Chemical Composition of crude extract of the tubers of *Cyperus articulatus* L. From Meru in Kenya

By Karambu E. Muriithi, Jacob O. Midiwo, John M. Wanjohi, Mbaabu P. Mathiu, Stephen G. Kiama

Abstract. The root tubers of *Cyperus articulatus* were collected from Meru in Kenya and extracted with organic solvents (CH_2Cl_2, 50%CH_2Cl_2 in CH_3OH, 5% H_2O in CH_3OH). The crude extract of 100% CH_2Cl_2 was subjected to a combination of chromatographic techniques including column chromatography and preparative thin layer chromatography for the isolation of compounds. The fractions obtained during the isolation were each subjected to GC/MS analysis. The GC- MS analysis was carried out at Surrey University (U.K.) in order to determine the structures of the compounds. A total of 59 compounds were identified, of which 48 (82.76%) were terpenes. Amongst the terpenes were 27 sesquiterpenes (45.76%), 20 monoterpenes (33.90%) 1 triterpene (1.69%) and there were 11 non-terpenes (18.64 %). The major sesquiterpene identified was α cubenene. The column chromatography method of isolation failed to produce any pure compound, this was attributed to the large number of monoterpenes present in the extract which are known to appear in complex mixtures too similar to isolate.

Key Words *Cyperus articulatus*, *Cyperaceae*, caryophyllene oxide, essential oil composition, α-pinene, mustakone.

Introduction

Family Cyperaceae (Cyperaceae-*Sedge Family)*

The plants in this family grow in wet areas along rivers, ponds or swamps. Their stems are usually solid and three-angled. The leaves when present, are slender. The flowers are clustered in spikelets. There are usually 3 stamens, and 2 to 4 feathery stigmas on the pistil [11]. Essential oils from *Cyperus* species are generally constituted mostly of sesquiterpenoids, and minor monoterpenoids [8]. In Tharaka the tubers of *C. articulatus* grow wildly in swamps and along the river bends. They poccess a strong pleasant smell. It is locally known as ndago. Methanol and aqueous extract of this plant have been investigated earlier for antiplasmodial activity and two compounds mustakone and colombolone tested.

Cyperus articulatus

Botanical information

Kingdom *Plantae* – Plants

Subkingdom *Tracheobionta* – Vascular plants

Super division *Spermatophyt*a – Seed plants

Division *Magnoliophyta* – Flowering plants

Class *Liliopsida* –Monocotyledons

Subclass *Commelinidae*

Order *Cyperales*

Family *Cyperaceae* – Sedge family

Genus *Cyperus L.* – flatsedge

Species *Cyperus articulatus L.* – jointed flatsedge

C. articulatus is a type of reed-like tropical grass, used in Tharaka- Meru for medicinal purposes as earlier mentioned. It is an aromatic herbaceous species of grass with short rhizomes, thin and resistant roots. It grows in damp, marshy and flooded areas along the rivers and streams (where it can help to control soil erosion). It can attain a height of 6 feet as shown in Figure 1

Fig. 1 Cyperus articulatus

It grows in clumps from dividing rhizomes which are about 1cm in diameter some times in a series of two or three, connected by an underground stem [16]. *C. articulatus* often occurs in almost pure stands in tropical and warm temperate localities that provide permanent water. It is distinguished by its robust, leafless culms. [5] The tall green stems are fibrous, round, and hollow at the base with jointed flat edge. Its blackish red tubers are 1 to 3 cm long. This is as shown in Figure 2.

Fig.2 Dried tubers of C. articulatus

C. articulatus has an aroma similar to lavender and the aromatic properties are used in folklore medicine to cause a feeling of warmth in the body which aids in the treatment of digestive disorders and its sedative effects [16]. The following compounds were previousily identified from *Cyperus articulatus* from other parts of the world.

