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RESEARCH ARTICLE
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Characterization, Yield, Growth, and Essential Oil of Parsley Local Lines of Sudan

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Abstract

This study explores the growth, yield, and essential oil properties of two Sudanese parsley lines, Dongola and Madani, focusing on their agronomic and medicinal potential. Parsley (*Petroselinum crispum*) is a key culinary herb with significant benefits in regions like Sudan, where climate conditions are crucial for its cultivation success. Conducted at the Medicinal and Aromatic Plants Research Institute (MAPRI) in Shambat, Khartoum State, Sudan, this winter-season experiment commenced on November 15, 2017. Using a factorial experiment within a completely randomized block design (CRBD), we examined two factors: variety (A) and cutting frequency (B). The objectives were to characterize and assess these local parsley lines for distinctness, uniformity, stability (DUS), growth performance, yield, and essential oil profile. Additionally, the study evaluated the resilience of the lines under multi-cut conditions by analyzing interactions between variety and harvest frequency. Visual descriptors for DUS adhered to the UPOV code (2005). Both lines exhibited similar leaf characteristics but differed in other traits. The Medani line showed superior growth metrics, including leaf blade length (14.54 cm), leaf blade width (19.33 cm), petiole thickness (12.51 mm), and plant height (39.45 cm). In contrast, Dongola had a higher dry weight (2.284 kg/m²), while Medani excelled in oil content (7.88 g/150g, 5.6%). The first cut produced higher biomass and oil content. GC/MS analysis revealed distinct essential oil profiles, with Medani having higher Alpha-Pinene and Beta-Pinene, while Dongola had higher Myristicin levels, indicating its potential for medicinal applications.

Keywords: Parsley, *Petroselinum crispum*, DUS, growth yield, harvest frequency, essential oil

1.Introduction

Parsley (*Petroselinum crispum*) is a herbaceous plant from the Apiaceae family, originally found in Southwestern Europe and Western Asia. It has been cherished since ancient Greek times for its culinary and medicinal uses (Zohary et al., 2012; Dalby, 2003; Riddle, 1985). Known worldwide for its versatility, parsley is used in cooking, traditional medicine, and as an aromatic herb. In Arabic-speaking regions, it's referred to as *baqdwnis* or *maqdwnis*. Fresh parsley leaves are often used as a garnish, while dried leaves, known as parsley flakes, are popular in processed foods like soups and sausages. Medicinally, parsley is valued for its carminative, diuretic, hypotensive, stomachic, nervine, and emmenagogue properties, with its distinctive flavor and aroma coming from its essential oil.

In Sudan, parsley has grown from a minor crop to a key ingredient in local cuisine and traditional medicine (Ahmed et al., 2023; Osman et al., 2021). It's primarily cultivated as a winter crop and adapts well to different soil types, though it prefers light, well-drained soils. The harvesting period lasts about five months, beginning two months after planting and continuing monthly. Local varieties, likely introduced through Egypt, are managed by Sudanese farmers without formal documentation, which affects their conservation. In Central and Northern Sudan, two native cultivars perform well in various agro-climatic conditions. However, research on these varieties' distinctiveness and agronomic traits is sparse, despite their cultivation in arid and semi-arid regions.

This study seeks to fill this research gap by examining the growth, yield, and essential oil properties of these local parsley lines. Insights gained will help improve cultivation practices, boost productivity, and support effective breeding and reintroduction efforts.

2. Materials and Methods

2.1. Materials

Two local lines of parsley (Petroselinum crispum) namely Dongla and Mesdani, were collected from the seed market of North Sudan, Dongola City and central Sudan, Gezira State. The research was conducted at the Medicinal and Aromatic Plants Research Institute (MAPRI) in Shambat locality, Khartoum State, Sudan at (15°40' N, 32°32' E) and 383.54 meters above sea level. Seed sowing took place at the winter season, starting on November 15, 2017. Shambat soil is classified as belonging to the central clay plain of Sudan and identity as vertisols. This region is shaped by the deposition of alluvium from the Nile, mainly basaltic in origin. It exhibits a moderate level of saline and sodic subsoil. The soil composition is consistently clayed across the experimental farm (Ali et al. 2016). Shambat has a subtropical desert climate. The locality's yearly temperature is 31.98ºC (89.56ºF) and it is 1.94% higher than Sudan's averages with winter temperatures ranging from 21-34 ºC. Precipitation is irregular and generally scarce, with the majority occurring from June to September. It typically receives about 14.28 millimetres (0.56 inches) of precipitation and has 31.03 rainy days (8.5% of the time) annually. The main metrological data including, minimum, maximum, and ambient temperature, during the experiment, is presented in Table 1.

