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GC/MS Analysis of Essential Oils Extracted from *Cymbopogon schoenanthus* Leaves, Spikes and Roots (Sudan)

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Abstract: *Cymbopogon schoenanthus (Marhabaib/ Maharaib) is a famous high-flowering aromatic plant which is widely used in Sudan for nutritional, medicinal and cosmetic purposes. This work was carried to investigate the yield percentage and chemical composition of leaves, spikes and roots essential oils. Whole plant samples were collected from Northern Darfur, River Nile and Gedarif States. The different oils were extracted by hydrodistillation. Leaves showed the highest mean oil yield (3.39%) followed by roots (2.37%) and spikes (1.54%). Considerable qualitative and quantitative variations in essential oils composition were shown by GC/MS analysis. The highest numbers of constituents were given by N. Darfur spikes (37) and leaves oil (34). River Nile and Gedarif leaves oil showed equal number of constituents as (24). The lowest constituents were observed in River Nile roots oil (13). The major common compounds in leaves, spikes and roots were Piperitone, elemol and β-eudesemol. γ-eudesemol was high in Gedarif (39.12%) and River Nile roots oil (28.87%) whereas, it was not detected in N. Darfur. High piperitone mean was shown by Gedarif oils (39.85%). Elemol mean value was higher in N. Darfur (50.56%), whereas β-eudesemol mean was higher in River Nile (22.77%).*

***Keywords*: Herbal tea, Hydrodistillation, Roots oil, Piperitone, γ-eudesemol**

1. Introduction

The WHO strategy (2014- 2023) encouraged the use of medicinal plants in health systems for it's member countries (Sánchez *et al.*, 2020, Abdel-Rahman *et al.*, 2022). *Cymbopogon* which is generally known as Lemongrass is a native aromatic plant in tropical and subtropical areas, where, it is traditionally used as active antirheumatic, antispasmodic, analgesic, antiseptic, hypotensive, antitussive and anticonvulsant (Karami S. *et al.*, 2021). It is a high-flowering herb which naturally grows at temperature ranging from 23°C to 30°C and average precipitation of 2500 and 3000mm (Spriha *et al.*, 2021). In Sudan the plant may be tolerant to more drastic environmental conditions like poor soil, high temperature and low annual rainfall rates. Figure (1), shows *cymbopogon schoenanthus* at the beginning of the rainy season, in a clearly fire damaged areas.

(a)

(b)

Figure 1. (a) and (b) *cymbopogon schoenanthus* at the beginning of the rainy season

The name lemon grass is derived from the odor of the essential oil (Malti C W *et al.,* 2020). The genus *Cymbopogon* belongs to the grass family, Poaceae (Gramineae), which contains nearly 184 species, subspecies, varieties and sub varieties, out of which 54 species are known and accepted worldwide (Bertea and Maffei., 2010). Lino *et al*., (2010) reported 56 species spreading through the Mediterranean area. The genus was described to be consisting of 144 species in the tropical regions of Africa, Asia and America (Khanuja *et al.,* 2005, Avoseh, O *et al.,* 2015, Pavlovic *et al.,* 2017**).** Around the world there are several species including, *Cymbopogon bombycinus, Cymbopogon ambiguus, Cymbopogon obtectus, Cymbopogon refractus, Cymbopogon flexuosus, Cymbopogon nardus, Cymbopogon Citratus*, *Cymbopogon marthini* and *Cymbopogon pendulus* (Nambiar and Matela, 2012, Spriha *et al.,* 2021). The Indian *Cymbopogons* are classified under three taxonomic series as *Cymbopogon Citrati*, *Cymbopogon Rusae* and *Cymbopogon Shoenanthi* (K. J. Thara Saraswathi, 2016). The most known and well-studied Sudanese species are *Cymbopogon schoenanthus* (marhabaib and/or maharaib), *Cymbopogon nervatus* which, is locally known as (Nal), and *Cymbopogon citratus* (Modawi *et al.,* 1984, Alameen S M A, 2020, Tibenda j j, 2022, Alameen S M A, 2020).

