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Oil Content and Relationships of Kepuh (*Sterculia foetida* L.) Seeds in Bali and Rote Ndao, East Nusa Tenggara

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Abstract

Kepuh is a plant belonging to the Malvaceae family, widely distributed in tropical regions, including Indonesia. It is a perennial tree that grows in lowlands, particularly in arid areas. The tree is known by various local names, such as halumpang (Batak); kepuh and kepoh (Bali); and kepo and kelompan (East Nusa Tenggara). Kepuh trees are commonly found in sacred sites, such as cemeteries. *Sterculia foetida* L. (Kepuh) is a tropical plant with potential as a source of alternative vegetable oil. This study aimed to determine the oil content of Kepuh seeds and analyze the phylogenetic relationships among Kepuh populations from Badung Regency, Denpasar City, and Rote Regency (East Nusa Tenggara). The research was conducted from June 2025 to January 2026, employing field observations, measurements of morphological characteristics (stem, leaf, and seed), and oil content analysis via Soxhlet extraction. Morphological and oil content data were analyzed using cluster analysis with PAST software to generate a dendrogram of phylogenetic relationships. The results revealed variations in morphological characteristics and oil content across locations. Among the Bali samples, the highest oil content was found in Monang-Maning 1 (40.15%), while the lowest was in Serangan 3 (20.10%). For the Rote samples, the highest oil content was observed in Oemasi 2 (35.15%) and the lowest in Oemasi 4 (13.81%). Cluster analysis showed that the 50 Kepuh samples formed two main groups with a similarity index of 93.5%, indicating a high degree of morphological similarity among populations despite their different geographical origins. The findings demonstrate that variations in oil content are influenced by differences in morphological characteristics and environmental conditions, and they identify Kepuh populations with the potential for development as alternative vegetable oil sources.

Keywords: *Sterculia foetida* L.; *Morphological characteristics; Oil content; Phylogenetic relationships; Bali; Rote (East Nusa Tenggara)*

Abstrak

Kepuh adalah tumbuhan dari famili Malvaceae yang banyak ditemukan di daerah tropis, termasuk Indonesia. Kepuh juga merupakan pohon tahunan yang tumbuh di dataran rendah, terutama di daerah gersang. Pohon ini dikenal dengan beberapa nama lokal, termasuk halumpang (Batak); kepuh, kepoh (Bali); kepoh, kelompang (Nusa Tengara Timur). Pohon kepuh biasanya ditemukan di tempat-tempat suci seperti kuburan. Kepuh (*Sterculia foetida* L.) merupakan tumbuhan tropis yang memiliki potensi sebagai sumber minyak nabati alternatif. Penelitian ini bertujuan untuk mengetahui kandungan minyak biji kepuh serta menganalisis hubungan kekerabatan antar populasi kepuh yang berasal dari Kabupaten Badung dan Kota Denpasar (Bali) dan Kabupaten Rote Ndao (Nusa Tenggara Timur). Penelitian dilaksanakan pada Juni 2025–Januari 2026 menggunakan metode observasi lapangan, pengukuran karakter morfologi batang, daun, dan biji, serta analisis kandungan minyak melalui ekstraksi menggunakan metode sokletasi. Data morfologi dan kandungan minyak dianalisis menggunakan analisis klaster dengan perangkat lunak PAST untuk menghasilkan dendrogram hubungan kekerabatan. Hasil penelitian menunjukkan adanya variasi karakter morfologi dan kandungan minyak antar lokasi. Kandungan minyak tertinggi pada sampel Bali diperoleh dari Monang-Maning 1 sebesar 40,15%, sedangkan terendah pada Serangan 3 sebesar 20,10%. Pada sampel Rote, kandungan minyak tertinggi ditemukan pada Oemasi 2 sebesar 35,15% dan terendah pada Oemasi 4 sebesar 13,81%. Analisis klaster menunjukkan bahwa 50 sampel kepuh membentuk dua kelompok utama dengan indeks similaritas 93,5%, yang mengindikasikan tingkat kemiripan morfologi yang tinggi antar populasi meskipun berasal dari lokasi geografis yang berbeda. Hasil penelitian menunjukkan bahwa variasi kandungan minyak dipengaruhi oleh perbedaan karakter morfologi dan kondisi lingkungan, serta mengidentifikasi

populasi kepuh yang berpotensi dikembangkan sebagai sumber minyak nabati alternative.
Kata Kunci: *Sterculia foetida* L; *Karakter morfologi; Kandungan minyak; Hubungan kekerabatan; Bali; Rote (NTT)*

1. INTRODUCTION

Indonesia is one of the most biodiverse countries in the world, possessing a wide variety of plant species with potential as sources of food, medicine, industrial raw materials, and renewable energy. One such plant is kepuh (*Sterculia foetida* L.), a member of the Malvaceae family that is widely distributed across tropical regions, including Bali and East Nusa Tenggara. Kepuh is known for its ability to grow in arid areas, on marginal land, and in coastal regions, demonstrating a high capacity to adapt to unfavorable environmental conditions (Metananda et al., 2015).

