

Morphological Characterization and GC-MS Profiling of Tukad Sumaga Tangerine (*Citrus reticulata*)

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Abstrak: Tukad Sumaga tangerine (*Citrus reticulata*) is a local citrus cultivar with potential as a horticultural genetic resource; however, its morphological characteristics and volatile chemical profile require systematic documentation. This study aimed to characterize the morphological traits and fruit quality of Tukad Sumaga tangerine and identify volatile compounds in its leaf extract using gas chromatography-mass spectrometry (GC-MS). Morphological characterization was conducted based on citrus descriptors, covering roots, stems, branching patterns, leaves, flowers, fruits, and seeds. Fruit quality was assessed based on total soluble solids (TSS), while leaf samples were extracted using 70% ethanol through maceration and analyzed by GC-MS. The plants exhibited a woody taproot system, upright cylindrical stem, sympodial branching with a spreading habit, ovate to elliptic glabrous leaves, actinomorphic white flowers, and ovoid to pyriform fruits with relatively rough peel surfaces. Fruit TSS reached 16 °Brix, with three to five seeds per fruit. GC-MS identified 15 compounds with similarity indices of 95–99%, including 3-hexanone, 2-hexanone, 3-hexanol, 2-hexanol, linalool, bicyclocymene, β -elemene, trans- β -caryophyllene, germacrene-D, and bicyclogermacrene. These findings provide baseline information for identification, conservation, and further investigation of Tukad Sumaga tangerine as a local citrus genetic resource.

Keywords: Citrus genetic resources; *Citrus reticulata*; GC-MS; Morphological characterization; Tukad Sumaga; Volatile compounds

Introduction

Citrus is an important perennial fruit crop cultivated widely in tropical and subtropical regions, including Indonesia. Beyond its economic value, local citrus germplasm represents an important genetic resource for cultivar identification, conservation, breeding, and future horticultural development. Indonesia has diverse locally adapted citrus cultivars whose characteristics may reflect interactions between genotype and agroecological conditions. Systematic characterization is therefore needed to document local diversity and provide a reliable basis for conservation and utilization.

Tukad Sumaga tangerine is a local citrus cultivar from Tukad Sumaga Village, Gerokgak District, Buleleng Regency, Bali. Local citrus cultivars in Bali

show variation in leaves, branches, flowers, fruits, and seeds, and these traits are useful as initial descriptors for cultivar identification. Previous studies have shown that morphological traits can support the evaluation of diversity and relationships among citrus genotypes (Aziztia et al., 2023; Khiavi et al., 2021; Yi et al., 2021). Fruit shape, peel characteristics, seed number, and total soluble solids are also relevant descriptors because they are associated with cultivar characteristics and fruit maturity.

Morphological information can be complemented by chemical characterization. Citrus tissues contain volatile compounds such as terpenoids, alcohols, ketones, and other metabolites that contribute to aroma and may vary among species, cultivars, tissues, developmental stages, and environmental conditions. Ethanol maceration is commonly used for extracting

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plant constituents, while gas chromatography-mass spectrometry (GC-MS) provides a useful approach for profiling volatile compounds and generating a chemical fingerprint (Mosić et al., 2020).

Previous studies have reported volatile constituents in Citrus, including linalool and several terpenoid-related compounds. Linalool is an important volatile associated with citrus and floral aroma and has been investigated for biological activities (An et al., 2021). Nevertheless, the composition and relative abundance of volatile compounds may differ among Citrus taxa and cultivars. Consequently, a chemical profile from one Citrus taxon cannot automatically be considered representative of another.

The unresolved scientific problem is that the morphological identity and volatile chemical profile of Tukad Sumaga tangerine have not been systematically documented together. In particular, a standardized description of its root, stem, branching, leaf, flower, fruit, and seed characters has not been integrated with a GC-MS profile of its leaf extract. This limits the availability of baseline information for distinguishing Tukad Sumaga from other local Citrus cultivars and for supporting subsequent comparative studies. The research gap therefore concerns the lack of an integrated morphological and volatile-chemical baseline, rather than simply the absence of research at a particular geographic location.

The novelty of this study lies in integrating morphological characterization, fruit quality assessment, and GC-MS profiling of the leaf extract of Tukad Sumaga tangerine. The study does not claim that the detected compounds constitute a definitive cultivar-specific fingerprint; instead, the combined dataset is intended as a baseline for cultivar documentation and future comparison with other Citrus cultivars.