1.1 Traditional and medicinal uses

Worldwide, many communities consume plant based medicines for a variety of medical disorders (Tsion Kassahun *et al.,* 2020). Depending on their pleasant aroma and taste *Cymbopogon* parts find high applications as herbal tea, medicinal supplement, insect repellant, insecticide, in flu control, as anti-inflammatory and analgesic (Ressources, 2005, Opeyemi *et al*., 2015). In Tunisia *Cymbopogon schoenanthus(L.) Spreng.*, is consumed in salads and traditional meat recipes in addition to rheumatism and fever treatment (Khadri *et al*., 2008, Abdelrahman *et al.,* 2020). In Egyptian folk medicine *C. schonanthus* is highly reputed as an effective renal antispasmodic and diuretic agent (Sherif R. Mohamed *et al.,* 2017). The herb decoction is used in Algeria to diminish cramping pain for pregnant women before delivery (F. Z. Bellik, et al., 2019). The aerial parts of *C. schoenanthus* are used for stomachache, antispasmodic and to treat diabetes (El Ghazali, *et al.,* 1994, Suleiman, 2015, Issa *et al*., 2018, Yagi, *et al.,* 2019). The dry leaves and roots are boiled in water and used as analeptic drink by the mothers after childbirth for the first three weeks of delivery (V. Hammiche and K. Maiza., 2006, Nazik A. G *et al*., 2023). Lemongrass leaves aqueous extract and infusion were reported to be used as Hypoglycemic/hypolipidemic, to promote lactation, eliminate postpartum abdominal pain, treat HIV, ease delivery, in addition to it is applications during maternity, menstrual cycle and other women's health conditions (Adeneye and Agbaje, 2007, Coe, 2008, Wright *et al.,* 2009, P.B. Yazbek *et al*., 2016). Inflorescence *C. nervatus* is used to relief kidney pains and indigestion problems (El-Kamali and El-Khalifa, 1999, El-Kamali, Hamza, and El-Amir, 2005). The plant leaves and oil were described for the treatment of bowel spasms, chest pain, elevated blood pressure, epilepsy, dysentery, cough, rheumatism, flu, common cold, tiredness, headaches, intestinal troubles, muscle pain, urinary diseases, rheumatisms, food poisoning, and bringing back the appetite (Khadri *et al*., 2008, Ramdane *et al*., 2015, Spriha *et al*., 2021). In Nigeria lemongrass is used for the treatment of fever, convulsion in children, throat inflammations, stomach upset, skin diseases, and ear/eye infections (Samson O, 2022). Most *Cymbopogon* species are declared to be safe for consumption as herbal tea, drinks, food additive, in addition to their, perfumery and cosmetics applications **(**Bakkali F. *et al*., 2008, Ekpenyong C. E *et al.,* 2015b, Tibenda J J, *et al*., 2022). Due to it is monoterpenes, diterpenes, sesquiterpenes and phenolic acids content *C. schoenanthus* was used as antimicrobial, antioxidant, anti-proliferative, anti-inflammatory, anticonvulsant, and to inhibit kidney stone formation **(**Abdel-Rahman *et al*., 2022, Ali A. Eltayeib and Nahla A, 2023). The anti-inflammatory effects of *C. schoenanthus* essential oil in addition to other medicinal plants may be due to their piperitone content (Leite BL *et al.,* 2010, Sun Z *et al.,* 2014, Golestaneh Talaei M. *et al.,* 2019). The high polyphenol content of *C. schoenanthus* extract may contribute directly to the antioxidant activity which can prevent or moderate the free radicals oxidative damage in the body (Sherif R. Mohamed *et al.*, 2017, Sief, M. M., *et al.,* 2020). In some parts of Algeria weak antioxidant activity of C. schoenanthus essential oils was reported (Hellali *et al.*, 2016, Wahiba Aous *et al.*, 2019). *C. schoenanthus* was found to be useful for treating aerophagia, flatulence, bad breath, gumboils and urinary incontinence (V. Hammiche and K. Maiza., 2006). Salma Hago *et al.*, (2023) reported high selectivity and effectiveness of *C. Schoenanthus* aerial parts ethanolic extract against breast and prostate cancer cell lines. *C. citratus* essential oil was also described to be highly effective on prostate cell lines (B. Bayala *et al.*, 2018). Depending on their active role as antioxidant, anti-inflammatory, antibacterial, antifungal, antiviral and their significantly promising anticancer activity against human breast carcinoma, human colon adenocarcinoma cell lines and cancer cell lines *C. schoenanthus* essential oils were strongly recommended for many therapeutic purposes and as effective natural anticancer agent (Nerio L. S *et al.*, 2010, Sakina Yagi, *et al.*, 2019, Gabriele Rocchetti *et al*., 2020, Mohamed Abdoul-Latif, F. 2022, Mohammad Mukarram *et al.,* 2022, Hassan Rammal and Alaa El-Hajjar, 2023, Bagora Bayala, *et al*., 2023). *C. schoenanthus(L.) Spreng.* oil was reported to be nontoxic, with high capacity to inhibit some key enzymes associated with some major health problems like Alzheimer's disease, skin disorders, and diabetes mellitus, therefore, it was suggested as a good new natural product for nutritional, pharmaceutical and perfumery applications (Khadri *et al.*, 2010, F.-Z. Bellik *et al.*, 2019, Sakina Yagi *et al.*, 2019, Sylvain *et al.*, 2019, Djamel Boukhalfa *et al.*, 2023). Abdelsalam A. *et al.*, (2023) suggested future applications of *C. schoenanthus subsp*. *Proximus* for producing biologically active compounds and to understand the physiological and molecular changes in gene expression in response to stress hormones treatment. The biochemical, physiological, nutraceutical and medicinal values of *C. schoenanthus* were significantly improved by treating lemongrass seeds by laser light (Okla, M. K. *et al.*, 2021). Karami S. *et al*., (2021) suggested further well-designed clinical trials and conclusive results to confirm preclinical findings, because, the safety and efficacy of *Cymbopogon* species are not fully evaluated in human. According to Taha El‑Bassossy, *et al*., (2023), the random use of *C. schoenanthus* EOs should be evaluated carefully, because the high doses may increase the levels of some cytokines and antioxidants which may lead to harmful effects on spleen, kidney architecture, congested red pulp, and fibrosis with increased hematopoiesis. On the other hand, Djamel Boukhalfa *et al.*, (2023) stated that, a dose of 2g/kg of *C. schoenanthus* essential oil of body weight is not toxic. The histological examinations indicated that, *C. schoenanthus* extract can effectively reduce the negative impacts of formalin toxicity on the liver and kidney (Sherif R. Mohamed *et al.*, 2017).

