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Review Article

PHYTOCHEMICAL COMPOSITION OF ESSENTIAL OILS ISOLATED FROM DIFFERENT SPECIES OF GENUS *NEPETA* OF LABIATAE FAMILY: A REVIEW

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ABSTRACT

Aromatic and medicinal plants have been regarded as foremost source of secondary metabolites (SMs). These SMs (less toxic and biodegradable) and their derivatives have been recognised as versatile source of biologically active drugs. The most of the drugs used in present medicinal system have direct or indirect relation with secondary metabolites. So, during last few decades the interest has increased in the study of phytochemical composition of aforementioned plants to evaluate their prospective in modern medicinal system. Amongst various plant families which have been known for their medicinal and therapeutic values, Labiatae (Mint) family (Genus *Nepeta)* remains quite important. Essential oils extracted from various parts of species of above said genus have been a vital source of terpenoid and oxygenated terpenoid hydrocarbons especially sesquiterpene hydrocarbons and their oxygenated derivatives. These compounds have been known for their inherent biological activities viz. sedative, diaphoretic, feberifuge, expectorant, diuretic, stomach tonic, antispasmodic, antipyretics, anti-viral, anti-inflammatory, antimicrobial, fungicidal, insecticidal, insect repellent and antidote against snakes and scorpion bites etc. The present communication constitutes a review on the chemical composition of essential oils (only key constituents) extracted from genus *Nepeta* along with the details of their specific area of collection, height, specific time in a year, stage of plant collection, method used for extraction and technique of analysis.

Keywords: Secondary metabolites, *Nepeta*, Phytochemical composition, Essential oils.

INTRODUCTION

Plants have been a rich source of valuable, cost effective and easily available natural products. Natural products have played a pivotal role in pharmacy and agriculture due to which inexhaustible development has been witnessed to synthesise and isolate new herbal and useful drugs. A few families viz. myrtacea, lauraceae, rutaceae, lamiaceae, asteraceae, apiaceae, cupessaceae, poceace, zingiberaceae and piperaceae have proven to be efficient in providing precious essential oils which are lipophilic in nature and are rich source of innumerable bioactive compounds. The latter belong to different classes of secondary metabolites viz. flavonoids, carotenoids, alkaloids, phenolics, terpenoids, tannins, phenolic acids etc. These potent biologically active compounds act as alternatives to numerous synthetic pharmaceutical drugs, agrochemicals etc. and it has been a competent approach for finding new bioactive compounds extracted from plants. Further, these natural products have been isolated in their pure form and their study involves identification and characterization of

their structures, in vitro synthesis and evaluation of their pharmaceutical and agrochemical activities viz. antioxidant, anti-inflammatory, antiseptic, anti-asthmatic, diuretic, antispasmodic, anticancer, antipyretic, diaphoretic, analgesic, sedative, antimicrobial, fungicidal, herbicidal, insecticidal and insect repellent. These biological activities depend upon the composition and nature of the natural products.[1] Secondary metabolites obtained from genus *Nepeta* have been used in various traditional medicines from prehistoric times. Essential oils isolated from different *Nepeta* species have been used as laxative for the treatment of dysentery, teeth troubles, ear pain, kidney, liver diseases[2,3] and many heart problems such as cardiac thrombosis, tachycardia, angina pectoris and weakness of the heart.[4,5] These have also been used as feberifuge, sedative, antiseptic, anti-tussive, diaphoretic, anti-asthmatic, antioxidant.[6-10] Along with this genus Nepeta showed many other biological activities viz. anti-atherosclerotic, anti-inflammatory,[11-13] expectorant, diuretic, antispasmodic,[8,14] feline and canine attractant [15] stomach tonic,[16] antipyretics, against snakes and scorpion bites[10,14] insecticidal, antimicrobial,[17] fungicidal and anti-viral agents.[18,19]