Therefore, this study aimed to characterize the morphological traits and fruit quality of Tukad Sumaga tangerine (*Citrus reticulata*) and to identify its volatile chemical profile using GC-MS. The results are expected to provide baseline information for cultivar identification, conservation, and further comparative investigation of Tukad Sumaga as a local citrus genetic resource.

Method

The conduct of this systematic review follows the Time and place of research

Plant materials were collected from Tukad Sumaga Village, Gerokgak District, Buleleng Regency, Bali Province, Indonesia. Morphological observations were conducted at the Agricultural Biotechnology Laboratory, Faculty of Agriculture, Udayana University, Denpasar, Bali. Chemical analysis of the leaf extract was

conducted at the Integrated Laboratory, Faculty of Mathematics and Natural Sciences, Udayana University, Bukit Jimbaran, Bali.

Tools and Materials

Young leaves of Tukad Sumaga tangerine were collected from the sampled trees. Approximately 10–15 young leaves were collected from each tree. Samples were placed in labeled bags and transported in a cool box to maintain sample condition before laboratory processing.

Eksperimental Design

Morphological characterization was conducted using citrus descriptor characteristics and included observations of roots, stems, branching pattern, leaves, flowers, fruits, and seeds.

Root characteristics included root system type, main root characteristics, lateral root development, color, and surface texture. Stem characteristics included growth direction, shape, surface texture, bark characteristics, and color. Branching characteristics included branching pattern, branch orientation, branch density, and growth habit.

Leaf characteristics included leaf shape, length, width, length-to-width ratio, leaf color, leaf apex, leaf base, leaf margin, surface characteristics, venation, and presence or absence of leaf wings. Flower observations included symmetry, petal number, petal color, flower arrangement, stamen characteristics, sepal characteristics, and floral aroma.

Fruit characteristics included fruit weight, diameter, height, peel thickness, fruit shape, peel color at different maturity stages, peel surface texture, ease of peeling, flesh color, number of segments, seed presence, seed number, and fruit taste. Seed characteristics included shape, color, surface texture, and size.

Fruit Quality

Total soluble solids (TSS) were measured using a refractometer and expressed as °Brix. The measured TSS value was used as an indicator of soluble solids and fruit sweetness.

Sample Preparation and Extraction

The collected leaves were cleaned and dried at 40 °C. The dried leaves were subsequently ground into a homogeneous powder. The sample was extracted using 70% ethanol by maceration with periodic shaking during the extraction period. The extract was concentrated using a rotary evaporator at 40–50 °C and filtered to obtain a concentrated extract. The extract was stored at 20 °C until chemical analysis.

GC-MS Analysis

The ethanol leaf extract was analyzed using gas chromatography–mass spectrometry (GC-MS) to identify volatile chemical compounds. Compounds were identified based on chromatographic retention times, mass spectral characteristics, and comparison with the available spectral database. The similarity index obtained from database matching was recorded for each identified compound.

The identified compounds were reported according to retention time, molecular formula, peak area (AUC), and similarity index. Because identification was based on spectral database matching, the reported compounds are interpreted as identified or putatively identified compounds rather than confirmed structures.

Data Analysis

Morphological data were analyzed descriptively and presented according to the observed characteristics of Tukad Sumaga tangerine. Fruit quality data were reported based on the measured TSS value. GC-MS data were interpreted according to identified compounds, retention time, AUC, and similarity index. The morphological and chemical observations were integrated descriptively to provide a baseline characterization of Tukad Sumaga tangerine.

Results and Discussion

Morphological Characteristics of Tukad Sumaga Tangerine

The morphological observations showed that Tukad Sumaga tangerine has several recognizable characteristics covering its root, stem, branching pattern, leaves, flowers, fruits, and seeds. The observed plants exhibited a woody root system with a prominent main root and lateral branching. The main roots were relatively thick, while the lateral roots developed horizontally and obliquely. The root surface was relatively rough, with colors ranging from yellowish brown to dark brown.

The stem was upright and cylindrical, with a relatively coarse and irregular surface. The bark was predominantly grayish-brown, with darker coloration near the basal portion. The branches showed a sympodial growth pattern, with lateral branches developing from the main stem and forming a spreading crown. This growth habit results in relatively broad leaf distribution within the canopy.

The leaves were ovate to elliptic, with acute apices and cuneate to gradually narrowing bases. The leaf surface was glabrous and relatively smooth, with dark green coloration on the adaxial surface and lighter green coloration on the abaxial surface. Pinnate venation was clearly visible.