2.2 Methods

Experimental design

A four-replication factorial experiment in a completely randomized block design (CRBD) with two factors, varieties (A) and frequency of Harvest (B), was examined. Variety had two levels (Dongola and Madani local Line), while the frequency of Harvest had two levels (first and second cut). Each plot consisted of four rows, each three meters long, with seeds sown in paired rows at an inter-row spacing of 15 cm. The main aims of this experiment were to systematically characterize and assess existing parsley local lines of Sudan for DUS (Distinctness, Uniformity, Stability), growth, yield performance and essential oil profile. The research is also aimed at measuring the resilience of the two local lines as multi-cut crops through measuring variety harvest frequency interaction. Planting took place directly in the field on November 15, 2017. Plants were consistently irrigated based on meteorological conditions, while manual

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weeding was employed to manage weed growth. Monitoring of the crop encompassed parameters such as development, the yield of fresh herbage, and phytosanitary status. Harvesting was initiated 70-90 days post-planting, with several harvests conducted. After harvesting, the leaves underwent trimming, washing, bundling, and preservation at -5°C until essential oil extraction.

Morphological Traits (Variety descriptors)

Morphological traits were assessed using visual descriptors by examining a total of sixty plants for each local line. Fifteen plants were selected randomly from each replication. Plants were hand-harvested at marketable foliage size by cutting at a height of five cm above the ground. Two harvests were taken at suitable intervals (70-140 days) from seeding. Fifteen Variety descriptors were visually scored according to the UPOV code: PETRO_CRI *Petroselinum crispum* (Mill.) Nyman ex A.W. Hill, issued by the International Union for the Protection of New Varieties of Plants (UPOV, 2005). The descriptors include plant height, plant width, the density of foliage, number of leaves, leaf attitude, leaf blade curling, leaf blade length, leaf blade width, leaf blade ratio length/width, leaf blade intensity of green colour, leaflet shape, leaflet shape, distance between 1st and ^{2nd} pair of leaflets, undulation of leaflet margin, petiole length and petiole thickness. The results are presented in Table 2.

Growth parameters

Morphological traits were measured or counted on the average of 10 plants selected randomly from each plot. Morphological traits include plant height, number of branches, canopy diameter, leaf blade length**,** leaf blade width, the distance between the first and second pair of Leaflets, petiole length, petiole thickness, number of leaves per plant, fresh weight, and dry weight. The data on morphological traits are presented in Table 3.

Biomass Yield

Biomass yield was estimated by harvesting 1m² from the central area of each plot. The yield was recorded in kilograms per square meter (kg/m²). The biomass yield and fresh and dry weight are presented in Table 4.

Essential oil yield and chemical compositions

Isolation of Essential Oils:

One hundred grams of fresh leaves were washed, dried, and finely ground for optimal extraction. The sample underwent hydro-distillation for three hours using Clevenger-type equipment. Distillate was collected, and the essential oil was extracted using dichloromethane dried over anhydrous sodium sulfate, and stored at 4°C in airtight amber vials until subjected to GC and GC-MS. Essential oil isolation was carried out as proposed by Huie (2002).

GC and GC-MS Analysis

The GC-MS analysis was conducted as per the methods and procedures described in Adams (2007). Essential oil analyses were carried out at the Department of Medicinal and Aromatic Plants Research, National Research Center, Sudan. 1-µL injection sample was analysed using a Gas Chromatograph Mass Spectrometer manufactured by Shimadzu Company's model GC/MS-QP2010-Ultra, serial number 020525101565SA. A capillary column (Rtx-5 ms-

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30 m × 0.25 mm × 0.25 µm) was used. The sample was injected in split mode, with the instrument operating in EI mode at 70 eV. Helium was used as the carrier gas at a flow rate of 1.2 mL/min. The temperature program started at 50°C and was held for 3 minutes, with a rate of 4°C/min reaching 280°C and held for 10 minutes. The injection port temperature was 300°C, the ion source temperature was 200°C, and the interface temperature was 250°C. The sample was analyzed in scan mode in the range of 40–500 m/z. The identification of components in the sample was done by comparing their retention index and mass fragmentation patterns with those available in the National Institute of Standards and Technology (NIST) library. Major essential oil profiles are presented in Table 5.