Table 1 Compounds formerly isolated in Piripiri *C. articulatus*

Compound	Group	Part of plant	Place
Caryophylene oxide	Sesquiterpene	Rhizome essential oil	Brazil
Corymbolol	α sesquiterpene	Rhizome	Cameroon
Corymbolone	Sesquiterpene	Rhizome	Cameroon
Cyperone	Asesquiterpene	Rhizome	Cameroon
Cyperotundune	Sesquiterpene	Entire plant	Canada
Mandassidion	Sesquiterpene	Rhizome	Cameron
Mustakone	Sesquiterpene	Rhizome-essential oil	Cameroon/Brazil
Patchoul-4(5)-en-3-one	Iso-Sesquiterpene	Rhizome	Cameroon
Pinene	α sesquiterpene	Rhizome essential oil	Cameroon

(adopted from [20]

Phytochemical analysis of *C. articulatus* has revealled that it mainly consists of essential oils. Essential oils have a complex composition, containing from a few dozen to several hundred constituents, especially hydrocarbons and oxygenated compounds which are highly odoriferous [17]. All essential oils are principally composed of a class of organic compounds built of *"isoprene units."* Molecules built of isoprene units are all classified as *"terpenes"* [3]. Monoterpenes, with sesquiterpenes, are the main constituents of essential oils. While a few, such as camphor, occur in a near pure form, most occur as complex mixtures, often of isomers difficult to separate [19].

Ethno-Medicinal Uses of *Cyperus articulatus*

Ethnopharmacology and natural product drug discovery remains a significant hope in improving the poor livelihoods of rural communities [10]. Over many years plants have been used for drugs and as fragrance materials. The chemical characterization of rhizomes of *C. articulatus L.* shows the presence of flavonoids, saponins, triterpenes, sesquiterpenes and ketones. As some of the diseases treated with *C. articulatus L.* (migraines, headaches and according to a personal communication also epilepsy) concern the nervous system, some pharmacological work has been done to define its interaction with this system. Decoction of rhizomes of *C. articulatus L.* possesses depressant activity in the central nervous system [12]. Piri-piri has a long history of use in herbal medicine systems in South America. It is a very common remedy for treating nausea, vomiting, stomach-aches and intestinal gas throughout the continent. In Peru, piri-piri is considered as an abortifacient, anticonvulsant and anti-epileptic and treats stomach-ache [21]. The crude drug prepared from the rhizomes of this plant has been used in traditional medicine as contraceptive [6]. It is used for diarrhea, dysentery, digestive disorders and intestinal infections, intestinal worms, epilepsy, to stop bleeding (internally and externally) and to heal wounds. In Africa, piri-piri is used for malaria, toothaches, headaches, diarrhea, indigestion and coughs [20]. *C. articulatus* is popularly known as priprioca in Pará State (Brazil). Priprioca has aroused scientific and economic interest because of the pleasant aroma of the volatile oil obtained from the plant rhizome. This species has great importance in the local pharmacopoeia of Brazil: It is mainly used as a contraceptive, a painkiller, and in the treatment of diarrhea. The volatile part of the priprioca extract (the essential oil obtained by hydro-distillation) mainly consists of α-pinene, β-pinene, limonene, Myrtenol, α-copaene, and Caryophyllene oxide [7]. In Brazil *C. articulatus* is cultivated and commercialized by small holders for direct market sale, and as a raw material for the perfumery industries. Anticonvulsant, sedative, antibacterial, and activity on epilepsy were reported from this plant [8]. Extracts from rhizomes of *C. articulatus* L. (*Cyperaceae*) used in Africa and Amazonia has been used for many different ailments including; digestive disorders, menstrual irregularity and has been used for its sedative properties and anticonvulsant properties in the treatment of epilepsy [2]. Rhizomes of *C. articulatus* L. pocesses anticonvulsant properties in animals and this explains its use as a traditional medicine for epilepsy in Africa [12]. In Cameroon qualitative chemical characterization of the total extract showed that *C. articulatus* contains flavonoids, saponins, polyphenols, tannins, terpenes and sugars. The total extract of the rhizome of *C. articulatus* did not appear to possess either anaesthetic or paralyzing effects. In contrast, spontaneous motor activity is significantly reduced by the extract. However, *C. articulatus* does not seem to have muscle relaxant effects. When associated with sodium thiopental or diazepam, the extract facilitates sleep induction, and increases the total sleep time without any concomitant analgesic effects [22]. *C. articulatus* has been used traditionally for the treatment of pain, cough, flu, common cold, fever, malaria and typhoid.Research on the plant in relation to a number of ailments has been carried out extensively including Brazil, S . Africa, Cameron and Nigeria and Peru. Many of its biological actions are attributed to various sesquiterpenes called cyperones which are also found in other *Cyperus* plants in the family. As [14] have isolated the sesquiterpenoic ketones, mandassidione, mustakone, corymbolone and the alcohol corymbolol, from Cameroonian grown *C. articulatus*. Earlier work on the essential oils from the Canadian grown *C. articulatus* has led to the isolation and characterization of a bicyclic ketone, cyperotundone [14]. Two of these compounds called cyperotundone and α-cyperone, have been reported to posses anti-malarial activities, as well as the ability to inhibit nitric oxide

