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Flowering type and morphological diversity of Bido coconut from Morotai Island District, Indonesia

SUKMAWATI MAWARDI[1,2,♥], MUHAMMAD ROIYAN ROMADHON[2], RAHMA[2], ISMAIL MASKROMO[3], DINY DINARTI[4], SUDARSONO[4]

[1]Program of Plant Breeding and Biotechnology, Graduate School, Institut Pertanian Bogor. Jl. Meranti, Kampus IPB Darmaga, Bogor 16680, West Java, Indonesia. Tel./fax.: +62-251-8629347, ♥email: umma.mawardi@gmail.com

[2]Indonesia Palm Crop Research Institute. Jl. Raya Mapanget, Manado 95259, North Sulawesi, Indonesia

[3]Research Center for Horticultural and Estate Crops, Research Organization for Agriculture and Food, National Research and Innovation Agency. Jl. Raya Jakarta-Bogor Km 46, Cibinong, Bogor 16911, West Java, Indonesia

[4]Departement Agronomy dan Horticulture, Faculty of Agriculture, Institut Pertanian Bogor. Jl. Meranti, Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia

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Abstract. *Mawardi S, Romadhon MR, Rahma, Maskromo I, Dinarti D, Sudarsono. 2023. Flowering type and morphological diversity of Bido coconut from Morotai Island District, Indonesia. Biodiversitas 24: 1473-1481.* In general, coconuts are divided into Tall and Dwarf types. Dwarf coconut is early bearing and has a short trunk, while Tall coconut yields high-quality copra and has a large fruit size. Furthermore, Bido-Tall coconut is an early bearing with a short trunk, medium size fruit, and high-quality copra. This research aims to evaluate Bido coconut population variations and study the flowering types of Bido and other coconut types in the research locations. Morphological and flowering type observation was conducted for Bido Tall, Local Tall, Local Dwarf, and Bido Tall outcrossing progenies at Bido Village, North Maluku, Indonesia. Flowering-type observations were carried out on three successive inflorescences. The Bido Tall, Dwarf, and the Bido Tall outcrossing progenies exhibited natural autogamy pollination, while the Local Tall coconut was semi-autogamy. The Principal Component Analysis (PCA) results indicated that the stem girth at 20 cm and 150 cm above ground, the internode length, the leaf numbers, the fruit color, and the fruit numbers cumulatively contributed to 68.80% of the observed coconut variabilities. Most Bido Tall coconut individuals were clustered separately from the existing local Tall and Dwarf coconuts. However, the clustering analysis showed average similarity among Bido Tall, the Local Tall, and Dwarf coconuts are still above 70%. The similarity coefficient among the Bido Tall coconut, the Bido Tall outcrossing progenies (natural hybrids), and the Local Tall was higher than among Bido Tall to the Local Dwarf coconuts.

Keywords: Analysis cluster, autogamy, flowering pattern, genetic diversity, principal component analysis

INTRODUCTION

Most coconut (*Cocos nucifera* L.) palm parts, such as roots, stems, and leaves, and every fruit component has many uses; therefore, coconuts are known as the tree of life (Kamaral et al. 2017). Endosperm and coconut water contain vitamins, minerals, amino acids, phytohormones, and monolaurin. They are useful as antioxidants, anti-microbial (DebMandal and Mandal 2011), decrease anxiety (Zubair et al. 2017), treatment for Alzheimer's (Bansal et al. 2019), healthy drinks, and hormone source for plant tissue culture (Yong et al. 2009). Coconut sap, obtained from tapping unopened spadix, has a higher nutritional and antioxidant content but a lower glycemic index than sugar palm and sugar cane juice (Asghar et al. 2019). Although it has many benefits, there are also some constraints in the coconut industry. The decreasing number of coconut climbers due to the considerable risk of coconut climbing and low productivity has become a significant constraint in future coconut development.

Coconuts are divided into Tall or typica (Nar.) and Dwarf or nana (Griff.) types. The unique characteristics of the Tall coconut include the presence of bole, high yearly height increment, late bearing (first flower at 6-10 years after planting), productivity up to 60-70 years, cross-pollination, large fruit size, and high oil content. On the other hand, Dwarf coconuts have no bole, low yearly height increment, early bearing (first flower at 3-4 years old), productive up to 30 years, and self-pollination (>95%). Cross-pollination may occur in Dwarf types surrounded by Tall coconuts. Moreover, the other Dwarf coconut's disadvantages include small fruit size and the chewy endosperm (Krisanapook et al. 2019) because of the high galactomannan and phospholipid content in the endosperm. Therefore, Dwarf coconut endosperm is unsuitable for the coconut oil processing industry by the dry method (Karouw et al. 2015).