Statistical analysis

A conventional factorial RCBD analysis was used to test the significance of differences between different genotypes. Data were analyzed using the MSTAT-C program, applying conventional ANOVA analysis to test for significant differences between varieties, harvest frequency and their interaction. The critical difference (C.D) at the 5% probability level was used to determine statistical significance as per the method suggested in Sokal and Rohlf, 1995.

3. Results and Discussion

The climatic conditions during the experiment, as shown in Table 1, indicated a range of temperatures, humidity, and rainfall throughout the study period. The average temperatures varied from 22.5°C in January to 31.8°C. The average temperature across the growing season is 28.35 ºC. Maximum temperatures peaked at 38.8°C in April, while minimum temperatures dropped to 15.9°C in January. Relative humidity decreased from 28.6% in December to 8.7% in April, and no rainfall was recorded throughout the experiment. Several studies demonstrate the significant role of temperature levels in influencing the physiological processes and fresh mass of parsley. A primary factor affecting plant growth development is temperature, as modulated by other factors including day length and vernalization (Hodges, 1991). The quantitative effects of temperature on plant growth have been studied extensively using the concept of thermal time (Jamieson et al., 1995; Walters and Lopez, 2021). An optimum temperature for parsley 'Giant of Italy' fresh mass is estimated at around 28°C when grown hydroponically under control conditions, (Walters and Lopez, 2021; Frąszczak and Knaflewski, 2009). The climatic data during this experiment align with recommendations from previous studies and also support local farmers' preference to cultivate parsley during this period in Sudan, highlighting the crucial role of environmental factors in parsley cultivation.

To better understand the varietal differences between these two local lines, the findings on morphological traits are presented in Table 2. The morphological trait score adheres to the UPOV code (International Union for the Protection of New Varieties of Plants, 2005). Dongola local Line and Madani's local lines exhibit similar traits for leaf attitude (erect), leaflet shape (medium triangular), leaf blade ratio length/width (medium), and absence of leaf blade curling. However, all other remaining characteristics set them apart. The differences observed between these two lines are sufficiently consistent and distinct from each other. Both lines are uniform within themselves and can be considered stable without the need for more than one growing cycle. The geographic isolation between these two lines and the absence of newly introduced lines have contributed over the years to stabilize both lines. The absence of leaf blade curling categorizes both lines under the flat-leaf form of parsley (*Petroselinum crispum* var. neapolitanum), also known as Italian parsley, with broad flat leaves and stronger flavour compared to curly-leaf parsley (Grin 2008). Such kind of descriptors are useful to identify morphological markers related to aroma and plant size/yield for productivity, (Boutsika et al., 2021).

Leaf parsley is a great candidate for multi-cut harvest every 60-70 days from the same plant throughout its growing season. The reaping and regrowth system is not only feasible for the production of leafy salad vegetables but has also been used in tea and grass production (Belesky and Fedder,1995; Fisher and Dowdeswell, 1995; Murtagh and Smith, 1996; Bore et al., 2003; Nayak and Maji 2018) .this system is also useful in other species such as leafy vegetables. The system can be applied to other species such as parsley. Hence it is essential to measure the growth rate and the total biomass produced after each cut. This can help determine the plant's ability to regenerate, recover, and maintain productivity. This can be influenced by the plant's genetic makeup and intervarietal differences as well as environmental conditions, and management practices. The two lines were tested and the findings were presented as per Tables 3 and 4 for growth and biomass yield parameters.

The Medani local Line showed significantly higher values for growth parameters at a 5% level of confidence for leaf blade length (14.542 cm), leaf blade width (19.329 cm), petiole thickness (12.51 mm), and plant height (39.450 cm) compared to Dongola Local Line. Harvest frequency also affected the growth parameters, with the first cut showing higher values for most traits except canopy diameter. The first cut recorded higher values for LBL (15.98 cm), LBW (19.46 cm), leaf blade distance between 1st and 2nd pair of leaflets (7.612 cm), petiole length (12.51 cm), plant height (45.68), and number of leaves (21.35). The second cut recorded the highest canopy diameter of (20.61 cm). In multicut cropping systems, repeated harvesting often increases canopy diameter due to stimulated branching and leaf production. Regular harvesting can make parsley and similar plants develop a bushier canopy as apical dominance is removed, encouraging lateral growth. Similar phenomena were observed in various herbaceous plants and leafy vegetables, suggesting similar outcomes for parsley (Sanderson et al., 1995; Fu, J. 2008). An interaction effect was observed between variety and harvest frequency for petiole thickness and number of leaves at a 5% confidence level. Dongola local line interacts significantly well showing a higher number of leaves per plant which indicates a better ability to regenerate, recover, and maintain productivity.