synthesis and prostaglandin synthetase inhibitor? Aspirin and ibuprofen are prostaglandin synthetase inhibitors [20]. Corymbolone is a sesquiterpenoid keto-alcohol first isolated in 1985, in South America, from the rhizomes of *Cyperus corymbosus Rottboll*. Some years later, corymbolone was isolated in Cameroon, from *C. articulatus* L along with another eudesmane sesquiterpene. Two sesquiterpenes, corymbolone and mustakone, isolated from the chloroform extract of the rhizomes of *Cyperus articulatus*, exhibited significant anti-plasmodial properties. Mustakone was approximately ten times more active than corymbolone against Plasmodium falciparum [18]. Ant-malaria activity of a water and methanol extract of the same plant was reported and [9] mentioned it as one of the medicinal plants used for treating malaria.

Methodology

Plant material Collection

Fresh root tubers (Rhizomes) of *C. articulatus* were collected from Meru October 2010 and were identified at the school of biological Sciences University of Nairobi Herbarium.

Plant Extraction

The root tubers of *C. articulatus* were washed dried under shade and ground using a Wiley mill from the department of Chemistry University of Nairobi to a grain size of < 2 mm. The powder was weighed and yielded 6 kg. Out of these 2 kg were preserved in a refrigerator for further analysis. The remaining 4 kg were subjected to serial extraction by cold percolation first with 100% dichloromethane (CH_2Cl_2) for 24 hours, with two subsequent repetitions; this was followed by a mixture of 50% dichloromethane in methanol (CH_2Cl_2/ CH_3OH) and finally 5% water in methanol. Each extract was concentrated using a rotatory evaporator at a temperature of 40°C to 60°C with an aspirator vacuum. The 5% water /methanol extract after concentration was freeze dried at the school of Biological Science University of Nairobi for 24 hours to ensure all the water was completely removed. The dry powder was tightly corked and kept in the fridge awaiting further analysis. The crude extracts for each of the others were combined, tightly corked and stored in the refrigerator to wait for further processing. The quantities yielded were 100% dichloromethane extract 100 grams, 50% dichloromethane in methanol 60 grams, and 5% water in methanol yielded 36 grams. The three extracts were brown in color, oily and all with a pleasant smell.

Laboratory analysis

General

Merck Silica gel 60 (0.063-0.200mm) was used for Column chromatography (CC) as the stationery phase.; PTLC on Merck Silica gel 60 PF254+366, coated on glass plates (20 by 20 cm) to make 1.0 mm layers; Analytical TLC was carried out using factory prepared aluminum base plates (0.25 mm) coated with silica gel (60F254, Merck) and spots visualized by observing under UV light at 254 or 366nm, followed by spraying with 1% vanillin in H_2SO_4 spray reagent. EI-MS spectra were recorded on Agilent GC-MS mass spectrometer.