Developing hybrid coconut varieties by crossing Tall × Dwarf coconuts is the alternative solution to overcome the limitations of the Tall and Dwarf coconut types. However, Indonesia's five commercial hybrid coconut varieties cannot meet market demands. The Indonesian Palm Crops Research Institute (IPCRI) exploration in the Morotai Islands District, North Maluku, Indonesia, in 2016 identified the Bido Tall coconut with prominent Tall coconut characteristics but low yearly stem height increment and early bearing similar to the Dwarf type (Tulalo et al. 2019). In addition, the Bido coconut exhibited characteristics of the aurantiaca-type or Semi-Tall coconuts (Kamaral et al. 2016). Due to the limited number of mother plants, the development and multiplication of Bido coconut are limited. Since the Bido coconuts are intermixingly grown in the same areas as the local Tall and Dwarf coconuts, there are possibilities of gene flows among them. Moreover, limited genetic diversity and flowering pattern information make it challenging to devise future breeding goals for the unique Bido coconut.

Understanding plant flowering biology is beneficial in supporting plant breeding (Rognon 1976) and understanding phylogenetic relationships and the evolutionary processes (Perera et al. 2010). Coconut flowering information regarding female phases is essential to determine the frequency and duration of artificial pollination (Thomas and Josephrajkumar 2013). In addition, the anthesis period is needed to determine the pollen harvest time as the male parent in hybrid coconut production (Maskromo et al. 2011). Generally, Tall coconut's flowering types are allogamy and indirect autogamy. While Dwarf is direct autogamy and semi-direct autogamy (Thomas dan Josephrajkumar 2013). However, some dwarf coconuts are cross-pollinated. For example, it has been reported that Nam Hom Dwarf coconut shows an excellent opportunity for cross-pollination because female receptive and male flower anthesis do not overlap (Luckanatinvong dan Siriphanich 2018). In other reports, some Chowghat Green Dwarf) and Malayan Green Dwarf coconuts showed partial overlapping between anthesis and receptive (Thomas et al. 2015).

Meanwhile, morphological characteristics have been used to analyze the phenotypic diversity and parents' selection for hybridization programs (Jerard et al. 2017). Moreover, phenotypic diversity analysis based on morphological characters is the first step for identifying desirable genotypes among the existing germplasm. Multivariate analysis can be completed using morphological diversity of many correlated phenotypes and cluster analysis. This study aims to evaluate the flowering types and analyze the morphological diversity among existing coconut populations in Bido Village, North Maluku, Indonesia.

MATERIALS AND METHODS

The study was conducted in Bido Village, Morotai Islands District, North Maluku Province, Indonesia (Figure 1) from March to August 2021. Flowering-type observations were carried out on five plants of Bido Tall, Local Dwarf, Local Tall, and Bido Tall outcrossing progenies (natural hybrid) in Bido Village, using three consecutive inflorescences. Historically, one single germinated Bido coconut was found in the sea by a local fisherman named Bosu Labaka and was planted in Bido Village with other local coconuts (Tall and Dwarf) (Tulalo et al. 2019).

Coconut-flowering types are classified according to the flowering pattern: allogamy, indirect autogamy, direct autogamy, and semi-direct autogamy (Rognon 1976). The observed characters are the male and female flower phases. That includes the male phase (MP), the beginning of the female phase (BFP), the end of the female phase (EFP), the Female phase (FP), the end of male phases in the previous inflorescence (EMP), and the beginning of a male phase in the following inflorescence (BMP). The male phase occurs when the male flower first anthesis (day of spathe open) until the last anthesis. The female phase occurs when the first female flower is receptive until the last female flowers have been pollinated (Thomas and Josephrajkumar 2013). Observation of the flowering type using a single factor Randomized Completely Block Design, i.e., coconut type in the coconut population in Bido Village. The DMRT testing is further carried out using the package (Agricolae) with the R software 4.05 if the mean values of the character are observed to be significant at α 5%.

The genetic material used for the morphological diversity was 148 Bido Tall, 31 Bido Tall outcrossing progenies, 13 local Dwarf, and 37 local Tall coconut trees. The characters measured were stem girth at 20 cm above ground, stem girth at 150 cm, eleven leaf scar length, leaves number, bunches number, fruit number, and fruit color. First, the morphological data obtained were calculated for the diversity coefficient. Next, analyzed using Mahalanobis software R 4.05 version with biotools packages, cluster analysis using packages cluster, and principal component analysis (PCA) using gg biplot packages (gg biplot) with software R 4.05 version.