1.2 Cymbopogon schoenanthus

In Asia and central Africa, the plant grows natively on the gravelly-stony soils of djebels in arid and tropical regions as a compact, perennial grass forming dense tussokes at the base, with numerous-erect stems (60-80 cm) and strongly curved linear leaves (Fig. 2) (Hashim *et al*., 2016, Alsnafi, 2016, F.-Z Bellik, *et al*., 2019, Malti *et al.*, 2020). *C. schoenanthaus spreng. (L.)* aerial parts and rhizomes produce pleasant odor essential oil which may be valuable in future biotechnology applications (Malti C. E. W *et al.*, 2020, Abdelsalam A. *et al*., 2023***)*****.** The plant leaves, stems, flowers and roots produce similar essential oils (Malti C. E. W. *et al.,* 2020). *C. schoenanthus subsp. (proximus)* is a densely-tufted grass, which grows in Upper Egypt, Sudan and south of Sahara from Mauritania to Ethiopia and Kenya (Boulos 1999).

Figure 2. Mature *C. schoenanthus* at the end of the rainy season (N. Darfur)

1.3 Cymbopogon oils

Lemongrass oil is known in the world trade as Cochin oil, because 90% of it is shipped from Cochin port of India, where different species are commercially cultivated. The essential oils contain, terpenoids, benzenoids, organic sulfer and nitrogenuous compounds (Malti C W *et al*., 2020). Historically lemongrass essential oil was used in folk medicine to stabilize menstrual cycles, promote digestion, increase immunity or for producing perfumes and pharmaceuticals (Ewa Majewska *et al*., 2019). Today there is a growing interest for using the EO as a general food additive to enhance quality or increase shelf-life of the products (Ewa Majewska *et al*., 2019). As reported by Khadri *et al*., (2008), *C. schoenanthus* EOs contain high monoterpene hydrocarbons (25.7 to 66.3%), dominated by, limonene (10.5 to 27.3%), β-phellandrene (8.2 to16.3%), δ-terpinene (4.3 to 21.2%) and α-terpineol (6.8 to 11.7%). According to Golestaneh Talaei *et al.,* (2019) *C. schoenanthus* oil is a mixture of piperitone (62%), α-terpinene (7.1%), *p*-cymene (2.9%), and limonene (2.3%). The anti-inflammatory and immunomodulatory effects of *C. schoenanthus* EO were expected to be due to it's piperitone, α-terpinene, p-cymene and limonene content (de Cássia da Silveira e Sá *et al*., 2013 Sun *et al*., 2014, Silva *et al*., 2015). Hashim *et al.,* (2017), reported, piperitone, β-elemene, α-eudesmol, β-eudesmol, γ-eudesmol, elemol, cyclohexane methanol, and 2-naphthalenemethanol as the major constituents of *C. schoenanthus* oil. In a study carried by Yagi *et al.,* (2016), the major constituents were, piperitone (18.4%), elemol (18.3%), eudesm-11-en-1-ol (17.0%), α-eudesmol (10. 7%), bulnesol (7.0 %) and *γ*-eudesmol (5.8%). Yagi A. *et al.,* (2019) showed Piperitone as (59.1%), Elemol (10.9%), δ-2-Carene (9.1%), β-Eudesmol (4.9%), α-Eudesmol (3.0%), γ-Eudesmol (2.1%) and Limonene (1.9%) in essential oil samples obtained from Northern Sudan. F. T. D. Bothon *et al.,* (2013) showed piperitone as (68.4%), δ-2-carene (11.5%) and α-eudesmol (4.9%). Piperitone was described to be the major constituent of *C. schoenanthus* oil in Burkina Faso (Siddiqui *et al.*, 1980; Menut *et al*., 2000). Bagora Bayala *et al.*, (2023) identified thirty-seven compounds in *C. schoenanthus* EO dominated by piperitone (49.9%), alphaterpinene isomer (24.02%), elemol (5.79%), limonene (4.31%), α-Eudesmol (2.65%), β-elemene (1.5%) and Spathulenol (0.15%). The constituents of leaves oil from Northern Darfur were described by Gibla Omer A. *et al.,* (2022) as piperitone (84.13%), (+)-2-carene (5.75%), d–Limonene (2.67%) and α– terpineol (2.21 %). El-Tahir and Abdel-Kader (2008) reported piperitone as (72.44%), Elemol (9.43%), Eudesmol (6.60%), α-terpinene (4.64%), limonene (2.40%), Bulnesol (2.11%) and carene (1.77%) in *C. proximus* oil. Piperitone content of *C. Proximus* oil was shown as (59.1%) by Avoseh et al., (2015). Bossou *et al.,* (2013) recorded piperitone as (58.9%), δ-2-Carene (15.5%), Elemol (5.3%), Limonene (3.6%), α- Eudesmol (2.1%), β-Eudesmol (1.2%) and γ-Eudesmol (1.1%). Twenty nine (29) components were identified by, Taha El‑Bassossy, *et al.,* (2023) including, Piperitone (47.93%), Elemol (11.91%), (+)-2-Carene (10.69%), β-Eudesmol (7.67%), α-Eudesmol (5.12%), and γ-Eudesmol (4.24%) as main components.