Table 4. presents the biomass yield, dry weight, and oil content of the parsley local line. Dongola local line produced a higher biomass yield of (5.849 kg/m²) compared to Madani (4.697 kg/m²), although the difference was not statistically significant.

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Dongola local Line recorded significantly higher dry weight (2.284 kg/m²) while Medani local line was significantly superior in terms of oil content (7.88 g/150g and 5.6%). The first cut showed significantly higher biomass yield and oil content compared to the second cut. Interaction effects between variety and harvest frequency were not significant for the parameters measured. The varietal differences observed in this study are consistent with previous research on parsley genetics and breeding (Fusain, et al. (2016); Al-Attar et al. (2021) and Salehi et al. (2022). Abed and Shebl (2016) reported similar differences in biomass yield between the first and second cut in spinach. The study suggests that the combined harvesting of spinach in the two cuttings can maximize the total fresh yield, even though the second cutting may produce a smaller yield than the first cutting.

Comparison of Essential Oil Components

The Gas Chromatography/Mass Spectrometry (GC/MS) analysis revealed distinct differences in the essential oil composition of both lines. The major components identified in both lines included Alpha-Pinene, Beta-Pinene, Beta-Phellandrene, Alpha-Terpinolene, Myristicin, Elemicin, and Apiole. The relative concentrations of major essential oil components in the fresh leaves of the two parsley local lines are presented in Table 5**.**

Medani local line exhibited higher concentrations of Alpha-pinene (8.37%), Beta-pinene (8.09%), and Alpha-phellandrene (2.05%). Interestingly, Beta-phellandrene was absent in Madeni but constituted a significant portion of Dongola's essential oil profile at (24.67%). This compound is valuable in perfumes, and various medicinal and cosmetic products (Bentley et al., 2013). A similar unique appearance for apiole at (0.41%) in the essential oil profile of Dongola local line. Both varieties contained Myristicin, but Dongola had a higher concentration of (23.81%) compared to Madeni local line (9.89%). The concentration of Elemicin was low in both varieties and slightly higher in Dongola recording an amount of (0.77%) and (0.53%) respectively. Dongla recorded 1,3,8-p-Menthatriene content of (0.77%) while Madeni local line recorded (0.53%) of 1,3,8-p-Menthatriene. This essential oil contributes along with others to the aroma of parsley and has antioxidant properties.

Essential oil composition plays a crucial role in determining the quality and commercial value of parsley. The variation in essential oil components between the two lines is consistent with findings from a study by Boutsika, et al. 2021 and Fusani, et al. 2016, which highlighted significant differences in essential oil profiles among parsley cultivars due to genetic diversity and environmental factors. The significant difference observed in the concentration of Myristicin between the Medani and Dongola local Lines of parsley is noteworthy. Myristicin is a naturally occurring compound found in several essential oils and has been extensively studied for its bioactive properties, including antifungal, antibacterial, and anticancer activities. Previous studies indicate that Myristicin, Apiole, and Beta-phellandrene are commonly found in significant amounts in parsley essential oils. The results from the Dongola line align with these findings, particularly in its high Myristicin and Beta-phellandrene content, (Matasyoh et al., 2009; Fusani, et al. 2017; Salehi et al., 2019; Salas Oropeza et al., 2021; Sany, et al. 2022). The higher concentration of Myristicin in the Dongola local line suggests that the Dongola local line may have greater potential for use in medicinal applications where Myristicin is a key active component (Seneme, et al. 2021; Zheng et al.1992). Alpha-pinene and Beta-Pinene are known for their anti-inflammatory and bronchodilator effects, making them valuable in the formulation of therapeutic agents for respiratory conditions (Salehi et al., 2019; Salas-Oropeza et al. 2021). Both local Lines have sufficient concentrations of Alpha-pinene and Beta-Pinene in their profile, making them equally effective in such therapeutic applications. Beta Phellandrene and Alpha -Terpinolene have been reported to possess antimicrobial properties, with potential applications in food preservation and pharmaceuticals (Vokk, et al. 2011; Pazyar, et al.2013; Cheng et al. 2017; Salas-Oropeza et al. 2021; Radice et. al. 2022;). The comparable levels of these compounds in both lines of parsley suggest that either variety could be used interchangeably for their antimicrobial benefits. Elemicin and Apiole, though present in lower concentrations, have also been studied for their biological activities. Elemicin has been identified as a potential anxiolytic agent (Barman, et al. 2023; Fernandes et al. 2024).), while Apiole is known for its antipyretic, insecticidal, diuretic, and antitumor effects (Punoševac et al.202). The consistent presence of these compounds across both local lines further highlights the therapeutic versatility of parsley essential oils. The absence of Beta-phellandrene in Madeni and its significant presence in Dongola, as well as the exclusive presence of Alpha-terpinolene in the Madeni local line, highlights the genetic diversity between the two lines. Alpha-terpinolene has antioxidant activities, sedative effects, and antimicrobial effects which make the Madeni local line a great candidate for this component (Pazyar, et al.2013). The differences in the essential oil composition of the parsley cultivars are mainly due to genetic variation. Previous research has also observed such variability across different parsley varieties and environmental conditions (Fusani, et al. 2017; Bentley et al., 2013). However, other factors, such as the plant's age, the specific part of the plant studied, its management, and the environmental conditions in which the plant is grown, can also affect the percentage of essential oils (Said-Al Ahl, et al. 2016).