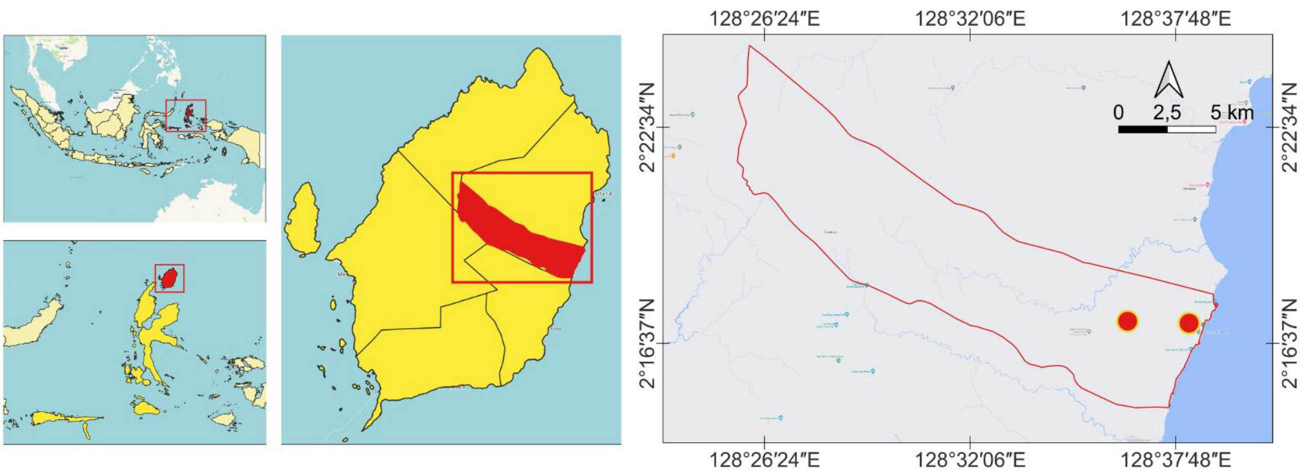

Figure 1. Map of research site of the coconut population in Bido Village, Morotai Island District, North Maluku Province, Indonesia

RESULTS AND DISCUSSION

The flowering types of coconut

Based on the evaluated data, Bido Tall, Bido Tall outcrossing progenies, and local Dwarf coconut have direct autogamous pollination types, where there is overlap between male and female phases in the same flowering. Meanwhile, the local Tall has a semi-direct autogamous, overlapping degree of some female and male phases in the same and the next inflorescence (Figure 2). The overlapping of flower receptive and receptive shows that the local Tall in Bido Village also has a chance of self-pollination. The possibility of overlapping increases due to more than one monthly inflorescence production (Weerasinghe et al. 2022). While the spathe of the next inflorescence is open, and the male flowers are anthesis, the following female flowers are still receptive (Nayar 2018). Therefore, environmental conditions in certain seasons could allow for self-pollination due to the overlap of male and female phases (Gangolly et al. 1957). Those factors may be the ones causing different flowering types of Tall coconut in this experiment. Therefore, further observation of continuous flowering cycles in some seasons needs to be carried out to confirm this hypothesis.

Dwarf coconuts also have the opportunity to cross-pollinate if surrounded by Tall coconuts (Krisanapook et al. 2019). In coconut plants, female flowers are receptive after the spathe is opened. So even though Bido coconut has a direct autogamous, because it is planted between Tall and Dwarf coconuts, it allows pollen contamination, especially by insects. Research conducted on the population of *kopyor* coconuts in Pati District showed that Dwarf coconuts had to be cross-pollinated with other Dwarf, Tall, and hybrid coconuts, as much as 18.1%, 7.2%, and 13.3%, respectively (Larekeng et al. 2015). This research found the existence of Bido progenies that change the fruit color characteristics and the distance between the leaf scars. In this study, the Bido progenies with such characteristic changes are categorized as Bido Tall outcrossing progenies (natural hybrid).

Male phases, the beginning of male and female phases are not significantly different in Bido Tall, Bido Tall outcrossing progenies, local Dwarf, and local Tall. However, Bido Tall significantly differs from Bido outcrossing progenies, Dwarf, and Tall in female phases (Table 1). Therefore, the longer receptive period of Bido coconut compared to Dwarf, Tall, and Bido Tall outcrossing progenies can provide information regarding the time required for artificial pollination of Bido coconut as female parents in the assembly of hybrid varieties.

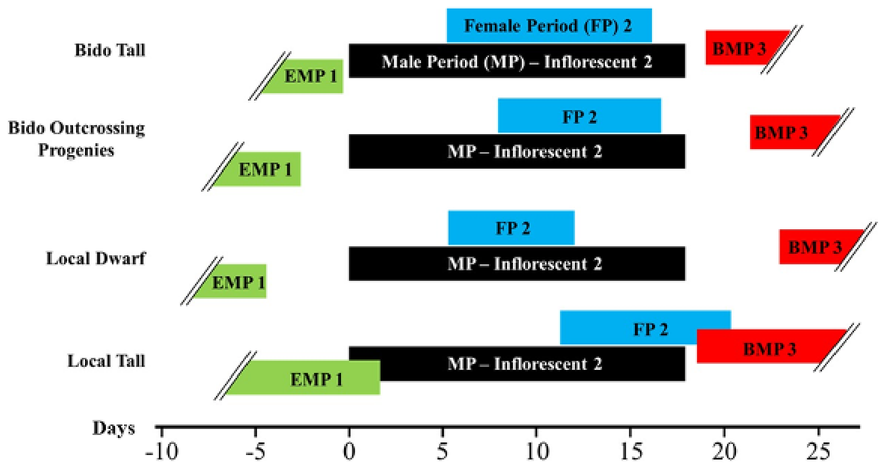

Figure 2. Flowering patterns of the coconut population in Bido Village, Morotai Island District, North Maluku Province, Indonesia, comprised Bido Tall, Bido Tall outcrossing progenies (natural hybrids), local Dwarf, and local Tall coconuts. EMP 1: End of the male period of inflorescent 1; FP 2: Female period of inflorescent 2; MP2: Male period of inflorescent; BMP 3: Beginning of the male phase of inflorescent 3