In addition to its ecological functions, such as providing shade and aiding in land conservation, the kepuh tree produces seeds containing vegetable oil that has potential as a biodiesel feedstock. According to Sudradjat et al. (2010), the oil content of kepuh seeds reaches approximately 25.2%, making the plant a promising alternative energy source that could support the development of renewable energy in Indonesia. Utilizing non-food vegetable oil sources like kepuh is becoming increasingly important due to rising energy demands and the dwindling reserves of fossil fuels (Prasetiyo et al., 2022).

Nevertheless, information regarding the oil content of kepuh seeds collected from different regions of Indonesia remains not yet comprehensively documented. he oil content in plant seeds is known to be influenced by genetic and environmental factors—such as temperature, rainfall, humidity, soil type, nutrient availability, and light intensity (Gao et al., 2025; Zemour et al., 2021). Differences in environmental conditions between Bali and Rote Regency in East Nusa Tenggara are thought to cause variations in the oil content of kepuh seeds.

In addition to oil content, another important aspect requiring study is the genetic relationship among kepuh populations from different locations. Information regarding these relationships is essential for determining the degree of trait similarity and genetic diversity within populations—data that can be utilized in conservation programs, plant breeding, and germplasm development. To date, research on the relationships between kepuh populations in Bali and Rote remains very limited; therefore, a more in-depth study of morphological characteristics and the degree of similarity between these populations is needed.

To address these issues, research is needed that combines oil content analysis with kinship analysis among kepuh populations. Oil content can be analyzed using soxhlet extractionthe soxhletation method, while kinship relationships can be determined based on the morphological characteristics of the stems, leaves, and seeds, which are then analyzed using the cluster method to produce a kinship dendrogram (Sudrajat, et. al., 2018).

This approach is expected to provide an overview of the variation in oil content among Kepuh populations in Badung Regency, Denpasar City (Bali) and Rote Ndao Regency (NTT). Furthermore, an analysis of genetic relationships can reveal the degree of similarity and difference in characteristics between populations, thereby determining whether the observed variations in oil content are linked to morphological differences and environmental growth factors. The research findings are expected to serve as a basis for selecting superior seed sources with high oil content, developing Kepuh as a biodiesel feedstock, and supporting efforts to conserve Kepuh genetic resources in Indonesia.

This study aims to examine the oil content of *S. foetida* L. (kepuh) seeds originating from Badung Regency, Denpasar City (Bali) and Rote Ndao Regency (NTT) and to analyze differences in oil content between the study locations. Additionally, the study seeks to analyze the genetic relationships among *S. foetida* populations based on morphological characteristics of the stem, leaves, and seeds, thereby determining the degree of similarity and diversity among populations from these three regions. The findings are expected to provide comprehensive scientific information regarding the potential of *S. foetida* as an alternative source of vegetable oil, while also serving as a foundation for efforts in development, conservation, breeding, and the sustainable utilization of its genetic resources.

Kepuh (*S. foetida* L.) is a tropical tree species capable of reaching heights of 30–40 meters and is widely distributed across Southeast Asia, including Indonesia. According to Metananda et al. (2015), the kepuh tree is classified as a multipurpose plant with high conservation value. Data regarding its population, distribution, and species associations highlight the importance of conserving the kepuh tree due to the ecological and economic benefits it offers to local communities (Sudrajat et al. 2011) identify kepuh as a plant with significant potential for cultivation across diverse environmental conditions; it holds promise as a source of plant-based energy, particularly given its ability to thrive on relatively unproductive land.