Column chromatography

According to the International Union of Pure and Applied Chemistry (IUPAC), Chromatography is a separation process that is achieved by distributing the components of a mixture between two phases, a stationary phase and a mobile phase. Fifty grams of the CH_2Cl_2 extract was subjected to column chromatography on silica gel. A total of 108 fractions were collected and analyzed using analytical thin layer chromatography (TLC) and the ones found similar combined. Further purification was carried out using column chromatography on silica gel and preparative thin layer chromatography (PTLC). After combining they were renamed A-P. The separation of compounds was monitored using analytical thin layer chromatography using aluminium coated factory made plates. Fraction C was weighed and gave three grams and was subjected to further separation as follows. A column

of fifty grams of silica gel was packed with 2% ethyl acetate in hexane. The three grams were mixed with 5 ml of the 2% ethyl acetate in hexane and charged on the column. The column was eluted with varying ratios of n-hexane/ethyl acetate (in order of increasing polarity). A total of forty nine fractions were collected and concentrated using a rotary evaporator with similar fractions being combined on the basis of TLC analysis. Fraction 37 which weighed 100.58 mg was mounted on 6 silica gel precoated PTLC plates and developed twice in 10% ethyl acetate/hexane. It produced C_1 which when viewed on UV lamp 254-366nm revealed one sport, but when sprayed with vanillin revealed overlapping sports which proved difficult to separate.

GC-MS

GC-MS studies are particularly suited to the analysis of the more volatile components of the plant metabolites, such as the monoterpenes and sesquiterpene hydrocarbons [4] The crude extract of *C.articulatus* was run on Agilent Technologies 7890A GC system connected to an Agilent Technologies 5975C Inert XL EI/CI MSD mass spectrometer with a triple axes detector. An HP-SMS column with a length of 30 m and i.d of 0.25 nm was used with a film thickness of 0.25 microns and a split ratio of 50:1. The oven temperatures were as follows; Starting temperature was at 50 degrees and was held for 3 minutes then ramped up at 10 degrees per minute up to 250 degrees, and held at 250 degrees for 2 minutes. The injection temperature was 250 degrees and the detector temperature was 230 degrees. Helium was used as the carrier gas. Two microlitres of aliquot (the crude extract of *C.articulatus* 100% CH_3Cl_2) was injected (introduced) in the ion source. A heated filament that produced a beam of electron (70eV) was used to bombard the sample. The retention times were recorded.

Identification of the compounds using GC-MS

Constituents of the oil were identified by comparing the experimental gas chromatographic retention indices RI and MS fragmentation pattern with corresponding reference data. In this case the components of the oils were identified matching their retention indices and mass spectra with those standards of National Institute of Science and Technology (NIST) library mass spectra data base of the GC-MS system from Surrey University in the UK.

Structure Elucidation.

The structures of the compounds were determined using spectroscopic methods. The spectra from GC-MS was compared with those of the NIST library of Surrey University in the UK and from these the structures were proposed.

RESULTS AND DISCUSSIONS

Phytochemical profile evaluation

Column Chromatography

When the crude extract was subjected to thin layer chromatography (TLC) to establish its Phytochemical profile, it produced UV-active spots when viewed on UV lamp 254nm and 366nm. After subjecting it to column chromatography it produced spots that seemed to be single spots, but when exposed to iodine or sprayed with vanillin the single spots revealed numerous overlapping spots, that were too difficult to isolate by column chromatography or by preparative thin layer chromatography (PTLC). When eluted in a sephadex column the compounds could not separate. The process of isolation of compounds was difficult and did not yield any pure compounds. As observed from the GC-MS results the extract contained several mono terpenes which are generally difficult to isolate as pure compounds as mentioned in the literature review. Column chromatography method did not work for the isolation of the compounds.

