narrow
		Short	8				
4	Leaf rachis length (m)	Very short	1	0.44	0.66	1.33	Narrow
		Short	4				
		Medium	4				
5	Petiole length (m)	Short	6	0.22	0.47	0.94	Narrow
		Medium	3				
6	Number of leaflets in one leaf (blade)	Few	5	0.83	0.91	1.83	Narrow
		Medium	1				
		Many	3				
7	Leaflet length (m)	Short	7	0.44	0.66	1.33	Narrow
		Medium	1				
		Long	1				
8	Leaflet width (cm)	Narrow	3	0.83	0.91	1.83	Narrow
		Medium	1				
		Wide	5				
9	Number of fruit bunches per plant (bunches)	Very few	1	0.5	0.70	1.41	Narrow
		Few	2				
		Moderat	1				
10	Number of fruit strands per bunch	Very small	1	0.68	0.82	1.65	Narrow
		Small	1				
		Medium	2				
11	Fruit diameter (mm)	Very small	4	0	0	0	Narrow
12	Weight per fruit (g)	Very heavy	4	0	0	0	Narrow
13	Seed diameter (mm)	Very small	1	3.23	1.79	3.59	Narrow
		Big	1				
		Very big	2				
14	Number of seeds per fruit	3 pieces	4	0.19	0.43	0.87	Narrow
15	Weight per seed (g)	Very heavy	4	2.68	1.63	3.27	Narrow

Three criteria were obtained for the leaflet length observed: short (7 accessions), medium (1 accession), and long (1 accession). Leaflet length tends to be shorter at altitudes < 700 m above sea level. Three criteria were obtained for leaflet width observed: narrow (3 accessions), medium (1 accession), and wide (5 accessions). The Leaflet width is not affected by altitude.

Nirawati *et al*. (2020), stated that the morphological characters that have a positive correlation with sufficient values are the characters of plant height, number of leaves, and leaf length. This shows that the taller the plant, the greater the number of leaves, and the longer the leaves, causing the Brix content of palm sap to increase. However, the Brix content negatively correlates with sufficient values with environmental factors, namely light intensity under tree stands. This shows that the higher the light intensity under the tree stands, the lower the Brix content of palm sap.

The number of fruit bunches per plant had three criteria were obtained: moderate (1 accession), few (2 accessions), and very few (1 accession). The number of fruit strands per bunch is more significant at an altitude of > 1000 m above sea level than 700 m above sea level. The number of fruit strands per bunch had three criteria were obtained: medium (2 accessions), small (1 accession), and very small (1 accession). The number of fruit strands per bunch is not affected by altitude. A total of 4 accessions that were observed only obtained one criterion in the parameters of fruit diameter (very small), weight per fruit (very heavy), number of seeds per fruit (3 pieces) and weight per seed (very heavy).

The fruit weight and seed weight of sugar palm plants are grouped into early maturing and mature. The average fruit weight of sugar palm plants was 26.15 ± 2.71 g for early maturity and 43.12 ± 5.25 g for tall. The average seed weight of sugar palm plants is 1.09 ± 0.34 g for early maturity and 5.12 ± 0.49 g for tall (Komara & Kurniawan, 2021). The research results showed that the fruit weight of sugar palm plants at this location ranged between 19.61 - 44.14 g, with an average of 34.69 g. Meanwhile, the weight range for sugar palm seeds is 0.6 - 5.93 g, with an average of 3.88 g. Accessions classified as early maturing are shown in accession 3, while accession 1, accession 2, and accession 5 are classified as high. Sugar palm plants with early maturity morphology have short tree sizes with a 5-6 years production age