Kepuh seeds contain vegetable oil with the potential to serve as a feedstock for biodiesel. Sudradjat et al. (2010) reported that kepuh seed oil can be processed into biodiesel via transesterification and possesses characteristics suitable for use as an alternative fuel. Developing biodiesel from local resources offers a solution to reduce reliance on fossil fuels and supports sustainable energy development (Nuva et al., 2019). Liu et al. (2025) state that oil formation in seeds results from plant metabolic processes influenced by genetic and environmental factors. Rasyad and Idwar (2010), state that the expression of a plant's traits results from the interaction between hereditary factors and environmental conditions, such as temperature, humidity, soil type, and water availability. Similarly, Sousa et al. (2019) report that variations in environmental conditions can affect plant growth and the accumulation of metabolites, including seed oil.

Plant phylogenetic relationships can be determined through the analysis of morphological traits or molecular approaches. According to Dini et al (2023), similarities and differences in morphological traits can be used to assess the degree of relatedness between plant populations; the greater the number of shared traits, the closer the phylogenetic relationship. Cluster analysis is a commonly used method for grouping individuals based on the degree of similarity in their traits.

Based on these theories, research into the oil content and genetic relationships of kepuh seeds in Bali and Rote Ndao Regency (NTT) is significant, as it can provide information on the potential of local genetic resources, identify populations with high oil content, and support efforts to conserve and develop kepuh as a sustainable source of renewable energy.

2. METHOD

2.1. Research Location and Timing

This study involved both field and laboratory research. Samples were collected from Kepuh populations across two locations: Bali (Monang-Maning, Kerobokan, Serangan, Jimbaran, and Kedonganan villages) and Rote Ndao Regency, East Nusa Tenggara (Holotula, Lasilai, Oedai, Oelua, and Oemasi villages). Oil extraction was conducted at the Plant Physiology Laboratory, Department of Biology, Faculty of Mathematics and Natural Sciences, Udayana University. The research was carried out from June 2025 to January 2026.

2.2. Research Instruments

The tools required for the research are: Field equipment: plastic bags, pencils, notebooks, and a camera. Laboratory equipment: a Soxhlet apparatus set, hot plate stirrer, analytical balance, separatory funnel, graduated cylinder, boiling flask, tubing, pipette, tweezers, petroleum jelly, porcelain dish, desiccator, pycnometer, viscometer, oven, label paper, filter paper, Erlenmeyer flask, heating mantle, beaker, distillation apparatus set, thermometer, water pump, and tissues.

The materials required are Kepuh plants, hexane solution, methanol, phosphoric acid, HCl, acetic acid, 95% alcohol, phenolphthalein indicator, iodine, Hanus solution, chloroform, sodium thiosulfate ($Na_2S_2O_3$), distilled water, and KOH for oil extraction.

2.3. Research Procedure

Sampling was conducted using an observational technique, involving traversing several villages in Bali and Rote Ndao Regency (NTT). Observations were supplemented by directly questioning local residents regarding the locations where kepuh trees grow. Morphological measurements included diameter at breast height (DBH), as well as observations of the trunk, leaves, and seeds. Samples from both Bali and Rote Ndao Regency (NTT) were labeled and photographed. Morphological characteristics of the trunk, leaves, and seeds were described for 50 samples: 25 from Bali (covering Monang-Maning, Kerobokan, Kedonganan, Jimbaran, and Serangan) and 25 from Rote Ndao Regency, NTT (covering Holotula, Oedai, Oelua, Lasilai, and Oemasi). A 500-gram sample of seeds that had ripened and fallen from the tree was collected; the best seeds were selected for oil extraction and labeled according to their source. Seed dimensions—length, width, and thickness—were measured using calipers, and seed weight was determined using an analytical balance, while leaf dimensions—length and width—were measured using a ruler.

Morphological character observations were conducted based on the plant morphology book by Tjitrosoepomo (2011). The morphological characters observed were as follows (results attached): Leaf—leaf texture/firmness (observed by squeezing a leaflet; if it tore, it was classified as firm/tough, whereas if it did not tear, it was classified as soft/tender), leaf margin (entire or undulate), and leaf apex (obtuse, acute, or acuminate). Leaf base (flat, notched, acute, or acuminate); color of the upper leaf surface (dark green, light green); color of the lower leaf surface (yellowish-green, dark green, light green). Number of leaflets (two, three, or many leaflets). Leaf venation pattern (palmate or pinnate); visibility of leaf veins (distinct or indistinct); leaf texture (thin/papery or thin/soft). Leaf blade shape (heart-shaped, elliptic, or lanceolate); leaf width; leaf length. Seeds: seed shape, seed color, seed type, seed coat surface, seed length, seed width, seed weight, seed thickness, seed size (small, medium, large), and oil content. The seeds used as samples were Kepuh seeds that were physiologically mature, free from defects, uninfested by pests or fungi, unbroken, and of relatively normal size. The seeds were cleaned of impurities and then dried to a condition suitable for morphometric analysis and oil extraction.