N. juncea plant has been known for its biological potential like antiglycation, cytotoxic, platelet aggregation, phytotoxic and antimicrobial.[20] *N. glomerulosa* had been used to cure digestive problem, pneumonia and itching.[21] *N. menthoides* has been reported for its phytotherapic properties viz. febrifuge, sedative and a relief agent for stomach pains whereas *N. cataria* has been used as disinfectant, fortifier and to cure colds,[10] *N. racemosa* as disinfectant, carminative, stomachic and *N. bracteata* as antiasthmatic and carminative.[9] Catnip plant's (*N. cataria*) flowers and leaves find utility for the preparation of calmative herbal tea to take sound sleep. It has shown varied medicinal properties like diaphoretic, nervine, antispasmodic, emmenagogue, stimulant and mild sedative. Further, these have been used for the treatment of colic, diarrhoea, cancer, common cold, anxiety and tension. Juvenile hormone activity has also been reported from catnip plant extract.[22] Joshandah prepared from *N. ciliaris* plant has been used as efficient remedy for curing common cold, catarrh, cough and associated respiratory distress and fever in many parts of India.[23] *N. ciliaris* plant has been also used for preparing squash and liquid extract recommended against phlegm and as antipyretic, antitussive agent.[24-26] All these properties showed by different species of genus *Nepeta* have been ascribed to their flavonoids and essential oil composition.[27]

GENUS NEPETA

Nepeta is multiregional genus and belongs to Labiatae (Mint) family. The name *Nepeta* was coined after the name of ancient Italian city Nephi.[28] Genus *Nepeta* has 280 species spread all over the world but extensively grown in many regions of Asia, Africa, North America, central and southern part of Europe out of which 30 are found in plains and foothills of the Himalayas in India.[29-32] Taxonomic position of genus *Nepeta* is as under:

Kingdom : Plantae
Class : Magnoliopsida
Order : Lamiales
Family : Lamiaceae (Labiatae)
Genus : *Nepeta*[33]

Most of the species of genus *Nepeta* are hairy perennial herbs having dense leaves which are covered with soft hairs. Flowers are of various colours and shapes occur in clusters bloom from July to September.[34]

CHEMICAL COMPOSITION

Many classes of compounds have been obtained from genus *Nepeta* like monoterpenes (nepetalactones, dehydronepetalactone, nepetalic acid, 1,8-cineole, α-terpineol, α-citral and geraniol etc);[7,19,35,36] sesquiterpenes (β-farnesene, α-bisbolene, β-caryophyllene and α-humulene, etc.);[37] flavonoids (luteolin 7-O-glucuronide; apigenin 7-O-glucuronide and 7-O-glucurono-glucoside etc.); phenolic acid (caffeic, rosmarinic and p-coumaric acids, vanillic acid, gallic acid etc);[38] steroids (ursolic acid, oleanolic acid, *β*-sitosterol, stigmasterol, stigmasterol glucoside, glutinol and *β*-amyrin etc.),[39] but the essential oils

isolated from different species of this genus has been mainly enriched with terpenes (mono and sesquiterpenes).

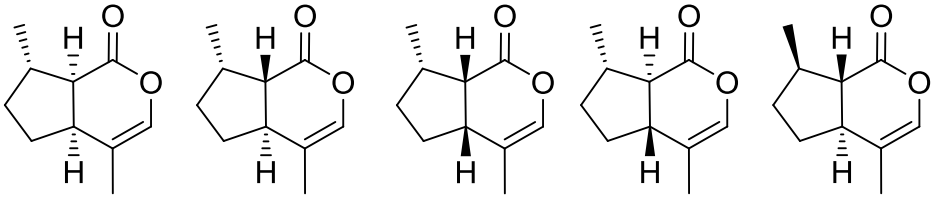
The essential oils obtained from different parts of plants viz. roots, stem, leaves, flowering parts etc. of genus *Nepeta* have been found to be rich in terpenoid hydrocarbons, sesquiterpene hydrocarbons including their oxygenated analogues.[37,40] Depending upon the composition of major compounds in the essential oils, *Nepeta* species have been divided into two groups one that contained different isomers of nepetalactone and the second that had compounds other than isomers of nepetalactone like 1,8-cineole, β-caryophyllene, caryophyllene oxide, β-farnesene, α-citral, β-citronellol etc as their major constituents.[7]

Group 1:

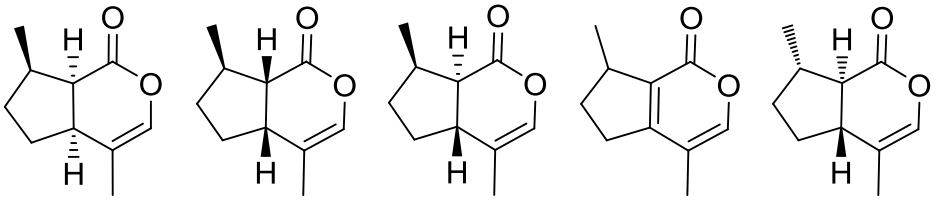
Species of this group contain 4aα,7α,7aα-nepetalactone, 4aα,7α,7aβ-nepetalactone, 4aβ,7α,7aβ-nepetalactone, 4aβ,7α,7aα-nepetalactone as their key compounds. These species also contained isomers 4aα,7β,7aβ-nepetalactone, 4aα,7β,7aα-nepetalactone, 4α-dihydronepetalactone, 4β-dihydronepetalactone and 5,9-dihydronepetalactone along with first four isomers but their percentage was very low as compare to principal compounds. Isomer **4aα,7α,7aα-nepetalactone (1)** has found as major ingredient in species like *N. assurgens, N. cadmea*, *N. caesarea*, *N. cephalotes*, *N. crassifolia*, *N. x faassenii, N. govaniana*, *N. mirzayanni, N. persica*, *N. racemosa* and *N. teydea* (see table no. 1).

Further isomer **4aα,7α,7aβ-nepetalactone (2)** found as key constituent in species like *N. argolica*, *N. atlantica, N. cataria*, *N. coerulea*, *N. granatensis*, *N. meyeri*, *N. nuda ssp nuda, N. nuda ssp. albiflora*, *N. nepetella*, *N. parnassica*, *N. racemosa*, *N. rtanjensis*, *N. septemcrenata*, *N. transcaucasica* and *N. tuberosa* (see table no. 1).

Furthermore, *N. bornmuelleri, N. eremophila*, *N. persica*, *N. racemosa*, *N. saccharata* and *N. sintenissii* have **4aβ,7α,7aβ-nepetalactone (3);** *N. argolica*, *N. grandiflora* and *N. kotschyi* contain **4aβ,7α,7aα-nepetalactone (4);** *N. crassifolia* have **4aα,7β,7aβ-nepetalactone (5);** *N. betonicifolia, N. crassifolia* and *N. nuda* have **4aα,7β,7aα-nepetalactone (6);** *N. angustifoliates*, *N. cataria, N. mahanensis* and *N. nepetella* have **nepetalactone (7)**; *N. mussini* contain **epinepetalactone (8):** *N. tuberosa subsp. tuberose* have **5,9-dehydronepetalacone (9)**; and *N. cataria* and *N. elliptica* have **(7R)-trans, trans-nepetalactone (10)** as their main compound (see table no. 1).



(1) **(2)** **(3)** **(4)** **(5)**

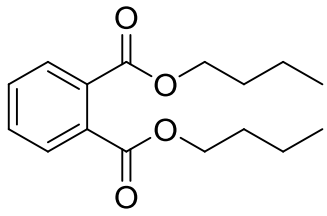


(6) **(7)** **(8)** **(9)** **(10)**

Group 2:

This group consists of species like *N. septemcrenata* which contain **1,2 benzene-dicarboxylic acid dibutyl ester (11);** *N. curviflora*, *N. daenensis, N. fissa, N. nuda* L. subsp. *albiflora* and *N. oxyodonta* contain (**trans**