Table 1. The variation of coconut flowering of the coconut population in Bido Village, Morotai Island District, North Maluku Province, Indonesia

Types	MP (day)		BFP (day)		EFP (day)		FP (day)		EMP (day)		BMP (day)	
Bido	17.86	a	5.14	a	16.07	a	11.93	a	-0.50	a	19.10	B
Bido Tall outcrossing progenies	17.33	a	8.00	a	16.56	a	9.55	bc	-2.67	a	21.83	Ab
Local Dwarf	17.22	a	5.11	a	12.00	a	7.89	c	-4.50	a	22.50	A
Local Tall	17.78	a	11.11	a	20.33	a	10.22	b	0.83	a	18.67	B

Note: A number followed by the same letter is not significantly different at α 5%; MP: male phase; BFP: the beginning of the female phase, EFP: the end of the female phase, FP: Female phase, EMP: The end of male phases in the previous inflorescence, BMP: The beginning of a male phase in the following inflorescence

Morphological diversity of the coconut population in Bido Village

Information on morphological characters is essential in population diversity analysis. The characters commonly used as a reference for the study are stem, leaf, and fruit (Gunawati et al. 2018). Based on the morphological observation results (Table 2), stem girth at 20 cm above ground, fruit number, bunches number, and eleven leaf scar length had a coefficient of variance (CV) >20%. The variability of a character is relatively high if the coefficient of variance is >20% (Yao et al. 2015). Characters with high diversity provide opportunities for selection to improve plant traits, especially those that correlate with increased yields (Miftahorrachman et al. 2017).

The character of fruit number is influenced by the potential of each individual to produce female flowers, the flowering phase, pollination opportunities, and the success rate of fertilization. Pollination can occur by pollen from the same or different inflorescence on the same tree or other trees. Pollination in coconut occurs with insects or wind; insects have the most significant role in pollination. Open pollination of Tall coconut flowers generated 51.6% development of the female flowers into fruits. However, forcing the male flowers to self-pollinate the female of the same inflorescence only resulted in 1.9% of female flower conversion into fruits (Ashburner et al. 2001).

Genetics and the environment influence the number of female flowers in each inflorescence, while the age of the palms also contributes considerable effects. The water and nutrient availabilities affect the number of female flowers during flowering. Since the inflorescence initiation process to the open spathe takes up to two years (Perera et al. 2010; Krisanapook et al. 2019); Therefore, prolonged drought will affect fruit production for two years in the future. In addition to the environment, the age of the plant also affects the number of female flowers of the coconuts. The number of female flowers is limited at the early ages (Thomas dan Josephrajkumar 2013) and increases at the later stages. Thus, the number of flowers produced on the same trees but in different bunches can differ (Maskromo et al. 2011).

The character of eleven leaf scar length and fruit number on the local Dwarf in Bido Village has a high coefficient of variance. Theoretically, Dwarf tends to self-pollinate and should have a more uniform morphology than the Tall with cross-pollinating. However, the Dwarf coconut in Bido village consists of several different accessions introduced by the locals, so they have high diversity in the population. The difference in fruit color in the Dwarfs population also shows differences in accession to the population found in Bido Village. In Dwarf coconut, variety naming is based on the fruit's color (Tammes dan Whitehead 1969). Then, the high variance coefficient in Bido Tall is predicted by pollen contamination from Tall coconut, resulting in progeny with a varying character of internodes length. For that reason, Bido progenies need selection and purification from the off-type progenies.

The local Tall coconuts found in Bido Village have a variety of fruit color characteristics. The Tall coconut has variation in fruit color due to the high probability of cross-pollinated among individual plants in the population. As a result, several variations in fruit color could be found in the same Tall coconut variety. Thereby, no fruit color attributes are assigned in the naming of Tall coconut varieties and their naming only refers to where the Tall coconut is found or the presence of certain special characters. The variation in the character of Tall coconut makes it challenging to distinguish between Tall coconut varieties (Tammes dan Whitehead 1969).

Based on the stem girth character, Bido coconut has a bole, that is the Tall coconut characteristic. However, the eleven-leaf scar length character (31.62 ± 7.65 cm) shows that Bido coconut is slowly growing, similar to Dwarf coconut. Other characteristics of Bido coconut are early bearing (i.e., bearing fruits at three years after planting), large fruit sizes, and green fruit color (Novarianto et al. 2016).