Oil extraction was performed by drying the seeds in an oven at 60°C for one week. The dried seeds were separated from their hulls, then ground using a mortar and pestle and sieved to ensure homogeneity. A 5-gram sample of the fine powder was weighed, wrapped in filter paper, and placed into a Soxhlet apparatus for extraction. Petroleum jelly was applied to all apparatus joints to prevent leakage. The boiling flask was filled with 175 mL of hexane, and ceramic chips were added to prevent solvent and oil spillage. The Soxhlet apparatus was assembled, connected to a water pump equipped with inlet and outlet hoses, and then connected to a heating mantle. The heating mantle was turned on, and the oil was extracted at 60°C for 30 minutes. The resulting mixture of oil and hexane solvent was then separated via distillation at 60°C (Arpiwi et al., 2013; Sivakumar et al., 2012). The distillation process concluded once all the hexane solvent had evaporated from the oil. The oil content of kepuh seeds is determined based on the percentage of oil obtained from extraction relative to the weight of the dry material used. Oil yield represents the percentage of oil successfully recovered during the extraction process. Thus, the oil yield is calculated using the following formula:

$$\text{Yield} = \frac{\text{weight of oil}}{\text{weight of sample}} \text{ x } 100\ \%$$

2.4. Data Analysis

Morphological characteristics and oil content were analyzed using the PAST software program to visualize their phylogenetic relationships via a dendrogram. Data obtained from observations of morphological traits—specifically regarding stems, leaves, and seeds—were grouped accordingly. Subsequently, cluster analysis was employed to assess similarity based on the aforementioned morphological traits; the specific method used was Correlation analysis. Cluster analysis is a multivariate statistical technique used to identify groups of objects sharing specific characteristics that distinguish them from other groups (Dini et al., 2023).

The observational variables used in this cluster analysis comprise all data regarding the morphological characteristics of the stem, leaves, and seeds, as well as oil content. The results of the cluster analysis are presented as a dendrogram, with the correlation coefficient distance expressed as a percentage of similarity; a higher percentage indicates a greater degree of similarity. Similarity is expressed as a percentage, where 0% signifies complete dissimilarity and 100% signifies exact or perfect identity (Dini et al., 2023). Furthermore, the quantitative data obtained from this study will be analyzed using a t-test.

3. RESULT AND DISCUSSION

3.1 Kepuh Oil Content

Based on the results of kepuh oil extraction, the highest oil yield was obtained from the Monang-Maning 1 sample (Bali) at 40.15%, while the lowest was from Serangan 3 at 20.10%. Among samples from Rote Ndao Regency (NTT), the highest yield was obtained from Oemasi 2 at 35.15% and the lowest from Oemasi 4 at 13.81%; these results are presented in Table 2.

Table 2. Kepuh seed oil content. Values represent the mean of three replicates. SD = Standard deviation.

No	Location	Oil Content (%)	Standard Deviation
1	Kedonganan 1	30,8	0,3
2	Kedonganan 2	31,1	0,5
3	Kedonganan 3	30,0	1,2
4	Kedonganan 4	25,1	2
5	Kedonganan 5	24,00	2,00
Amount		**141,00**	
Average		**28,2**	
6	Serangan 1	22,5	0.62
7	Serangan 2	24,5	0.41
8	Serangan 3	20,1	0.80
9	Serangan 4	25,71	0.93
10	Serangan 5	30,9	0,92
Amout		**123,71**	
Average		**24,7**	
11	Monang-Maning 1	40,15	0.80
12	Monang-Maning 2	35,12	2.14
13	Monang-Maning 3	35,80	0.9
14	Monang-Maning 4	32,73	0.13
15	Monang-Maning 5	31,07	0.32
Amout		**174,87**	
Average		**34,97**	
16	Jimbaran 1	38,52	0.81
17	Jimbaran 2	27,27	1.10
18	Jimbaran 3	25,93	0.83