GC-MS

Chemical analysis of the compounds from *Cyperus articulatus*

The GC-MS analysis of the crude extract revealed the presence of fifty nine compounds. Terpenes accounted for the highest number of compounds analyzed with forty eight (81.36 %). The most abundant terpene was α cubenene. There were twenty seven sesquiterpenes (45.76%), twenty monoterpenes (33.90%) one triterpene (1.69%) and eleven other compounds (18.64%). The retention time, structural formula and the relative peak area % of the maximum for the compounds in *Cyperus articulatus* from Tharaka were as recorded in table 2. For several centuries it is a known fact that Terpenes are components of the essential oils (fragrant oils) obtained from leaves, flowers and fruits of plants example α Pinene, β Pinene Caryophyllene oxide, Mertenol, Thymol and Eucalyptol [23]. The above named compounds were found to be among the components of the essential oils of *C. articulatus* from Tharaka. Both the crude extracts and all the fractions from *C. articulatus* were sweet smelling. This was attributed to the high number of terpenes in the essential oils of *Cyperus articulatus* from Tharaka. These compounds were as shown in table 2 below.

Table 2 Retention time, structural formula and corresponding peak area % of maximum

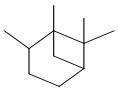
Compound	Retention Time	Structural-formula	Relative peak area % of maximum
1). 1R-α pinene	6.159	$C_{10}H_{16}$	1.16
2). 1S-α pinene	6.59	$C_{10}H_{16}$	0.57
3). 7 vinyl-Bicyclo[4.2.0]oct-1-ene	6.571	$C_{10}H_{14}$	2.90
4). Bicyclo[3.1.0] hex-3-ene-2-ol,2methyl 1(1methyl ethyl),(5,alpha)	6.71	$C_{10}H_{14}O$	1.55
5). Beta pinene	7.006	$C_{10}H_{16}$	3.99
6). alpha phellandrene	7.533	$C_{10}H_{15}$	0.66
7). D-Limonene	9.979	$C_{10}H_{15}$	1.39
8). Eucalyptol	8.031	$C_{10}H_{18}O$	0.52
9). Benzene,1-methyl-4(1-methylethyl)	7.899	$C_{10}H_{14}$	1.39
10).3cyclopentene-1-acetaldehyde 2,2,3 trimethyl	7.684	$C_{10}H_{16}O$	1.11
11).Bicyclo[3.1.0]hexane-3-ol,4methylene,-1-(1methyl)1s-(1alpha 3 beta ,5alpha)	9.925	$C_{10}H_{16}O$	18.25
12).Bicylo(3.1.1)hept-3-en-2-ol4,6,6 trimethy (lS -(alph,.2beta,5alpha)	10.005	$C_{10}H_{14}O$	13.13
13).Bicyclo[3.2.0]-3-ol,2methylene,6,6,dimethyl	10.176	$C_{10}H_{16}O$	0.78
14). Alpha cubenene	13.495	$C_{15}H_{24}$	77.89
15).8 Isopropyl-1,5-dimethyl cyclodica -1,5-diene	13.678	$C_{15}H_{24}$	2.54
16).3H-3a,7methano2,4,5,6,7,8 hexahydro-1,4,9,9tetramethyl-(3a-alpha,4beta,7alpha	13.850	$C_{15}H_{24}$	77.89

