Morphological diversity and relationship among cashew (Anacardium occidentale L) individuals in three districts of Southeast Sulawesi, Indonesia

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Abstract. Cashew (Anacardium occidentale L), a species belonging to the family Anacardiaceae, has been cultivated throughout most of Indonesia’s areas and has become a priority commodity in Southeast Sulawesi for years. However, the information about its variation on morphology and relationship among individuals are still limited. This study aimed to determine the morphological variations and relationships among cashew individuals in three districts (Konawe, South Konawe, and East Kolaka) of Southeast Sulawesi. As many as ninety individuals were analyzed on 15 morphological variables for the variations and 47 variables using the complete linkage method based on Gower distance for the clustering. The coefficients of variation were varied on all evaluated variables. The highest was the height of main branches (cm), ranging from 47.32% to 73.72%. Meanwhile, nut length had the lowest coefficient of variation (6.75%-7.99%). The individuals were divided into two main clusters with two sub-clusters for each cluster.

1. Introduction

Cashew (Anacardium occidentale L) is a tree in the family Anacardiaceae originating from southern America (Bolivia, Brazil, Ecuador, and Peru) [1,2]. In Indonesia, this species has been cultivated for years in Central Java, Yogyakarta, East Java, Bali, South Sulawesi, West Nusa Tenggara, East Nusa Tenggara, and Southeast Sulawesi [3]. The cashew cultivation area in Indonesia reaches approximately 506.752 ha, and its production is approximately 135,569 tons [4]. It is selected as one of the priority commodities by the government for agricultural and economic development [5].

Southeast Sulawesi is one of cashews’ central productions in Indonesia, was reported to produce as many as 25,902 tons in 2015. However, in the following years, the production continued to decrease consistently from 25,366 tons in 2016 to 23,816 tons in 2017 [6]. The reduction in production is assumed due to insufficient cultivation techniques, plant genetic, as well as environmental issues.

Genetic variation or genetic diversity is crucial for a species because it affects the capacity of a species to adapt to climate changes [7] [8]. The variations in morphological characters indicate the adaptive evolution and the reflection of a species reacting to the climatic conditions [9]. The higher the genetic variation of a species in a population, the higher the possibility of a species to survive in environmental stresses [10]. Moreover, a strategy to increase plant genetic diversity is by crossing plants with a distant genetic relationship. This strategy is beneficial not only to increase genetic diversity but also for breeding and conservation programs.
The information about genetic diversity and relationship among cashew accessions in Southeast Sulawesi, particularly in South Konawe, Konawe, and East Konawe, is still limited. Thus, the present study investigated the morphological diversity and relationship among ninety cashew accessions from South Konawe, Konawe, and East Konawe, Southeast Sulawesi, Indonesia.

2. Materials and method

2.1. Plant materials
As many as thirty accessions of cashew were selected as samples from three districts in Southeast Sulawesi: South Konawe, Konawe, and East Konawe. The total sample used in this study was ninety accessions. The selected accessions were above 20-year-old adult trees, which were selected using purposive sampling.

2.2. Research procedure
The variables of morphological characters were based on the cashew descriptor released by IBPGR (1986) and Nayakporate (2014) [11] (Table 1). The data were collected by measuring and counting (for quantitative data) and observing (for qualitative data). The coordinate of each tree was recorded using Garmin Montana 680 (Figure 1).

![Figure 1. Map of the selected cashew individuals in three districts (South Konawe, Konawe, and East Kolaka), Southeast Sulawesi, Indonesia.](image)

| No | Morphological character               |
|----|--------------------------------------|
| 1  | Internode length of twig             |
| 2  | Height of main branches              |
| 3  | Leaf size                            |
| 4  | Extension growth of twigs            |
| 5  | Twig diameter                        |
| 6  | Number of leaves per flush           |
| 7  | Angle of leaf petiole                |
| 8  | Inflorescence length                 |
| 9  | Inflorescence width                  |
| 10 | Nut weight                           |
| 11 | Cashew apple length                  |
2.3. Statistical analysis
The quantitative data collected were analyzed using the coefficient of variation (%CV) = (standard variation x mean) x 100. All data (quantitative and qualitative) were then used to cluster the evaluated cashew accessions using a complete linkage method based on Gower distance. All analyses were carried out using R statistics (R Core Team, 2021).