Diversity of morphological characters based on PCA analysis

Determining the number of principal components in taro being research at three different heights uses eigenvalues more significant than one (Agustin *et al*., 2024). An eigenvalue of more than one indicates greater diversity. The eigenvalues in PC1 show diversity and other variations are shown in the diversity in subsequent PCs. An eigenvalue smaller than one indicates that the diversity of the data is also getting smaller (Wicaksono *et al*., 2022). The eigen, proportion, and cumulative values of nine sugar palm plant accessions can be seen in Table 3. The eigenvalues obtained in this study were 5.6940 – 0.0382 with 8 axes or 8 PCs. The PC used in this research is a PC that has an eigenvalue greater than 1, resulting in 3 axes, namely PC1, PC2, and PC3. The eigenvalues were chosen only up to PC3 because they represent 86.6% of the data diversity. This research shows that sugar palm plants have various morphological adaptations based on eigenvalues and character distribution at different altitudes.

Table 3. Eigen, Proportion and Cumulative Values for nine sugar palm plant accessions

Eigenanalysis of the Correlation Matrix								
	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Eigenvalue	5.694	49.625	23.303	0.7688	0.7326	0.3465	0.1272	0.0382
Proportion	0.38	0.331	0.155	0.051	0.049	0.023	0.008	0.003
Cumulative	0.38	0.71	0.866	0.917	0.966	0.989	0.997	1

The Eigenvector value of the characters observed in nine sugar palm plant accessions based on PC1, PC2, and PC3 can be seen in Table 4. The eigenvalue on PC1 is 5.6940 with a contribution of 38% to the diversity of six characters: bark color, frond shape, petiole shape, build leaflets, leaflets surface, and palm fiber color. The eigenvalue in PC2 is 4.9625 contributing 33.1% to the diversity in four characters, namely leaflets edge, frond length, leaf rachis length, and leaflet length. The eigenvalue in PC3 is 2.3303 with a contribution of 15.5% to the diversity in five characters: trunk circumference, plant height, petiole length, number of leaflets in one leaf, and leaflet width.

Table 4. Eigenvector values of the characters observed in nine sugar palm plant accessions based on PC1, PC2, and PC3

Characteristics	PC1	PC2	PC3
Bark color	**-0.351**	0.237	0.076
Frond shape	**0.351**	-0.237	-0.076
Petiole shape	**0.351**	-0.237	-0.076
Build leaflets	**0.351**	-0.237	-0.076
Leaflets edge	0.092	**0.332**	0.095
Leaflets surface	**-0.351**	-0.189	0.178
Palm fiber color	**-0.351**	-0.189	0.178
Trunk circumference	-0.055	0.258	**0.481**
Plant height	0.185	0.085	**0.45**
Frond length	0.136	**0.359**	0.036
Leaf rachis length	0.255	**0.263**	0.087
Petiole length	-0.027	-0.312	**0.407**
Number of leaflets in one leaf	-0.157	0.219	**-0.435**
Leaflet length	-0.147	**-0.415**	0.073
Leaflet width	0.292	0.057	**0.317**

Biplot is a combination of score plot and loading plot data which forms a graph consisting of a main component and a second component of vector lines to represent the characters of plant accessions. Long vector lines show high genetic diversity while short vector lines show low genetic diversity (Wicaksono *et al*., 2022). The biplot of the sugar palm plant accession can be seen in Figure 1. The biplot of the sugar palm plant accession has four quadrants, which characterize the character criteria in each quadrant. Characters that have similarities in quadrant 1 are leaflets edge (TAD), frond length (PP), leaf rachis length (PRD), leaflet width (LAD), and plant height (TT). Character similarities observed in quadrant II were trunk circumference (LB), bark color (WK), and number of leaflets in one leaf (JADSP).