2. Methodology

C. Schoenanthus samples were collected at their maturity stage from Northern Darfur, River Nile and Gedarif States (Fig. 3). The plant leaves, spikes and roots were air-dried at room temperature. Hydrodistillation was used for oil extraction. The extracted oils were then dried by anhydrous sodium sulfate. The chemical constituents were determined by GC/MS analysis.

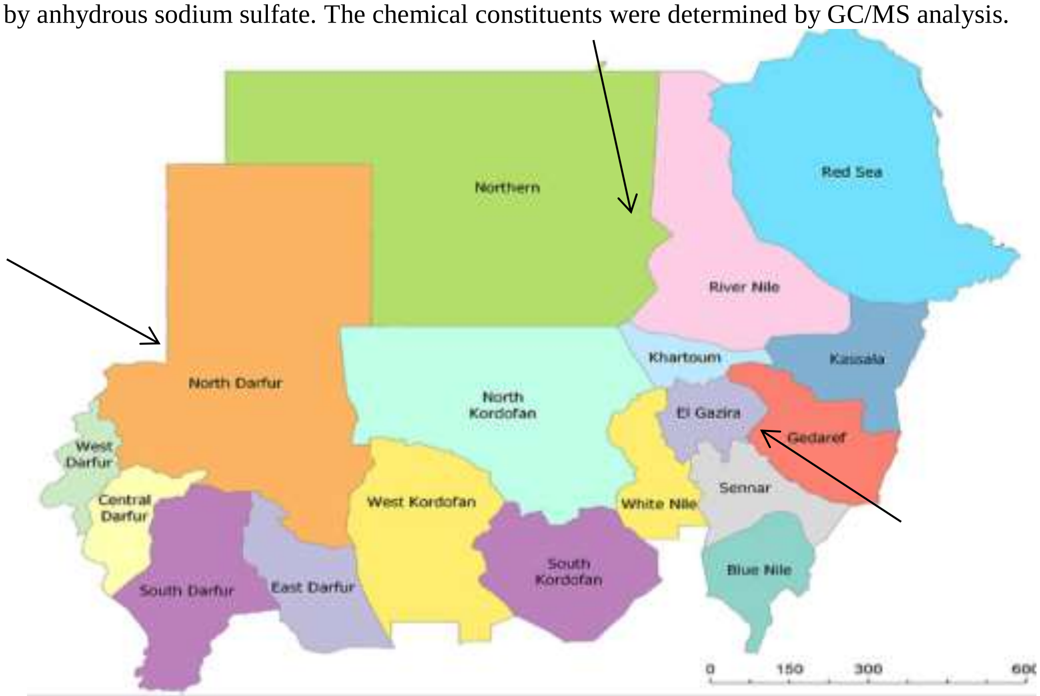

Fig. 3: States of Sudan

3. Results and discussion

As shown by table (1) Northern Darfur samples gave the highest oil yield, followed by River Nile. The plant leaves were rich with essential oil followed by roots and spikes. The oil yield of leaves, spikes and roots in the three States was relatively high when compared with many previous studies (Ketoh *et al.*, 2005, Shah *et al.*, 2011, Bossou *et al.*, 2013, Yagi *et al.*, 2016, Eihab O. *et al.*, 2016, Ivan Pavlovic, 2017, F.-Z. Bellik, *et al.*, 2019 and Alameen S. M. A. 2020) but, it may agree with that of Djamel Boukhalfa *et al., (*2023). From economic and commercial sight of view *C. schoenanthus* leaves may be suggested as a good source of essential oil in the three areas with a mean value as (3.39%).