or β)-caryophyllene (12); *N. Cilicia*, *N. betonicifolia* and *N. nuda* L. ssp. *nuda* have **β-caryophyllene oxide (13)**; *N. baytopii, N. binaludensis*, *N. congesta, N. Crispa*, *N. denudate, N. discolor*, *N. fissa, N. flavida*, *N. gloeocephala, N. haussknechtii, N. heliotropifolia, N. involucrate, N. ispahanica, N. italica, N. menthoides*, *N. pannonica, N. pogonosperma, N. rivularis, N. royleana, N. schiraziana* and *N. sulfuriflora* which contain **1,8-cineole (14)**; *N. cataria* have **α-citral (15)**; *N. citnodora* have **β-citronellol (16)**;[41] *N. elliptica* have **β-elemene (17)**; *N. raphanorhiza* have **(Z)-β-farnesene (18)**; *N. laevigata* and *N. ucraininca* have **germacrene-D (19)**; *N. pungens* have **geranyl acetate (20)**; *N. deflersiana* and *N. nuda* L. ssp albiflora have **hexadecanoic acid (21)**; *N. clarkei* and *N. leucophylla* have **iridodial β-monoenol acetate diastereomers** and **iridodial β-monoenol acetate (22)**; *N. erecta* and *N. govaniana* have **isoiridomyrmecin (23)**; *N. clarkei* have **kaur-16-ene (24)**; *N. cilicia* have **limonene (25)**; *N. betonicifolia* and *N. satureioides* have **linalool (26)**; *N. sessilifolia* have **linalool acetate (27)**; *N. floccosa* have **neral (28)**; *N. discolar, N. glomerulosa* and *N. laxiflora* have **α-pinene (29)**; *N. govaniana* have **pregeijerene (30)**; *N. pratti* have **pulegone (31);** *N. bracteata, N. cilicica, N. depauperata, N. macrosiphon* and *N. sessilifolia* have **spathulenol (32);** *N. sintenissii* have **α-terpinolene (33),** *N. asterotrichus* have **terpinen-4-ol and (34)** *N. makuensis* have **viridiflorol (35)** as their major constituent (see table no. 2).



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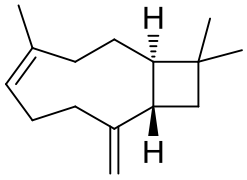

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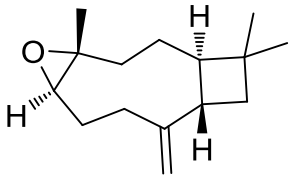

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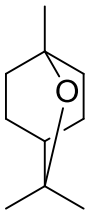

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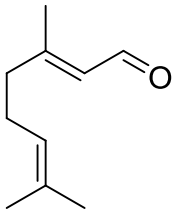

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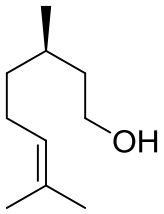

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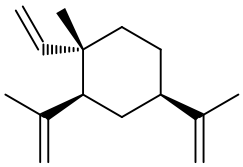

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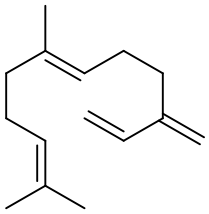

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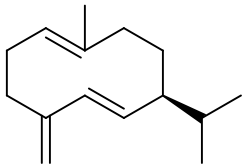

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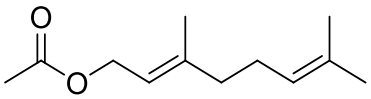

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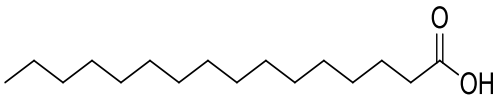

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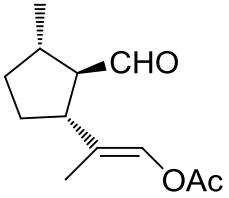

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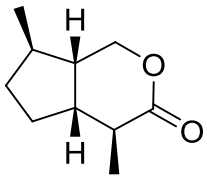

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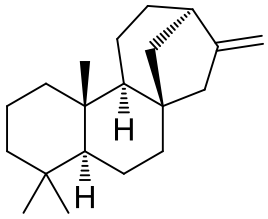

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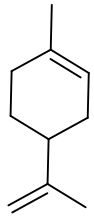