Table 2. Means and Coefficient of Variance (CV) of seven characters of the coconut population at Bido Village, Morotai Island District, North Maluku Province, Indonesia

Parameters	Bido tall		Bido outcrossing progenies		Local tall		Local dwarf	
	Average	CV	Average	CV	Average	CV	Average	CV
Stem girth at 20 cm above the ground (SG20 cm)	147.98	15.16	173.45	10.49	166	15.35	87.12	24.6
Stem girth at 150 cm above the ground (SG150 cm)	85.61	8.62	91.1	7.09	102.47	9.89	71.38	12.58
Eleven leaf scar length (EL, cm)	31.62	24.18	57.75	21.02	81.86	19.96	35.62	39.45
Leaves number (LN)	30.6	11.23	30.84	7.37	30.17	8.96	25.31	12.14
Fruit Color (FC)	G	G, BG, YG, GB, LB, YB	G, YG, BG, LB, RB, YB, GB	G, B, LB, O				
Bunch number (BN)	13.35	19.05	11.52	25.8	13.09	19.02	9.42	22.72
Fruit number (FN)	6.73	27.46	7.38	37.01	8.92	35.79	6.71	83.61

Note: G: green; BG: brownish green; YG: yellowish green; GB: greenish brown CM: light brown; CME: reddish brown; CK: yellowish brown; O: orange; B: brown

Principal component analysis of the coconut population in Bido Village

Multivariate analysis based on phenotypic data is the most widely used genetic diversity analysis method. The multivariate analysis provides various important information for the conservation of accessions, individuals, populations, and varieties, as well as the identification of novel accessions and their genetic improvement (Kumar et al. 2020). The principal component analysis (PCA) is a multivariate analysis that explores the factors contributing to evaluating plant characteristics (Suzana et al. 2020). The PCA was used to simplify the data presented (Rahevar et al. 2021). Based on the analysis results, the three main components contributed to the diversity of 68.80%, with an Eigen-value significant of more than one (Table 3). Eigenvalue greater than one can be a criterion because if it is smaller than one, it is considered non-significant (Jadhav et al. 2021).

The first principal component (PC1) contributed the most significant diversity (30.17), followed by PC2 (22.90), PC3 (15.72), PC4 (9.89), and PC 5 (8.70). The characteristics of stem girth at 150 cm above ground, eleven leaf scar length, fruit color, fruit number, leaves number, and stem girth at 20 cm above ground gave positive and significant contributions to the observed coconut variability, viz 0.682, 0.660, 0.646, 0.642, 0.536, 0.554, respectively. Meanwhile, the character of the bunch number (-0.631) gave a negative contribution. Characters with a variability value >0.5 significantly affect the principal component analysis.

Most Bido coconuts are grouped into one cluster (Figure 3), thus with the Dwarf and Tall coconuts. The character of eleven leaf scar length gave the most significant contribution to the grouping, followed by fruit color, leaves number, bunch number, stem girth at 150 cm above ground, fruit number, and stem girth at 20 cm above the ground (Figure 4). Several genotypes of Bido coconut grouped with Tall, possibly contaminated by pollen from Tall around the Bido coconut parents. However, it did not affect much the main distinguishing characteristic of Bido coconut. Coconuts categorized as Bido outcrossing progenies are those with changes in fruit color or the length of internodes characteristics. Several outcrossing progenies are clustered with Dwarf, Tall, or both coconut; the possibility depends on the type of coconut that is the source of contaminants. Efforts to purify Bido coconut must provide the true-to-type Bido coconut as parent sources (Novarianto et al. 2022).

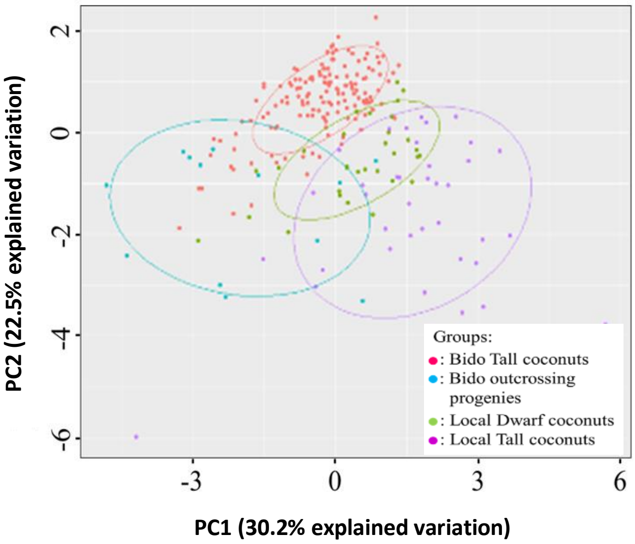

Figure 3. The cluster plot represents the distribution of 229 accessions of the coconut population in Bido Village, Morotai Island District, North Maluku Province, Indonesia

Table 3. The Eigen-values, score factors, and principal component axis contribution of seven traits in 229 accessions of the coconut population in Bido Village, Morotai Island District, North Maluku Province, Indonesia