The flowers were actinomorphic and characterized by five white petals and numerous stamens. The flowers produced a characteristic citrus-like fragrance. The fruit was predominantly ovoid to pyriform, with a relatively rough peel surface. At the observed maturity stage, the peel showed a yellow-orange coloration with some green areas remaining.

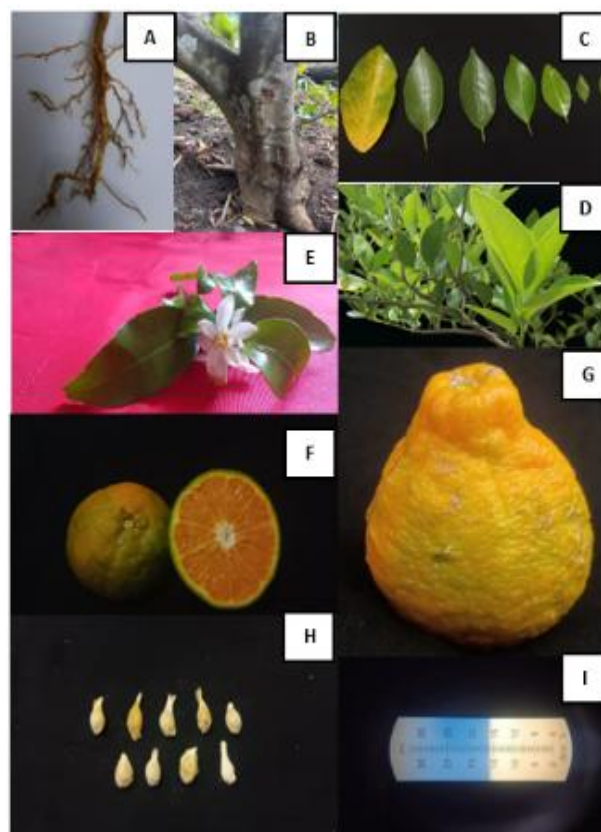


Figure 1. Morfologi Tanaman Jeruk Keprok Tukad Sumaga
A. Roots B. Stems C. Leaves D. Branching E. Flowers F. Fruit
G. Shape of Fruit H. Seeds I. Sweetness Level of Fruit

The observed combination of ovate–elliptic glabrous leaves, sympodial branching with a spreading habit, actinomorphic white flowers, and ovoid–pyriform fruits with a relatively rough peel provides a useful morphological baseline for Tukad Sumaga. These traits overlap with the general variation reported in *Citrus*, indicating that individual characters should not be treated as diagnostic in isolation. The combination of characters is therefore more useful for documentation and future comparative evaluation among local cultivars. Standardized descriptor scoring and sampling across multiple cultivars would be needed to determine which traits consistently distinguish Tukad Sumaga.

Fruit Quality

The measured total soluble solids (TSS) of Tukad Sumaga fruit was 16 °Brix. This value provides a fruit-quality baseline for the sampled material. TSS is

influenced by cultivar, maturity stage, environmental conditions, and cultivation practices; therefore, the observed value should not be interpreted as an absolute defining characteristic of the cultivar.

The 16 °Brix value should be considered representative of the sampled fruit rather than a fixed cultivar value. Comparative sampling across different trees, harvest periods, and agroecological conditions is required to evaluate the consistency of this trait and its usefulness for distinguishing Tukad Sumaga from other Citrus cultivars.

The number of seeds observed ranged from three to five per fruit. Seed number and morphology may contribute to cultivar characterization, but these traits can also vary with pollination, genetic background, and environmental conditions. Thus, the observed range should be regarded as part of the morphological baseline rather than a definitive taxonomic character.

GC-MS Profile of Tukad Sumaga Leaf Extract

GC-MS analysis identified 15 compounds in the Tukad Sumaga leaf extract, with similarity indices ranging from 95–99%. The detected profile comprised ketones, alcohols, and terpenoid-related compounds, including 3-hexanone, 2-hexanone, 3-hexanol, 2-hexanol, linalool, bicycloelemene, β -elemene, trans- β -caryophyllene, germacrene-D, bicyclogermacrene, and germacrene B. The occurrence of several sesquiterpenes indicates that the leaf extract has a substantial terpenoid component.