19	Jimbaran 4	23,73	0.61
20	Jimbaran 5	35,33	1.01
Amout		**150,78**	
Average		**30,15**	
21	Kerobokan 1	26,52	0.81
22	Kerobokan 2	24,60	0.53
23	Kerobokan 3	22,14	0.46
24	Kerobokan 4	26,45	1.40
25	Kerobokan 5	25,25	0.31
Amout		**124,96**	
Average		**24,99**	
26	Holotula 1	15,9	0.4
27	Holotula 2	15,3	0.7
28	Holotula 3	30,1	0.3
29	Holotula 4	26,5	0.6
30	Holotula 5	25,6	1.6
Amout		**113,4**	
Average		**22,68**	
31	Lasilai 1	28,6	1.28
32	Lasilai 2	26,0	0.2
33	Lasilai 3	31,2	0.8
34	Lasilai 4	31,4	0.9
35	Lasilai 5	25	2
Amout		**142,2**	
Average		**28,44**	
36	Oedai 1	27,9	1.8
37	Oedai 2	30,86	0.60
38	Oedai 3	24,5	0.9
39	Oedai 4	23,25	1.91
40	Oedai 5	29,0	1.0
Amout		**135,51**	
Average		**27,10**	
41	Oemasi 1	31,3	0,95
42	Oemasi 2	35,15	0.31
43	Oemasi 3	20,07	1.36
44	Oemasi 4	13,81	0.60
45	Oemasi 5	21,07	0.99
Amout		**122,41**	
Average		**24,68**	
46	Oelua 1	30,67	0.30
47	Oelua 2	25,07	0.6
48	Oelua 3	20,9	0,94
49	Oelua 4	26,4	1.24
50	Oelua 5	20,3	1.02
Amout		**123,34**	

Average	**26,66**

Extraction of *S. foetida* L. (kepuh) oil yielded widely varying oil content levels. Based on average values per location, the highest oil content among samples from Bali was found in Monang-Maning (34.97%), while the lowest was in Serangan (24.7%). Among samples from Rote Ndao Regency (NTT), the highest average content was recorded in Lasilai (28.44%) and the lowest in Holotula (22.68%). These results differ from the findings of Sudrajat et al. (2010), who reported a *S. foetida* seed oil content of 25.2%. The primary factors contributing to these variations are differences in environmental conditions and soil texture.

Comparative analysis reveals variations in the oil content of *S. foetida* L. (kepuh) seeds across the Monang-Maning, Serangan, Holotula, and Oedai sites; these variations are likely driven by the interplay between genetic factors and environmental conditions. Differences in habitat characteristics—such as temperature, light intensity, water availability, soil conditions, humidity, salinity, and seed maturity—can influence plant growth, seed development, and oil accumulation. The distinct ecological conditions of these sites—ranging from the urban environment of Monang-Maning and the coastal setting of Serangan to the relatively drier locations in East Nusa Tenggara (NTT)—can result in varying oil content. Consequently, the observed differences in oil content reflect physiological responses and potential population adaptations to specific environments; identifying the site with the highest oil yield requires basing decisions on analytical data, supported by physical seed characteristics and environmental conditions. he transmission of traits to offspring is governed by genes that control the formation of observable characteristics through interactions with environmental factors—such as soil conditions, temperature, soil type, climate, humidity, and altitude (Rasyad and Idwar, 2010).

3.2. Morphological Similarity Analysis

The results of the qualitative and quantitative data analysis, illustrating morphological similarity relationships in the form of a dendrogram, are presented in Figure 1:

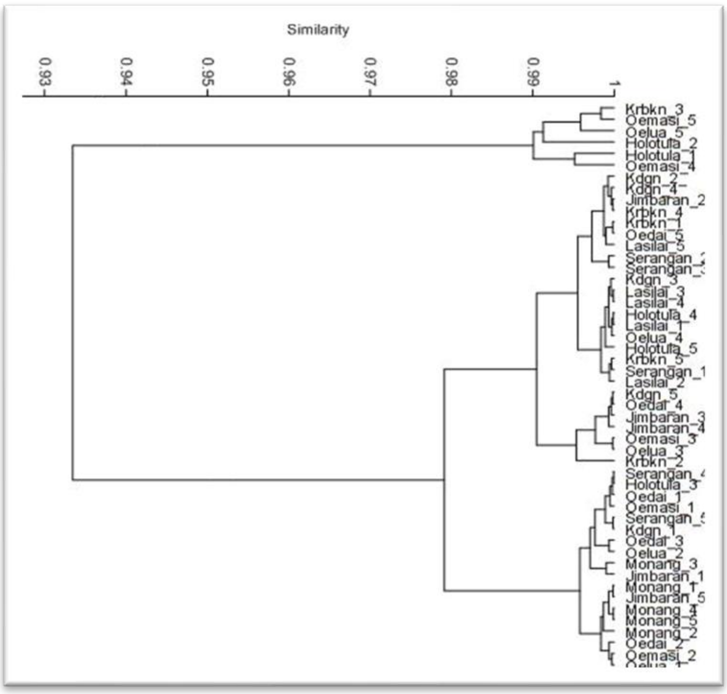

Figure 1. Dendrogram showing the clustering of 50 Kepuh plant samples based on qualitative and quantitative data.