Traits	PC1	PC2	PC3	PC4	PC5
Stem girth at 20 cm above the ground (SG20)	0.554	0.131	**-0.736**	0.123	-0.122
Stem girth at 150 cm above the ground (SG150)	**0.682**	-0.082	0.050	-0.680	0.224
Eleven-leaf scar length (EL)	0.587	**0.660**	-0.205	0.153	0.017
Leaves number (LN)	0.536	**-0.570**	-0.097	0.153	0.182
Fruit color (WB)	0.329	**0.646**	0.501	0.211	0.332
Bunch number (BN)	0.435	**-0.631**	0.184	0.352	0.193
Fruit number (FN)	**0.642**	-0.057	0.468	0.001	-0.602
The Eigen-value	2.112	1.603	1.100	0.692	0.609
Explained variation (%)	30.173	22.900	15.721	9.892	8.698
Cumulative explained variation (%)	30.173	53.073	68.795	78.686	87.385

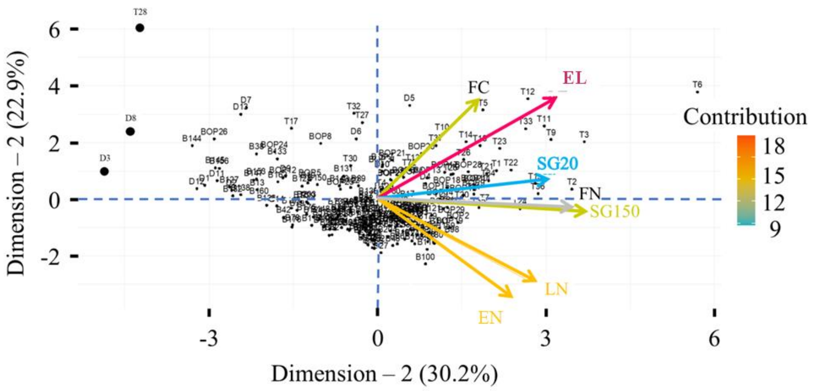

Figure 4. The contribution of various traits and accession distributions across two components of 229 accessions of the coconut population in Bido Village, Morotai Island District, North Maluku Province, Indonesia

Cluster analysis

The coconut population in Bido Village can be divided into three main clusters with six sub-cluster and four sub-sub-cluster (Figure 5). Cluster 1 consisted of 181 genotypes from a total of 229 genotypes observed. In this cluster, there are 136 Bido Tall (B), 23 local Tall (T), and 22 Bido Tall outcrossing progenies (BOP). Cluster 2 has 21 genotypes consisting of 14 Tall coconuts, 3 Bido Tall outcrossing progenies, and 4 local Dwarf (D). Cluster 3 consisted of 27 genotypes, 12 Bido Tall, 6 Bido Tall outcrossing progenies, and 9 local Dwarf. The genotypes in cluster 1 are divided into two sub-clusters. Each is further divided into two sub-subclusters (1.a.1, 1.a.2, 1.b.1, 1.b.2). In sub-subcluster 1.a.1, there are 64 Bido Tall, one local Tall, and four Bido Tall outcrossing progenies. Meanwhile, sub-subcluster 1.a.2 has only Bido tall with 48 genotypes. Sub-subcluster 1.b.1 consists of five Bido Tall outcrossing progenies, 18 local Tall, and one Bido Tall, while sub-subcluster 1.b.2 has 12 Bido Tall outcrossing progenies, four local Tall, and 24 Bido Tall. In cluster 2, there are eight local Tall in sub-cluster 2.a, six local Tall genotypes, three Bido Tall outcrossing progenies, and four local Dwarf in sub-cluster 2.b. Finally, there are 27 genotypes in cluster 3, consisting; of 12 Bido Tall and six Bido Tall outcrossing progenies in sub-cluster 3.a, and nine local dwarfs in sub-cluster 3.b.

Bido coconuts are dominant in cluster 1.a. The Bido Tall outcrossing progenies are in cluster 1.b along with 24 Bido coconut and 22 Tall coconut accessions. Meanwhile, the Dwarf coconuts are in cluster 3.b, and some Tall ones are in cluster 1.b. Several Bido Tall accessions are also in cluster 2 with some Tall accessions and in cluster 3 with some Dwarf coconuts, although they have main characters similar to Bido Tall coconuts. Such clustering is probably due to the stem girth characteristics, which contribute to the diversity of Bido coconut. For example, genotype B81 has a stem girth of 150 cm above ground, similar to the local Tall.

Meanwhile, the local Tall T29 is clustered with most Bido coconuts because the fruit color and the stem girth characters of T29 matched those of Bido, even though the late bearing and the eleven-leaf scar length indicated that it is a Tall type. Figure 5 shows that the BOPs are grouped into several clusters. In cluster 1.b, BOPs are grouped with Tall, and in cluster 3.b, Dwarf. The possibility of this grouping is related to the coconuts type, which probably is the source of progeny contaminants.