Table 1. Oil yield percentage (ml/100g)

State / Plant part	N. Darfur	R. Nile	Gedarif	Mean
Leaves	3.76%	3.34%	3.06%	3.39%
Spikes	2.5%	1.02%	1.10%	1.54%
Roots	2.8%	2.45%	1.86%	2.37%

The constituents number was higher in N. Darfur oils, as (34) for leaves and (37) for spikes (Table. 2). Equal number of constituents was shown by leaves oil in R. Nile and Gedarif as (24). Yagi *et al*., (2016) reported (49) constituents for dried leafy stems essential oil. Gibla Omer A. *et al*., (2022) reported (48) compounds in spikes and (16) in leaves oil. Olayemi, R. F, (2017) described significant variability in oils yield and constituents**.** The qualitative and quantitative differences were suggested to be due to environmental factors, season of harvesting, grinding mode or extraction technique (F.- Z. Bellik, *et al.*, 2019, Nathan M. K, 2020, Spriha *et al.*, 2021).

Table. 2. The number of oil constituents

Plant part / State	Leaves	Spikes	Roots
N. Darfur	34	37	16
R. Nile	24	20	13
Gedarif	24	28	19

3.1 Leaves oil constituents

The major common compounds in leaves oil were, Elemol, β-Eudesmol and Piperitone (Fig. 4). Elemol was high in N. Darfur (48.87%) and R. Nile (30.34%), whereas, Piperitone was significantly higher in Gedarif oil (76.40%). β-Eudesmol was (21.85%) in R. Nile, (15.61%) in N. Darfur, and (2.23%) in Gedarif. γ-Eudesmol (Machilol) was (8.07%) in R. Nile, (2.21%) in N. Darfur and not detected in Gedarif. γ-Eudesmol (8a oct) was detected only in R. Nile as (21.69%). (6-Methyl-3.5-heptadiene-2-on2) and (3-Tetradecyn-1-ol) were appeared only in N. Darfur as (9.38%) and (1.87%) respectively. Gedarif leaves oil showed $\delta-$Elemene (8.56%) and β-Selene (0.71%). β-Elemene was (1.28%) in N. Darfur and (0.82%) in Gedarif. Isocaryophyll availability was almost similar in R. Nile (0.59%) and Gedarif (0.58%). Low α-Selenen was observed only in R. Nile (0.13%). Taha El‒Bassossy, *et al.*, (2023) identified (29) components in the aerial parts oil including, Piperitone (47.93%), Elemol (11.91%), 2-Carene (10.69%), β-eudesmol (7.67%), α-eudesmol (5.12%), and γ-eudesmol (4.24%). Piperitone, elemol, β-Eudesmol, α-Eudesmol, γ-Eudesmol, δ-2-Carene and Limonene were reported as major constituents of *C. schoenanthus* oil by Siddiqui *et al.,* (1980), Menut *et al*., (2000), El Tahir and Abdel-Kader (2008), F. T. D. Bothon*, et al.*, (2013), Bossou *et al.,* (2013), Avoseh *et al*., (2015), Yagi A. *et al.*, (2019), Gibla Omer A. *et al.*, (2022), Tibenda *et al*., (2022) and Bagora Bayala, *et al.,* (2023). The major constituents of *C. schoenanthus* fresh aerial parts essential oil were reported by (Hellali *et al.,* 2016) as piperitone (63.35%), β- eudesmol (9.305%) and elemol (6.915%). To some extent different constituents were shown by Fatouma *et al.,* (2022) including, 3-Isopropenyl-5-methyl-1-cyclohexene (32.3%), D-Limonene (11.3%), α-Terpineol (8.5%), β- elemol (7.8%) and 2-p-Menthen-1-ol (5.1%) whereas, piperitone was not detected.