The clustering analysis based on seven morphological characteristics and oil content from the 50 observed kepuh samples is presented as a dendrogram in the figure above. The dendrogram results reveal two groups—Group A and Group B—with a similarity index of 93.5%. Group A comprises: Kerobokan 3, Oemasi 5, Oelua 5, Holotula 2, Holotula 1, and Oemasi 4. Group B comprises: Kedonganan 2, Kedonganan 4, Jimbaran 2, Kerobokan 4, Kerobokan 1, Oedai 5, Lasilai 5, Serangan 2, Serangan 3, Kedonganan 3, Lasilai 3, Lasilai 4, Holotula 4, Lasilai 1, Oelua 4, Holotula 5, Kerobokan 5, Serangan 1, Lasilai 2, Kedonganan 5, Oedai 4, Jimbaran 3, Jimbaran 4, Oemasi 3, Oelua 3, Kerobokan 2, Serangan 4, Holotula 3, Oedai 1, Oemasi 1, Serangan 5, Kedonganan 1, Oedai 3, Oelua 2, Monang-Maning 3, Jimbaran 1, Monang-Maning 1, Jimbaran 5, Monang-Maning 4, Monang-Maning 5, Monang-Maning 2, Oedai 2, Oemasi 2, and Oelua 1.

Group A consists of locations with oil content ranging from 13.81% to 22.14%, while Group B1 comprises locations with oil content between 15.9% and 35.15%; Group B2, meanwhile, includes locations with oil content ranging from 24.50% to 40.15%. (Group A and B are not based on the location where they grow, but the groups formed are a mixture of locations, in group A locations namely Kerobokan 3, Oemasi 5, Oelua 5, Holotula 2, Holotula 1, Oemasi 4 and in group B locations namely Kedonganan 2, Kedonganan 4, Jimbaran 2, Kerobokan 4, Kerobokan 1, Oedai 5, Lasilai 5, Serangan 2, Serangan 3, Kedonganan 3, Lasilai 3, Lasilai 4, Holotula 4, Lasilai 1, Oelua 4, Holotula 5, Kerobokan 5, Serangan 1, Lasilai 2, Kedonganan 5, Oedai 4, Jimbaran 3, Jimbaran 4, Oemasi 3, Oelua 3, Kerobokan 2, Serangan 4, Holotula 3, Oedai 1, Oemasi 1, Serangan 5, Kedonganan 1, Oedai 3, Oelua 2, Monang-maning 3, Jimbaran 1, Monang-maning 1, Jimbaran 5, Monang-maning 4, Monang-maning 5, Monang-maning 2, Oedai 2, Oemasi 2, and Oelua 1. This shows that the oil content of the two population groups is similar, even though the locations are different, the two groups have a similarity index of 93.5%).

This indicates that kepuh trees in Badung Regency, Denpasar City, and Rote share many morphological characteristics. Furthermore, the B1 entries were grouped together due to shared characteristics—specifically lower oil content, smaller seed size, and lower seed weight—while the B2 entries were similarly grouped based on relatively high oil content, large seed size, and high seed weight; this resulted in a similarity index of 98.0%, indicating a greater degree of morphological similarity than that observed in groups A and B

This occurs due to numerous similarities in characteristics (seed shape, color, surface, length, width, thickness, weight, and oil content). Similarities and differences in plant characteristics can be used to determine the closeness of phylogenetic relationships (Dini et al., 2023).

4. CONCLUSION

Among the samples from Badung Regency and Denpasar City, the highest oil content was found in Monang-Maning 1 (40.15%) and the lowest in Serangan 3 (20.10%); meanwhile, among the samples from Rote (NTT), the highest oil content was found in Oemasi 2 (35.15%) and the lowest in Oemasi 4 (13.81%). Analysis of genetic relationships based on morphological characteristics and oil content revealed that the 50 kepuh samples formed two main groups with a similarity index of 93.5%, indicating a very high level of similarity among the populations.

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