Bido Tall is separated into several clusters (clusters 1.a, 1.b, and 3.a), indicating the existence of variation in the Bido Tall coconut population, so selection and purification of Bido coconuts is needed. Purification of Bido Tall using morphological data needs to be verified using molecular markers to eliminate the environmental effect on morphological diversity. Several studies on diversity analysis in palm plants using molecular markers have been conducted (Natawijaya et al. 2019). Research on the population of Puan Kalianda Tall kopyor coconut using SSR markers shows that the coconut has high genetic diversity (Rahayu et al. 2022). SSR markers using a specific locus are also able to distinguish pure Sri Lanka Yellow Dwarf (SLYD) from Sri Lanka Yellow Semi Tall (SLYST) and mixed morphological group (ML), which cannot be distinguished morphologically in seedlings (Kamaral et al. 2017).

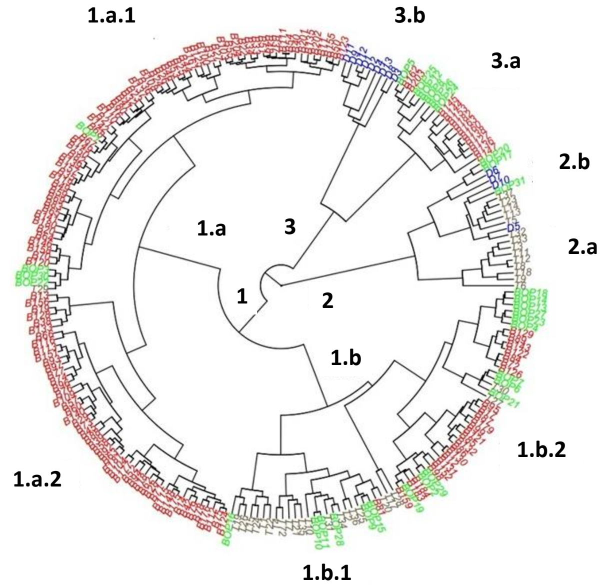

Figure 5. Grouping of 229 coconut accessions at Bido Village, Morotai Island District, North Maluku Province, Indonesia

The average similarity coefficient between genotypes in Bido coconut is 0.8998 or 89.98%. In contrast, the average coefficient of similarity of Bido Tall with genotypes of Tall, Bido Tall outcrossing progenies, and Dwarf are 82.52%, 85.77%, and 80.12%, respectively. The average percentage similarity between Bido with Tall, Bido Tall outcrossing-progenies, and Dwarf were 78.70%, 84.89%, and 77.35%, respectively (Table 4). Generally, the Dwarf coconut has low diversity because it is self-pollinated, and the allele is homozygous (Perera et al. 2016). However, this study shows the percentage of similarity between individuals of Dwarf is the lowest compared to other types of coconut. The low similarity is maybe due to the dwarf coconuts being different accessions from several areas outside Bido Village; another possibility is a cross or mutation. Dwarf germplasm in Borneo showed high diversity, correlated with mutations in the rbcL region (Mursyidin dan Ahyar 2022). Overall, the average similarity coefficient for the coconut population in Bido Village is 84.45% which showed that the similarity coefficient between individuals in all coconut types was quite significant.

D^2 Mahalanobis analysis

The inter and intra-cluster estimation can be done by the D2 Mahalanobis method (Fasikaw et al. 2019). Based on the results of the Mahalanobis analysis, the coconut population in Bido Village is divided into nine clusters (Figure 6). Cluster 1 is the most significant (75.11%), followed by cluster 2 (11.79%). Most Bido coconuts were found in cluster 1, i.e., 79.73% of the total Bido coconuts observed. Local Tall (81.08%) and Bido outcrossing progenies (74.19%) were also the most abundant in cluster 1. Meanwhile, the local Dwarf was mostly in cluster 2 (61.54.78%). Bido coconut, which is in the same cluster as Tall, shows that Bido coconut is morphologically closer to Tall. However, 18 of 147 Bido Tall individuals are in cluster 2 with Dwarf, probably because their parents resulted from a cross between Bido and Dwarf. In another experiment, Pan et al. (2017) also found that Hybrid Coconut WY78F1 (Yellow Dwarf x Hainan Tall), whose morphological character is more dominant than Dwarf coconuts and was grouped as Dwarf based on molecular analysis using ISSR markers. Several genotypes are independent in clusters, namely B182, D6, and G28. The genotypes in this cluster indicate the maximum diversity. The highest intra-cluster D2 value in Table 5 was found in cluster 1 (27.09), followed by cluster 3 (23.51) and cluster 2 (19.80). In comparison, the smallest value is in cluster 4 (5.97). Table 5 shows the vast genetic diversity between genotypes in cluster 1, which consists of Bido coconuts, Bido outcrossing progenies, and Tall coconuts. Clusters 6 (Dwarf) and 8 (Tall) have the most considerable intercluster distance, indicating that their morphological characters are distinct.