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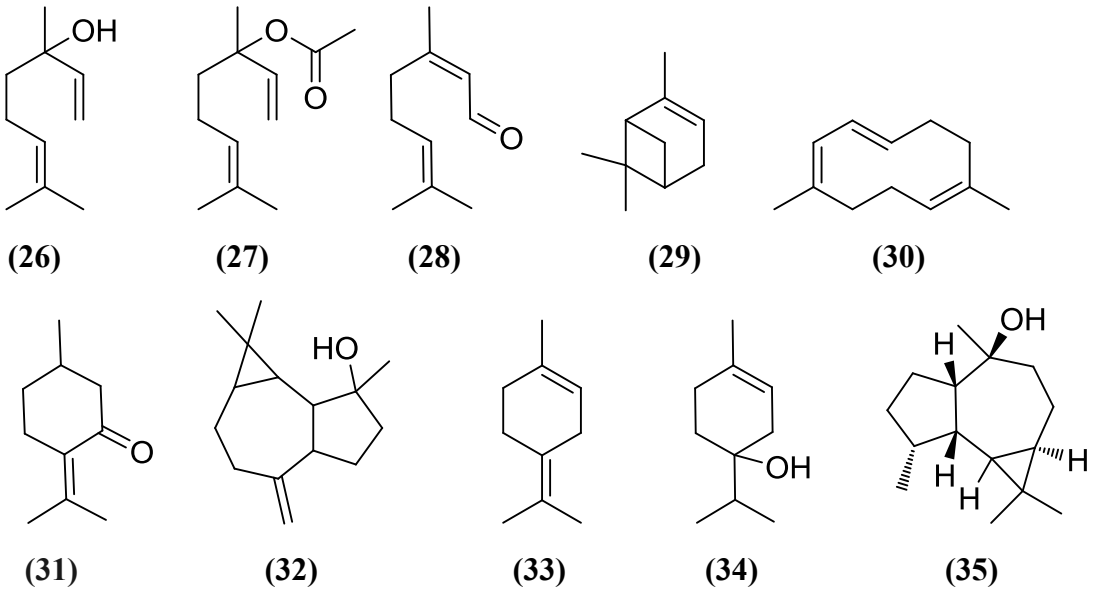


(26) **(27)** **(28)** **(29)** **(30)**

(31) **(32)** **(33)** **(34)** **(35)**

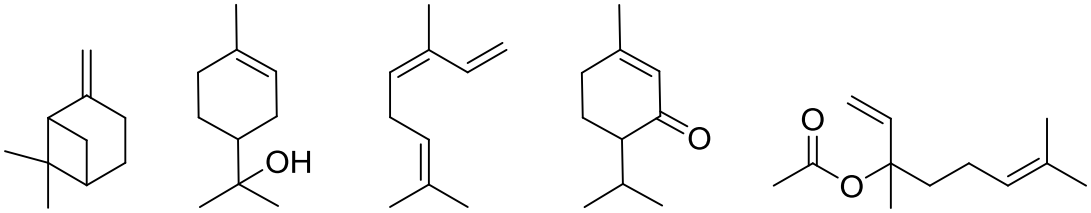
Chemical Composition of Various Species of Genus *Nepeta*

Species with nepetalactone as principal constituents:

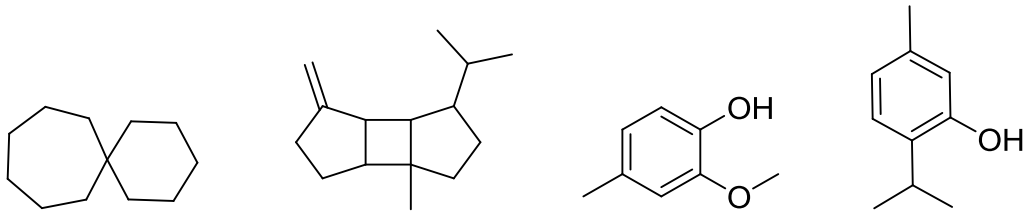
N. assurgens essential oil taken out from the air dried aerial parts (collected during full flowering stage in June, 2011 from Lalehzar Mountain in the Baft area, Iran) has been analysed by using GC and GC-MS revealed the presence of twenty-two compounds which form 98.4% of the total oil composition. The oil contained seven monoterpenes (17.6%), two sesquiterpene (1.3%), ten oxygenated monoterpenes (78.0%) and three oxygenated sesquiterpenes (1.5%). **4aα,7α,7aα-nepetalactone (44.6%)**, 1,8-cineole (21.3%), β-pinene **(36)** (5.3%), α-terpineol **(37)** (3.8%), (*Z*)-β-ocimene **(38)** (3.7%), α-pinene (3.1%) and 4aα,7α,7aβ-nepetalactone (2.8%) have been the core constituents of the total oil.[42] Dabiri and Sefidkon (2003)[48] reported the presence of twenty one components in the essential oil (extracted with hydrodistillation for 6 hours from air-dried aerial parts) of ***Nepta crassifolia*** (collected during full flowering stage in month of September from north part of Tehran). The composition of oil has been analysed with GC and GC-MS. β-caryophyllene (0.58%), 4aβ,7α,7aβ-nepetalactone (0.64%), germacrene D (0.73%), piperitone **(39)** (0.80%), linalyl acetate **(40)** (2.6%) and **4aα,7α,7aα-nepetalactone (92.6%)** have been found to be the major components present in the oil. Mahboubi *et al.* (2011)[51] analysed the essential oil of ***Nepeta persica*** (collected from Central Province Novazen, Arak, Iran at flowering stage in July 2009) with GC and GC-MS and investigated fourteen compounds which form 97.3% of total oil composition. The oil has been isolated from air-dried aerial parts with steam distillation (using Clevenger-type apparatus) for 6 hours. **4aα,7α,7aα-nepetalactone (80.0%)**, spiro [5,6]dodecane **(41)** (14.2%), β-bourbonene **(42)** (1.5%), 2-methoxy-4-methylphenol **(43)** (0.8%) and caryophyllene oxide (0.7%) have been the principal compounds present in the oil. Adiguzel *et al.* (2009)[56] examined the essential of ***Nepeta cataria*** (the plants were collected from Olur at height of 800m during flowering stage in August, 2004) extracted with methanol using Soxhlet and Clevenger-type apparatus from air dried plant material. Oil has been subjected to GC/MS analysis and 22 compounds have been identified which form 93.00% of the total oil. **4aα,7α,7aβ-nepetalactone (70.4%)**, 4aα,7α,7aα-nepetalactone (6.0%), 4aβ,7α,7aβ-nepetalactone (2.5%), thymol **(44)** (2.3%) and pulegone (1.8%) have been the principal compounds present in the oil.