17). Naphthalene 1,2,3,4 tetrahydro-1,1,6 trimethyl	13.890	$C_{13}H_{18}$	100
18). Caryophylene	14.089	$C_{15}H_{24}$	5.75
19). Bicyclo[5.2.0]nonane,2methylene4,8,8 trimethyl,4,vinyl	14.084	$C_{15}H_{24}$	1.87
20). Azulene1,2,3,4,5,6,7,8,octahydro-1-4-dimethyl-7-[1alpha,7,alpha]	14.296	$C_{15}H_{24}$	6.90
21).1H-cycloprop(e)azulene,1a,2,3,4 ,4a,5,6 ,7b octahydro-1,1,4,7tetramethyl(1aR (1a ,alpha,4alpha,4abeta,7a,alpha]	14.439	$C_{15}H_{24}$	1.97
22).Naphthalene1,2,3,4,4a,5,6,8,octahydro7methyl -4methylene-1-(1-methyl)-(1alpha,4a,alpha,8a,alpha)	14.439	$C_{15}H_{24}$	2.76
23).Azulene1.2.3.5.6.7.8,8aoctahydro7,methyl-4methylene-(1-methyl)-(1alpha,4a,alpha,8a,alpha)	15.177	$C_{15}H_{24}$	16.41
24). Dodecanoic acid	15.784	$C_{12}H_{24}O$	7.15
25). Caryophylene oxide	16.190	$C_{15}H_{24}O$	51.63
26).6-isopropyl-4.8a-dimethy8al-1,2,3,5,6,7,8 , octahydro naphthalene-2-0	16.493	$C_{15}H_{22}O$	19.99
27).1H1,5Benzodiazepine2,3,4,5tetrahydro-2-methyl	16.562	$C_{10}H_{14}N_2$	14.99
28).1,2,3,4,5,6hexahydro1,1,5,5,tetramethyl-2,4a-methanonaphthalene-7(4a,H)-one	16.654	$C_{15}H_{22}O$	24.34
29). Isoaromandrene epoxide	16.745	$C_{15}H_{24}O$	6.64
30).1H-cycloprop[e]azulene,decahydro-1,1,7trimethyl-4-methylene	16.991	$C_{15}H_{24}$	12.34
31) .2(10)-pinen-3-one	10,308	$C_{10}H_{14}O$	6.77
32).Bicyclo(2.2.1)heptan-3-one6,6dimethyl-2-methylene	10.314	$C_{10}H_{14}O$	6.77
33).Bicyclo(3,1,1)hepta-3-one,2,6,6 trimethyl	10.491	$C_{10}H_{16}O$	1.16
34).3cyclohexane-1-o l- 4-methyl1-(1-methyl)-R	10.531	$C_{10}H_{17}0$	1.16
35). Thymol	10.634	$C_{10}H_{14}O$	2.22
36). 3cyclohexene-1-methano,alpha,alpha,4 trimethyl	10.737	$C_{10}H_{18}O$	1.70
37). Myrtenol	10.840	$C_{10}H_{16}O$	18.32
38).2-cyclohexane-1-ol,2methyl-5-(1methyl ethyl	11.160	$C_{10}H_{16}O$	2.30
39).1,8Nonadiene,2,7dimethyl-5-(1methylethyl)	12.717	$C_{14}H_{24}$	3.69