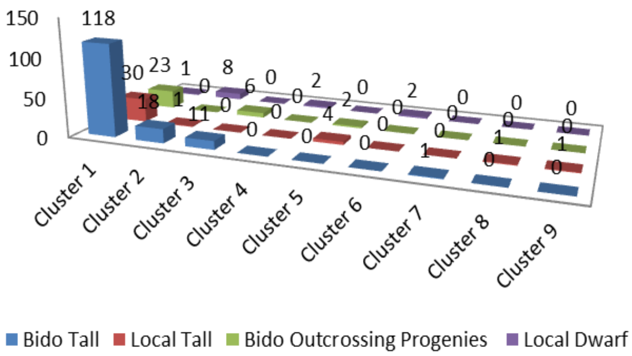

Figure 6. Distribution of 229 genotypes of coconut in clustering using D^2 Mahalanobis analysis of the 229 coconut population in Bido Village, Morotai Island District, North Maluku Province, Indonesia

Table 4. Average of similarity coefficient between Bido Tall, Bido outcrossing progenies, local Tall, and local Dwarf of the coconut population in Bido Village, Morotai Island District, North Maluku Province, Indonesia

	Bido Tall	Bido outcrossing progenies	Local Tall	Local Dwarf
Bido Tall	0.8998			
Bido outcrossing progenies	0.8489	0.8577		
Local Tall	0.7870	0.8102	0.8252	
Local Dwarf	0.7730	0.7322	0.6903	0.8012

Table 5. Average of intra-cluster dan inter-cluster distance among nine clusters in 229 coconut genotypes of the coconut population in Bido Village, Morotai Island District, North Maluku Province, Indonesia

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Cluster 8	Cluster 9
Cluster 1	**27.09**	57.61	93.69	126.00	47.10	97.82	101.64	92.25	42.13
Cluster 2		**19.80**	99.28	85.39	100.99	43.33	79.46	145.88	70.04
Cluster 3			**23.51**	91.14	112.91	116.28	49.20	153.90	107.55
Cluster 4				**5.97**	166.45	63.71	42.86	213.38	136.72
Cluster 5					**13.07**	141.90	136.22	48.75	53.24
Cluster 6						**10.61**	79.63	186.89	105.95
Cluster 7							**0.00**	182.33	116.13
Cluster 8								**0.00**	91.46
Cluster 9									**0.00**

Analysis cluster and D^2 Mahalanobis analysis showed that Bido coconut is closest to Bido outcrossing progenies. It may be because that seed's source comes from Bido coconut. However, there are morphological changes both from a distance between leaf marks and fruit color, which are thought to be due to pollen contamination from other coconuts around Bido coconut. The most frequent character changes occurred in Bido outcrossing progenies is the distance between the leaf marks, while the fruit color is typically similar to the Bido coconut (green). Two loci (R or r and G or g) control the fruit color character. Green fruit has genotypes (rrG-), red (R-gg), yellow (rrgg), and coconut, which have dominant genes at both loci (R-G-), producing brown fruit color (Bourdeix 1988). Several generations of Bido coconut retain its green fruit color, indicating the possibility of being homozygous at the G locus (rrGG), and there is a tendency to self-pollinate. Just a few BOPs with a fruit color characteristic other than green, possibly due to pollen contamination by red or brown coconuts, resulting in brown fruit color.

Besides that, Bido coconut was more abundant in the same cluster as local Tall in the Mahalanobis and cluster analysis. It showed that Bido coconut was closer to the Tall type than the Dwarf type. The Bido coconut has a thick and stout shape like the Tall coconut but also has the characteristic of fast fruiting and slow to grow taller like a Dwarf. The characteristics of early fruiting are related to the photoperiod gene. Dwarf, which early fruiting has only one transcript type lacking six nucleotides, while Tall was abundant (Xia et al. 2020). Meanwhile, there was a segment deletion on chromosomes 4 and 12 in Dwarf for the characteristic of plant height, which was related to plant height and cellulose content (Wang et al. 2021).

The plant height and stem circumference are characteristics which their inheritance is influenced by additive genes and controlled by many genes (Sivakumar et al. 2020). The characteristic of the flowering pattern in Bido coconut, which tends to self-pollinate, allows these genes to be homozygous and become fixed. So that the slow-growing characteristic can still be maintained by Bido coconut even though it is planted between Tall coconuts that can be the source of pollen contaminants. Different genes control the bole and height characteristics; a single codominant gene regulates the bole character. The tall coconut has genotype B- and the Dwarf is bb (Perera et al. 2016).

In conclusion, Bido Tall, local Dwarf, and Bido Tall outcrossing progenies coconuts have a direct autogamous pollination type; in Tall, the pollination type is semi-autogamous. Based on the morphological characteristics, most Bido Tall coconut individuals were clustered separately from the existing local Tall and Dwarf coconuts. However, the average similarity between Bido Tall with local Tall and Dwarf coconuts is still above 70%. Based on morphological characteristics, the similarity coefficient between Bido Tall to Bido Tall outcrossing progenies (natural hybrids) and the Local Tall was higher than the Bido Tall and the Local Dwarf coconuts. While based on the flowering characteristic, Bido Tall has similarities with the Dwarf coconut. Meanwhile, in clustering analysis based on morphological characteristics of Bido coconut is closer to Tall. So it is necessary to consider grouping the Bido Tall into semi-Tall types.

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