4. Conclusions and Recommendations

The study demonstrated significant variations between the Medani local line and the Dongola local line in terms of growth parameters, morphological traits, biomass yield, and essential oil composition. Medani local Line was superior in terms of growth parameters and essential oil content, while the Dongola local Line had higher biomass yield and specific essential oil components like Beta-phellandrene. The harvest frequency also played a critical role, with the first cut generally producing better results across most parameters. The varietal differences and their response to harvest frequency provide valuable insights for farmers and breeders in selecting appropriate varieties and optimizing harvest schedules to maximize yield and oil content. Overall, the findings of this study contribute to growing knowledge on the diversity that exists in local lines of Sudan, the chemical diversity and the potential use of parsley essential oils. The significant difference in Myristicin concentration warrants further investigation into the genetic and environmental factors influencing its biosynthesis in parsley under Sudan conditions. With the growing importance of the crop in Sudan, we highly recommend the introduction of new lines to increase the gene pool for any future breeding program.

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Table 1. Mean monthly temperature, relative humidity and total rainfall precipitation

Parameters	Year					
	2017		2018			
	November	December	January	February	March	April
Average Temperature (C°)	28.7	27	22.5	29.2	30.9	31.8
Maximum Temperature (C°)	34.9	33.4	29.1	36.4	38	38.8
Minimum Temperature (C°)	22.4	20.8	15.9	21.9	23	24.1
Average relative Humidity (%)	21	28.6	22.7	18.5	11.4	8.7
Total Rainfall (mm)	0	0	0	0	0	0

Source: Shambat Meteorological Station (2018)

Table 2. Evaluation of parsley local lines morphological traits-UPOV code descriptor

UPOV code Descriptor	Parsley Local Line	
	Dongola local Line (D)	Madani (M)
Plant height	medium	tall
Plant width	medium	broad
Plant density of foliage	medium	Dense
Plant number of leaves per plant	many	medium
Leaf attitude	Erect	Erect
Leaf blade curling	absent	absent
Leaf blade length	short	Medium
Leaf blade width	medium	Broad
leaf blade ratio length/width	medium	medium
Leaf blade intensity of green colour	Medium	Dark
Leaflet shape	medium triangular	medium triangular
Leaf blade distance between 1st and 2nd pair of leaflets	medium	Long
Leaflet undulation of the margin	Weak	medium
Petiole length	Short	Medium
Petiole thickness	Thin	Thick

Table 03. Evaluation of parsley local lines growth parameters

Source of variation		LBL (cm)	LBW (cm)	DLB 1&2 (cm)	Petiole Length (cm)	Petiole Thickness (mm)	Plant Height (cm)	No. of Leaves	Canopy Diameter (cm)
Factor A (Variety)	Medani	14.54[a]	19.33[a]	6.77	9.73	12.51[a]	39.45[a]	15.78	17.82
	Dongola	13.17[b]	16.28[b]	6.16	8.70	10.37[b]	35.68[b]	19.45	17.12
CD 5%		**0.986**	**2.19**	**NS**	**NS**	**1.18**	**2.75**	**NS**	**NS**
Factor B (Harvest Frequency)	First Cut	15.98[a]	19.46 [a]	7.61[a]	12.51[a]	11.49	45.68[a]	21.35[a]	14.33[b]
	Second Cut	11.73[b]	16.14[b]	5.32[b]	5.91[b]	11.39	29.45[b]	13.88[b]	20.61[a]
CD 5%		**0.986**	**2.19**	**0.718**	**1.413**	**NS**	**2.75**	**4.376**	**3.05**
Interaction AB	Medani × First Cut	17.01	21.75	8.08	13.31	13.36[a]	47.80	14.65[b]	14.50
	Medani × Second Cut	12.08	16.91	5.46	6.14	11.66[b]	31.10	16.90[b]	21.14
	Dongola× First Cut	14.96	17.18	7.14	11.71	9.62[c]	43.55	28.05[a]	14.17
	Dongola × Second Cut	11.38	15.38	5.18	5.68	11.11[bc]	27.80	10.85[b]	20.08
CD 5%		**NS**	**NS**	**NS**	**NS**	**1.678**	**NS**	**6.103**	**NS**