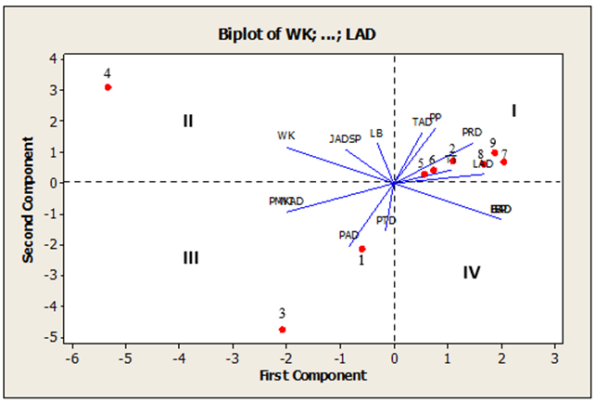

Figure 1. Biplot of nine sugar palm plant accessions

Uniformity of morphological characters based on cluster analysis

Cluster analysis is one of the methods in multivariate analysis. Cluster analysis aims to group an object into several groups with different properties so that objects in one group have relatively homogeneous properties. One cluster analysis method is hierarchical cluster analysis which aims to group observations based on the closest similarities. This method will form a hierarchy or level between objects displayed as a dendrogram. A combination of quantitative and qualitative data in kinship analysis of plant accessions is recommended to determine more informative genetic distances (Rohaeni & Greece, 2017).

A dendrogram from the results of observations of morphological characters in nine accessions of sugar palm plants can be seen in Figure 2. Cluster analysis in this study showed that the morphology of sugar palm plants was not influenced by environmental factors altitude, but by genetic factors. The qualitative and quantitative characters of 9 sugar palm plant accessions were grouped into two clusters: cluster I and cluster II. Cluster I is divided into two groups, namely IA and IB. Group IA consists of two accessions, namely accession 1 and accession 3. Group IB consists of 6 accessions: accessions 2, 7, 8, 9, 6, and 5. Cluster II consists of 1 accession, namely accession 4.

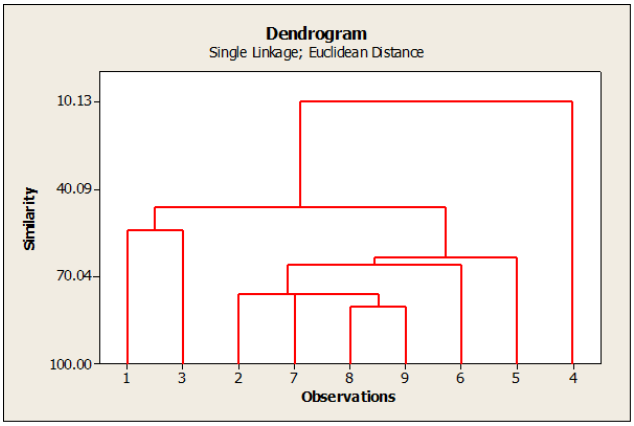

Figure 2. Dendogram of nine sugar palm plant accessions

The kinship analysis of nine sugar palm plant accessions had a level of similarity with a coefficient value of 10.13 – 80.39%. The higher the value of the plant similarity coefficient, the greater the level of plant similarity. The closest relationship distance is shown in Accession 8 and Accession 9, with a similarity level of 80.39%. Meanwhile, accession 4 has a distant relationship with accessions 1, 3, 2, 7, 8, 9, 6, and 5, with a similarity level of only 10.13%. This

shows that 8 accessions of sugar palm plants at different altitudes have relatively high similarity values and levels of kinship relationships. Hasibuan *et al*. (2023) stated that high plant relationships indicate that the source of the propagation of sugar palm plants that grow comes from areas with geographic locations that are still close together.

CONCLUSIONS

The quantitative and qualitative characteristics of sugar palm plants have relatively narrow phenotypic variability values. The kinship analysis of sugar palm plants has a level of similarity with a coefficient value of 10.13 – 80.39%. The closest relationship distance is shown in accession 8 and accession 9 with a similarity level of 80.39%. Meanwhile, accession 4 has a distant relationship with accessions 1, 3, 2, 7, 8, 9, 6, and 5 with a similarity level of only 10.13%. PCA analysis shows that accession 4 is different from other accessions based on the characteristics of bark color, frond shape, petiole shape, and build leaflets.

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