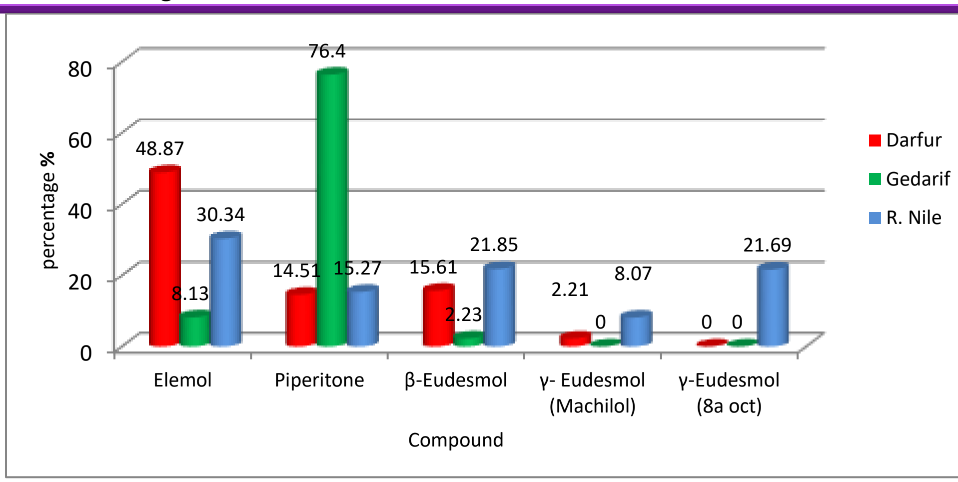

Figure 4. The major constituents of leave oils in the three States (%)

3.2 Spikes oil constituents

The spike oils were dominated by, Elemol, Piperitone and β-Eudesmol (Fig. 5). Elemol was also higher in N. Darfur (49.58%), followed by R. Nile (36.38%) and Gedarif (27.32%). Piperitone was relatively low in N. Darfur (24.56%) compared with that of R. Nile (47.80%) and Gedarif (38.84%) whereas, β-Eudesmol was almost similar in the three states, as (10.86%) in N. Darfur, (10.27%) in R. Nile and (11.48%) in Gedarif. γ-Eudesmol (8a oct) was shown in Gedarif only as (10.81%). 6-epi-Shyobunol was (3.03%) in N. Darfur and (2.40%) in Gedarif. δ-Elemene was (1.35%) in N. Darfur and (3.17%) in Gedarif. N. Darfur spikes oil showed γ-Eudesmol (Machilol) as (3.63%), and Ledane..Spathulenol (2.98%). Low levels of Tetradecyn-1-ol (1.01%), 3-Octen-5-yne-2,7-dimethyl-(E) (1.30%), Naphthalene,1,2,3,5,6,8a-hexahydro-4,7-dimethyl-1-(methylethyl)-(cis) (0.48%) and Limonene (0.31%) were shown only by R. Nile oil. β-Elemene was (0.49%) in R. Nile and(0.67%) in Gedarif. Gibla Omer A. *et al.*, (2022) identified (48) components in the spikes oil, dominated by Piperitone (35.96%), Elemol (20.45%), (+)-2-Carene (8.18%), Guaiol (6.04%), β-eudesmol (5.97%), γ-eudesmol (4.28 %), Bulnesol (3.14%), Limonene (1.44%) and α-Eudesmol (1.37%).

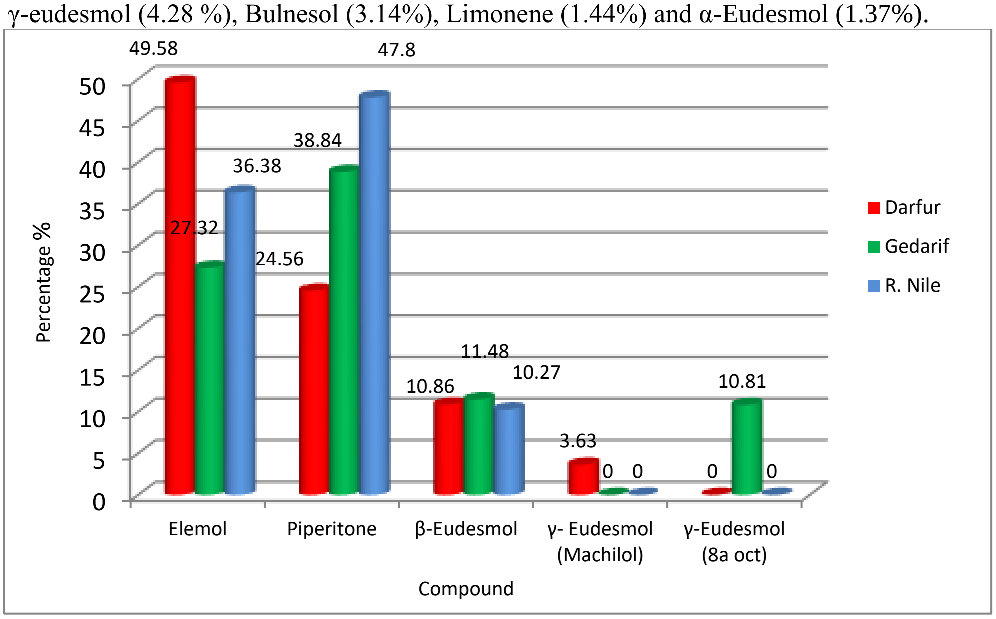

Figure 5. The major constituents of spike oils at the three States (%)