3. Results and discussion
The coefficient of variation (CV%) analysis (Table 2) shows that the observed morphological characters of cashew accessions from three evaluated populations were varied. The highest variation was detected in the height of main branches with a range of 47.32% - 73.72%, whereas the lowest one was observed on nut length (6.75% – 7.99%).
CV\% is categorized as low if the value less than 10\% (CV\% < 10\%), medium if it is between 10\% and 20\% (10\% < CV\% < 20\%), high if it is between 20\% and 30\% (20\% < CV\% < 30\%), and very high if it is more than 30\% (CV\% > 30\%) (Gomes, 1987).

Table 2. Coefficient of variation (CV\%) of cashew morphological characters from South Konawe, Konawe, and East Kolaka.

| No | Character              | South Konawe | Konawe | East Kolaka |
|----|------------------------|--------------|--------|-------------|
| 1  | Internode length of twig | 36.10        | 56.98  | 30.87       |
| 2  | Height of main branches | 47.32        | 56.59  | 73.72       |
| 3  | Leaf size              | 21.08        | 16.87  | 21.86       |
| 4  | Extension growth of twigs | 27.36        | 38.45  | 23.49       |
| 5  | Twig diameter          | 18.53        | 15.39  | 22.03       |
| 6  | Number of leaves per flush | 31.57       | 28.84  | 34.56       |
| 7  | Angle of leaf petiole  | 22.27        | 33.21  | 28.32       |
| 8  | Inflorescence length   | 29.80        | 20.32  | 26.91       |
| 9  | Inflorescence width    | 35.07        | 25.66  | 30.26       |
| 10 | Nut weight             | 16.87        | 12.28  | 20.71       |
| 11 | Cashew apple length    | 12.17        | 16.37  | 12.39       |
| 12 | Cashew apple width     | 9.05         | 11.74  | 15.63       |
| 13 | Nut length             | 7.99         | 6.82   | 6.75        |
| 14 | Nut width              | 8.66         | 5.78   | 7.74        |
| 15 | Nut thickness          | 28.08        | 41.27  | 21.84       |

The variations of cashew morphology in South Konawe population were varied, ranging from low to very high. The low variations were observed on cashew apple width (9.05\%), nut length (7.99\%), and nut width (8.66\%). The medium level of variation was detected on twig diameter, nut weight, and cashew apple length, which were 18.53\%, 16.87\%, and 12.17\%, respectively. Moreover, leaf size, extension growth of twigs, angle of leaf petiole, inflorescence length, and nut thickness were classified as high variation with 21.08\%, 27.36\%, 22.27\%, 29.80\%, and 28.08\%, respectively. Four morphological characters as very high variation were internode length of twig (36.10\%), height of main branches (47.32\%), number of leaves per flush (31.57\%), and inflorescence width (35.07\%).

Cashew accessions from Konawe showed slightly different from South Konawe on variation classifications of morphological characters. The low variation was observed on nut length (6.82\%) and nut width (5.78\%), where its nut width variation was the lowest compared to South Konawe and East Kolaka. Leaf size (16.87\%), twig diameter, nut weight, cashew apple length, and cashew apple width were grouped into medium variation level. Number of leave per flush, inflorescence length, and inflorescence width were 28.84\%, 20.32\%, and 25.66\%, respectively, which were classified as high. Meanwhile, internode length of twig, height of main branches, extension growth of twigs, angle of leaf petiole, and nut thickness had very high variations, 56.98\%, 56.59\%, 38.45\%, 33.21\%, and 41.27\%, respectively.