40).Naphthalene1,2,3,4tetrahydro-1,6dimethyl-4-(1-methylethyl)-(1s-cis)	13.306	$C_{15}H_{22}$	7.20
41).Bicyclo(7.2.0)undec-4-ene 4,11,11trimethyl(-8-metylone	17.088	$C_{15}H_{24}$	12.38
42). 3,7,cyclododec-1-one 3,7 dimethyl-10-(-1-methylethylidene(-EE)	17.420	$C_{15}H_{22}O$	17.20
43). 1Pylorine-2-amine,N-(1 adamantyl)	17.495	$C_{14}N_2H_{19}$	30.87
44).2H-Cycloprop[a]naphthalene-2-one ,1,1a,4 ,5,6, 7, 7a octahydro-1,1,7,7a,tetramethyl (1a,alpha, 7 alpha,7a, alpha,7b,alpha)	17.607	$C_{15}H_{22}O$	22.70
45). Caryophylene(11)	18.113	$C_{15}H_{24}$	36.31
46). Alloaromandrene oxide-(1)	18.513	$C_{15}H_{22}O$	37.67
47). Culmarine	18.954	$C_{15}H_{24}O_2$	32.18
48). Ciz-2-alpha Bisobolene epoxide	19.028	$C_{15}H_{24}O$	42.16
49).5-Isopropenyl-2-methyl-7-oxabicyclo[4.1.0]heptan-2-ol	19.234	$C_{10}H_{15}O_2$	38.44
50).Tricyclo[4.3.0.0](7,9)nonane 2,2,5,5,8,8hexamethyl-alpha,6beta,7alpha,9alpha. 2,2,5,5,8,8-Hexamethyl-tricyclo[4.3 .0.0*7,9*]nonane	19.394	$C_{15}H_{26}$	22.65
51). Longifolenaldehide	19.680	$C_{15}H_{24}O$	36.72
52).1H-Inden-ol-2,4,5,6,7,7a hexahydro-4,4,7a-trimethyl	20.762	$C_{12}H_{20}O$	8.95
53).1H-Cycloprop[e]azulene, 1,1a,2,3,5,6,7,7a,7b,octahydro,-1,1,4,7,tetramethyl,9,1aR(1a,alpha,7a,beta,7,alpha	23.783	$C_{15}H_{24}$	3.58
54). Methyl4,6-decadienyl ether	25.334	$C_{11}H_{18}O$	8.96
55). Dodecanoic acid, tetradecyl ester	26.804	$C_{26}H_{52}O_2$	7.76
56). Dodecanoic acid, hexadecyl ester	28.212	$C_{28}H_{56}O_2$	18.15
57). Succinic acid, heptyl tridec-2-ynl ester	28.916	$C_{24}H_{44}O_4$	2.06
58). Dodecanoic acid ,octadecyl ester	29.763	$C_{30}H_{60}O_2$	4.02
59). Longipinocarveol,trans	28.618	$C_{15}H_{22}O$	1.27

Below are the structures of compounds from *Cyperus articulatus* from Tharaka in Meru- Kenya.

Monoterpenes



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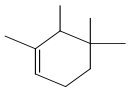

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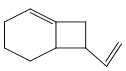

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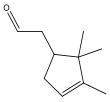

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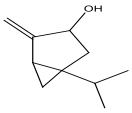

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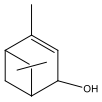

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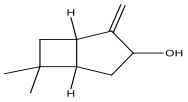

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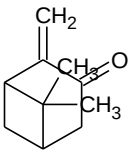

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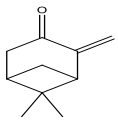

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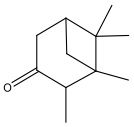

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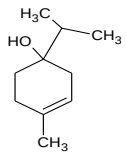

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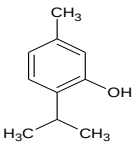

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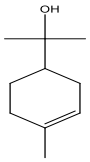

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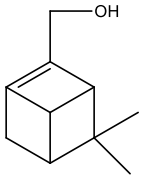

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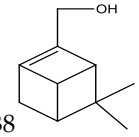

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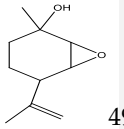

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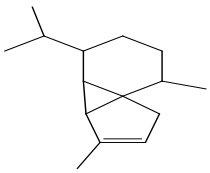
Sesquiterpenes



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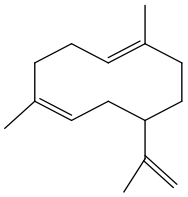

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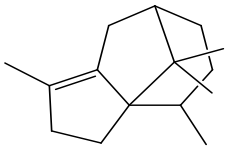

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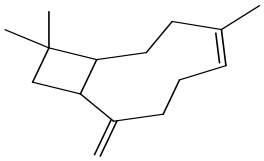

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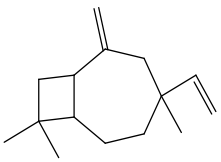

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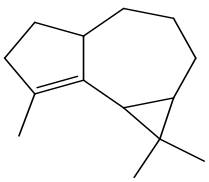

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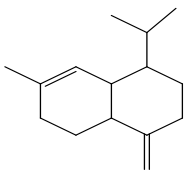