3.3 Roots oil constituents

The major common compounds in roots oils were, Elemol, β-Eudesmol, Piperitone, 3-Tetradecyn-1-ol and β-Elemene. Elemol was (53.23%) in N. Darfur, followed by β-Eudesmol (17.08%), piperitone (10.85%), 3-Tetradecyn-1-ol (8.25%) and β-Elemene (4.07%). R. Nile oil showed, Elemol as (33.96%), β-Eudesmol (30.19%), γ-Eudesmol (Machilol) (28.87%), Piperitone (03.41%), 3-Tetradecyn-1-ol (2.65%) and β-Elemene (0.40%) whereas, the constituents of Gedarif oil were γ-Eudesmol (Machilol) (39.12%), Elemol (27.39%), β-Eudesmol (22.62%), Piperitone (04.31%), 3-Tetradecyn-1-ol (4.11%), and β-Elemene (0.23%). Low

(Patchoulane) was detected in R. Nile and Gedarif oils. In N. Darfur low levels of (Tetracyclo(6.1.0.0).0(5,7))nonane,3,3,6,6,9,9-hexamethyl-,cis,cis,trans), (3-Decyn-2-ol), (p-Menthane,1,2:8,9-diepoxy) and (n-Nonadecanoic acid) were detected. Low levels of Germacrene D-4-ol, Spathulenol, Linoleoyl chloride, Farnesol and Tau-Muurolol were shown by Gedarif roots oil. Bicyclo (5.2.0) nonane,4-methylene-2,8,8-trimethyl-2-vinyl, was appeared only in R. Nile oil. High γ-Eudesmol (Machilol) was detected in R. Nile and Gedarif oils. Piperitone was significantly low in root oils of the three states when compared with that of leaves and spikes (Fig. 6). This may strongly agree with Ali. A. Eltayeib and Nahla Agab, (2023), who showed elemol as (20.14%), β-eudesmol (11.31%), Piperitone (1.71%) and disagree with Djamel Boukhalfa, *et al.*, (2023) where *C. schoenanthus* roots oil from southern Algeria contain (50.25%) piperitone and (11.06%) α-elemol.

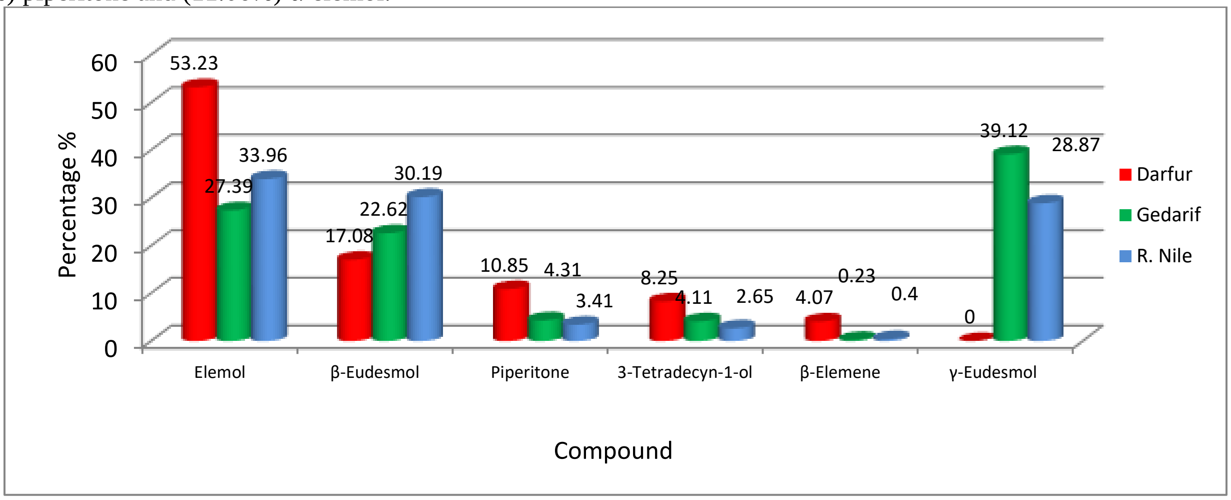

Fig 6.The major roots oil constituents of the three States (%)

Fig. (7) Shows the mean percentage of Elemol, β-Eudesmol and Piperitone in leaves, spikes and roots essential oils of the three areas. Elemol mean content was almost similar in spikes (37.76%) and roots (38.19%) and relatively low in leaves oil (29.113%). β-Eudesmol mean was higher in roots (23.30%) than that, of leaves (13.23%) and spikes (10.87%). Significantly low of piperitone mean was shown by roots oil as (6.19%). As major *C.schoenanthus* essential oil constituents, Elemol, β-Eudesmol and Piperitone were reported to possess good antimicrobial, pesticide, antiproliferative, antioxidant and enzymes inhibition activity (Ketoh *et al.*, 2006; Hashim *et al.*, 2017; Sakina Yagi *et al.*, 2019, Malti *et al.*, 2020). Djamel Boukhalfa *et al.*, (2023) stated that, the strong antifungal and antibacterial activity of *C. schoenanthus* essential oil is mainly due to its richness with piperitone. All microbial strains were reported to be inhibited by fresh *C. schoenanthus* oil especially the growth of *Enterococcus faecium* (Hellali *et al.*, 2016, Wahiba Aous, *et al.*, 2019).