Note: (LBL) Leaf Blade Length, (LBW) Leaf Blade Width,(DLB1&2L) Leaf blade distance between 1st and 2nd pair of leaflets.
Means superscript with roman letter are significant at 5% level of confidence.
NS; Not significant at 5% level of confidence.
CD 5%; Critical difference at 5% level of confidence.

Table 04. Evaluation of parsley local lines biomass yield, dry weight and oil content

Source of Variation		Biomass yield (kg/m^2)	Dry Weight (kg/m^2)	Oil (mg/150g)	Oil %
Factor A (Variety)	Medani local Line	4.697	1.880[b]	8.40[a]	5.60[a]
	Dongola local Line	5.849	2.284[a]	7.88[b]	5.25[b]
CD 5%		**NS**	**0.393**	**0.429**	**0.285**
Factor B (Harvest Frequency)	1st Cut (Harvest)	7.075[a]	2.082	8.40[a]	5.60[a]
	2nd Cut (Harvest)	3.471[b]	2.082	7.88[b]	5.25[b]
CD 5%		1.768	**NS**	**0.429**	**0.285**
Interaction AB	Medani local Line × 1st Cut	5.835	1.881	8.40	5.600
	Medani local Line × 2nd Cut	3.560	1.881	8.40	5.600
	Dongola local Line × 1st Cut	7.075	2.284	8.40	5.600
	Dongola local Line × 2nd Cut	3.471	2.284	7.88	5.250
CD 5%		**NS**	**NS**	**NS**	**NS**

Note:
- Means superscript with roman letter are significant at 5% level of confidence.
- NS; Not significant at 5% level of confidence.
- CD 5%; Critical difference at 5% level of confidence.

Table 05. Relative concentration of major essential oil components in fresh leaves of parsley

Oil components	CAS Registry Number	% Compound		Significance
		Medani local Line	Dongola local Line	
α- pinene	CAS 80-56-8	8.37	7.74	Promote wound healing process; antimicrobial, anticancer, anti-inflammatory, and antiallergic properties. (Salehi et al., 2019; Salas-Oropeza et al. 2021).
ß-pinene	CAS 127-91-3	8.09	6.81	Antimicrobial activity against various microorganisms (Salehi et al., 2019).
α-Phellandrene	CAS 99-83-2	2.05	0.45	Exhibits antimicrobial and antifungal activities and used as natural insecticide; have applications in food preservation; promote wound keeling process (Radice et. al. 2022; Cheng et al. 2017; Salas-Oropeza et al. 2021).
β -Phellandrene	CAS 555-10-2	0	24.67	β -phellandrene is a key ingredient in perfumes, as well as in medicinal, cosmetic, and cleaning products, (Bentley, et al. 2013).
α-terpinolene	CAS 586-62-9	8.20	-	Antioxidant activities, sedative effect, antimicrobial effect,(Pazyar, et al.2013).
Myristicin	CAS 607-91-0	9.89	23.81	antioxidant properties , Anti-inflammatory and Analgesic , Antiproliferative activity with potential use in cancer, Antimicrobial Activity ,acts as a natural insecticide, psychoactive and Neuroprotective activities properties (Seneme, et al. 2021; Zheng et al.1992).
Elemicin	CAS 487-11-6	0.53	0.77	Antifungal activity (Fernandes et al. 2024).
Apiole	CAS 523-80-8	-	0.41	Used historically in treating menstrual disorders and as Abortifacient, (Tisserand and Young, 2014).
1,3,8-p-menthatriene	CAS 18368-95-1	0.53	0.77	Contributes to the aroma and has antioxidant properties (Kasting, et al. 1972).