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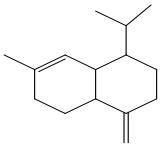

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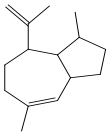

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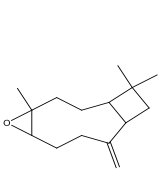
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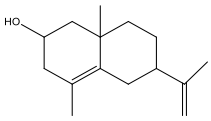

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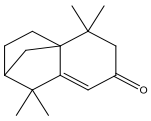

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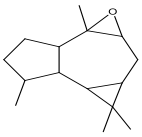

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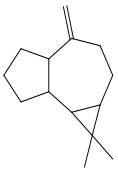
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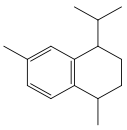
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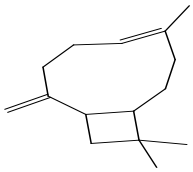
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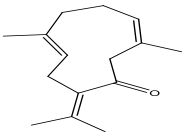

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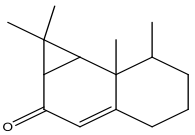

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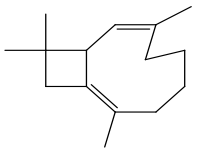
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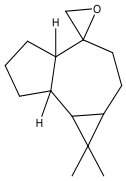

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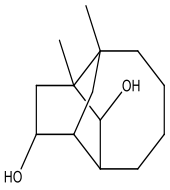

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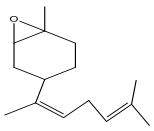

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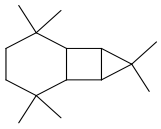
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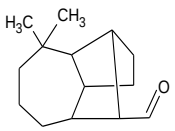

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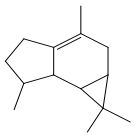
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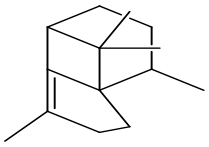
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Conclussions and Recomenditions

Comparing the present results with those previously reported in literature on essential oils of *Cyperus articulatus* it is apparent that there are many differences regarding the major constituents of the oils. *Cyperus articulatus* from Nigeria was reported to have cyperotundone as its major component [13] and this was absent in the *Cyperus articulatus* from Tharaka in Kenya. The major component of *Cyperœus articulatus* from Tharaka was α-cubenene. This compound was not found in the Nigerian *C. articulatus*. Other main components of the Kenyan *C. articulatus* essential oil that were missing in the Nigerian essential oil were Myrtenol, alloaromandrine oxide, culmarine and Longifolenaldehide. This could be due to different climatic and environmental conditions in both Kenya and Nigeria where varying secondary metabolites produce different ecotypes of the same species in different locations due to different microclimates [15]. As in the previous findings the sesquiterpenes were the major components of the essential oil of *C . articulatus* from Tharaka, these were twenty seven in number. Going by the relative peak area percentages gotten they were in larger quantities than the monoterpenes which were twenty in number and in smaller quantities . This was the case in the Nigerian essential oil where the sesquiterpenes were major and the monoterpenes were the minor components. The number of compounds identified in Kenya was greater than that roprted from Nigeria (Kenyan oil-59, Nigerian- red tubers-37 and black tubers-47). The high number of monoterpenes from *C. articulatus* explains the reason why it was difficult to isolate pure compounds from the crude extract of *C. articulatus* by column chromatography method. The

monoterpenes have almost similar chemical structures and masses which made them to elute from the column together in a mixture. The research should be extended to the other *Cyperus* species found in the area of study example *Cyperus rotundus* which from literature is found to have related compounds. α cubenene which was the major compound in *C. articulatus* from Tharaka was missing in the *C. articvculatus* from Nigeria and also *C. rotundus* from S. Africa . More research should be done as *C. rotundus* that is found in other parts of the world and with similar compounds to *C. articulatus* was abundant in Tharaka and Meru region in general. From literature these two plants have been found to have high potential for cosmetics and pharmaceutical applications.

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