In East Kolaka, the cashew accessions were also divided into four variation levels (low, medium, high, and very high). Similar to that of in Konawe accessions, the low variation was observed on nut length (6.75\%) and nut width (7.74\%). Cashew apple length and width were categorized as medium level with 12.39 \% and 15.63\%. Leaf size (21.86\%), extension growth of twigs (23.49\%), twig diameter (22.03\%), angle of leaf petiole (28.32\%), inflorescence length (26.91\%), nut weight (20.71\%), and nut thickness (21.84\%) were high level of variations. While, the characters with very high variation level were internode length of twig (30.87\%), height of main branches (73.72\%), number of leaves per flush (34.56\%), and inflorescence width (30.26\%).
Morphological characters in the evaluated individuals tended to show high to very high variation levels based on the number of characters in each variation level. The high-level variation was assumed because this species is crossed-pollinated species [12]; consequently, it has a diverse genetic diversity. A study by Saefudin and Wardiana (2011) reported that eight cashew accessions from Southwest Sumba were phenotypically different not only because of their genetic but also environmental factors. An environmental factor that affects plant morphology is the direction of sunlight. Leaves respond to the sunlight by moving their position to receive better sunlight; thus, it increases the variation in leaves shapes. Similar results on cashew accessions reported by Haryudin and Rostiana (2016) proved that sixteen grafting cashew accessions had varied morphological characters, particularly leaf shape, leaf tip, and base shapes, canopy shape, branch direction, and leaf color [3]. Haryudin et al. (2018) also reported variations on leaf morphological characters of 25 cashew accessions [4].

The clustering analysis (Figure 2) depicts the ninety evaluated cashew individuals were grouped into two main clusters (1 and 2), and each cluster had two sub-clusters (1.1, 1.2, 2.1, and 2.2). All individuals were distributed in all clusters, except for the 2.1 sub-cluster, which only had individuals from Konawe and South Konawe. Furthermore, all sub-cluster had different numbers of individuals where the highest individual number had by 2.2 sub-cluster.

The first cluster had 55 cashew individuals that were divided into two sub-clusters. The first sub-cluster (1.1) consisted of 26 individuals (ten individuals from Konawe, 14 individuals from South Konawe, and two individuals from East Kolaka). As many as 29 individuals were grouped in the second sub-cluster (1.2), fifteen individuals from Konawe, seven individuals from South Konawe, and seven individuals from East Kolaka.

A total of 35 individuals were clustered into the second cluster. The first sub-cluster (2.1) consisted of five individuals (one individual from Konawe and four individuals from South Konawe), which was the least individual number of all sub-clusters. Sub-cluster 2.2 had 21 individuals: two individuals from Konawe, five individuals from South Konawe, and 21 individuals from East Kolaka.

The evaluated cashew-based on the clustering can be assumed that low variation between populations as observed on the scattered individuals’ distribution in the clusters. Haryudin and Rostiana (2016) also reported a similar result who observed two main clusters formed in their sixteen evaluated cashew accessions based on qualitative and quantitative morphological characters [3]. In addition, individual #10 from Konawe and #19 from Konawe had a very close relationship or assumed from the same parents. On the other hand, this study identified a very distant relationship between individuals #10 from Konawe and #26 from East Kolaka that can be the potential parents to improve variation in the future breeding program of cashew in Southeast Sulawesi.

Figure 2. Clustering of ninety cashew accessions from three districts of Southeast Sulawesi based on complete linkage method of Gower distance.
4. Conclusion
The morphological diversity of cashew accessions from Konawe, South Konawe, and East Kolaka were varied, from low to very high. The highest coefficient of variation was the height of main branches (47.32%-73.72%), and the lowest level was nut length (6.75%-7.99%). The ninety cashew individuals were divided into two main clusters, and each cluster had two sub-clusters.

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