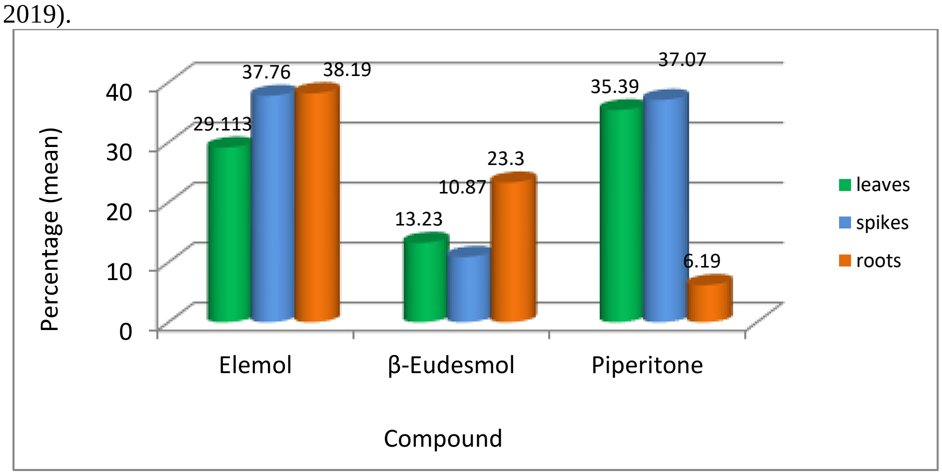

Fig. 7: Elemol, β-Eudesmol and Piperitone (mean) in *C. schoenanthus* oils

Figure. 8. Shows the mean content of piperitone, elemol and β-eudesmol in *C. schoenanthus* essential oils at the three States. N. Darfur showed the highest elemol mean content (50.56%), whereas piperitone mean was higher in Gedarif (39.85%) and β-eudesmol mean in R. Nile (20.77%). These qualitative and quantitative regional variations may reflect the effect of some differences in soil composition, climatic conditions, or maturity stage. Ewa Majewska *et al.*, (2019) reported that, the essential oil composition may differ depending on the geographical origin, farming practices, plant age, photoperiod, harvesting time, genetic differences, and extraction methods. According to Saikia Debajit *et al*., (2015), the essential oils composition of *Cymbopogon* species and cultivars may be governed by complex genetic interactions. Ethanolic extract of *C. schoenanthus* aerial parts from Gezira State was reported by Salma Hago, *et al*., (2023) to contain elemol as (42.53%) and piperitone (03.55%).

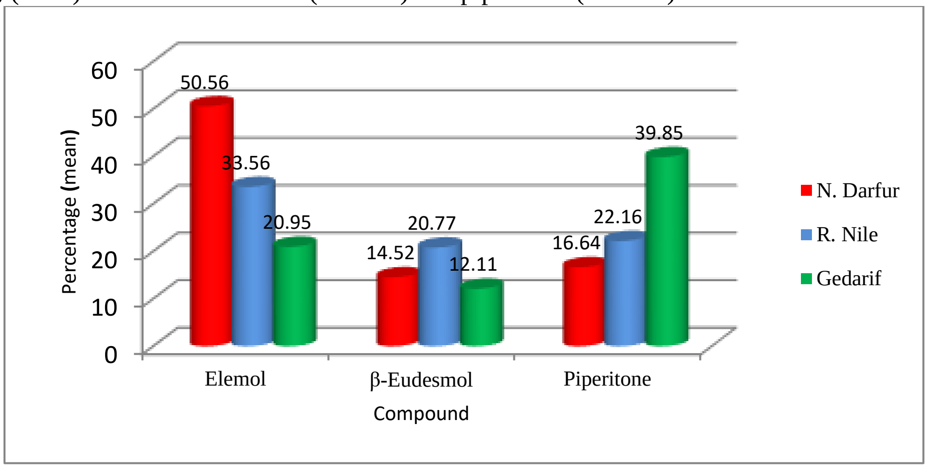

Fig. 8: Elemol, β-Eudesmol and Piperitone mean of *C. schoenanthus* oils in the three States

4. Conclusion

In the three sampling areas, the leaves oil yield was the highest, followed by roots and spikes. Considerable qualitative and quantitative variations were shown by the extracted oils. Piperitone, elemol and β-eudesemol were the major common compounds in leaves, spikes and roots oil. Roots oil showed significantly low piperitone content in the three regions. The major available compounds may need to be isolated for further studies concerning their medicinal, pharmaceutical and biological activity roles.

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