Linalool is also reported in Citrus and is associated with citrus and floral aroma (An et al., 2021), indicating that this compound is not unique to Tukad Sumaga. In contrast, the combined occurrence of linalool with

bicycloelemene, β -elemene, trans- β -caryophyllene, germacrene-D, bicyclogermacrene, and other sesquiterpene-related compounds provides a chemical profile that can be used as a starting point for comparison with other Citrus cultivars. Such comparison should consider relative abundance and analytical conditions rather than compound presence alone

The similarity indices of 95–99% indicate strong spectral matches with database entries, but they do not by themselves constitute definitive structural confirmation. Authentic standards and, where appropriate, retention indices would strengthen compound identification. Accordingly, the compounds reported here should be regarded as identified or putatively identified based on GC-MS spectral matching.

The Tukad Sumaga profile can therefore serve as a baseline for comparative Citrus studies. Differences in volatile composition may reflect species, cultivar, tissue type, developmental stage, extraction procedure, and environmental conditions. Future comparisons should use the same plant tissue, extraction procedure, and GC-MS conditions so that differences among cultivars can be interpreted more reliably.

Overall, the results provide preliminary evidence that Tukad Sumaga leaves contain a diverse mixture of oxygenated compounds and sesquiterpenes. The present dataset is useful for baseline documentation, but additional quantitative analyses involving multiple trees, harvest periods, and Citrus cultivars are needed before the chemical profile can be considered a cultivar-specific fingerprint

GC-MS Analysis Results

Types of Tukad Sumaga tangerine leaf extract compounds.

Table 1. GC-MS analysis results with a similarity level of 95–99.

Name	Molecular Formula	Retention time (minutes)	AUC (%)	Function of the compound
3-Hexanone (CAS) Hexan-3-one	C ₆ H ₁₂ O	4,029	94,013	Organic solvent; aroma component
2-Hexanone	C ₆ H ₁₂ O	4,139	50,568	Industrial solvent; volatile compound found in plant extracts
3-Hexanol (CAS) Hexan-3-ol	C ₆ H ₁₄ O	4,386	52,380	Aroma compound; volatile component of fruits and flowers
2-Hexanol (CAS) n-C ₄ H ₉ CH(OH)CH ₃	C ₆ H ₁₄ O	4,512	140,782	Secondary alcohol; naturally occurring and synthetic aroma compound
LINALOOL L	C ₁₀ H ₁₈ O	11,984	79,669	Floral aroma; reported sedative, anti-inflammatory, and antimicrobial activities
Benzene, 2-methoxy-4-methyl-1-(1-methylethyn)	C ₁₁ H ₁₄ O	14,226	67,687	Aroma component; volatile aromatic compound with reported antibacterial activity
1,6-Octadien-3-ol, 3,7-dimethyl-, 2-aminobenz	C ₁₀ H ₁₈ O	14,523	526,000	Major essential-oil component; reported antioxidant activity; fragrance compound
Bicycloelemene	C ₁₅ H ₂₄	15,848	615,395	Sesquiterpene with reported anti-inflammatory and antibacterial activities
(-)-beta -Elemene	C ₁₅ H ₂₄	16,694	116,567	Reported anticancer and antioxidant activities

Name	Molecular Formula	Retention time (minutes)	AUC (%)	Function of the compound
TRANS(BETA)-CARYOPHYLLENE	C ₁₅ H ₂₄	17,167	632249	Reported anti-inflammatory, analgesic, and antibacterial activities
,gamma,-Elemene	C ₁₅ H ₂₄	17,251	586,605	Reported anticancer and antioxidant bioactivities
,alpha -Humalene	C ₁₅ H ₂₄	17,669	110,866	Reported anti-inflammatory and anti-allergic activities
GERMACRENE-D	C ₁₅ H ₂₄	18,009	674,912	Reported anticancer and antifungal activities
Bicyclogermacrene	C ₁₅ H ₂₄	18,203	201,041	Reported antibacterial and antifungal activities
Germacrene B (CAS) 1,5-Cyclodecadiene, 1,5	C ₁₅ H ₂₄	19,058	961,540	Volatile compound with aromatic properties and reported bioactivity

Conclusion

Tukad Sumaga tangerine (*Citrus reticulata*) exhibited a characteristic combination of ovate-elliptic glabrous leaves, sympodial branching with a spreading habit, actinomorphic white flowers, and ovoid-pyriform fruits with relatively rough peel surfaces, with a measured TSS of 16 °Brix and three to five seeds per fruit. GC-MS profiling of the leaf extract identified 15 compounds with similarity indices of 95–99%, including linalool and several sesquiterpene-related compounds. Together, these morphological and volatile-chemical data provide a baseline for cultivar documentation and support future comparative research, conservation, and utilization of Tukad Sumaga as a local citrus genetic resource.

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Author contribution

All authors have contributed to the completion of this manuscript. They have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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