Zenasni *et al.* (2008)[55] examined the chemical composition of four *Nepet*a species collected from Moroccan regions viz. ***Nepeta atlantica*** (collected from Boumia-Tounfit), ***Nepeta cataria*** (collected from Kenitra region), ***Nepeta***

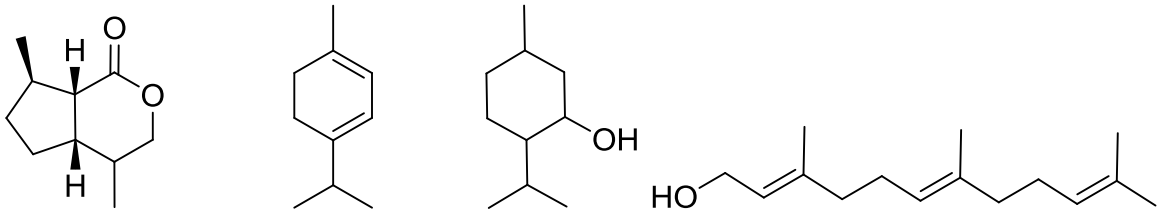
granatensis and ***Nepeta tuberosa*** (collected from Iran region). The oil has been isolated from whole plant material with steam distillation and the distillate so obtained has been further extracted with ethyl acetate and analysed with GC-MS. 4aα,7α,7aβ-nepetalactone has been the key compound in the four *Nepeta* species. Major compounds present in four *Nepeta* species have been given in table no. 3. Essential oil obtained (with hydrodistillation for 3 hours) from the air dried aerial part of ***Nepeta parnassica*** (wild population) collected during vegetative stage in June and flowering stage in September 2000 (from Mt Parnassos at an elevation of 1600 m) constitute about 94.8% and 98.7% of the total oil composition respectively. The oil composition has been analysed with GC-MS. Fifty five compounds have been identified from the extracted oil of these two stages. The oil extracted during vegetative stage have **4a*α*,7*α*,7aβ-nepetalactone (22.0%)**, 1, 8-cineole (21.1%), *α*-pinene (9.5%) and 4a*α*,7β,7aβ-nepetalactone (7.9%) as the main components, while **1,8-cineole (34.6%)**, 4a*α*,7*α*,7a*α*-nepetalactone (17.3%), *α*-pinene (11.4%), 4a*α*,7*α*,7aβ-nepetalactone (8.9%) and 4a*α*,7β,7aβ-nepetalactone (2.0%) have been the key component of oil obtained from flowering stage.[40] Grbic *et al.* (2008)[64] analysed the essential oil (isolated by hydro-distillation with Clevenger-type apparatus for 2 hours) of ***Nepeta rtanjensis*** obtained from air-dried aerial parts with GC-MS. The plants have been collected from experimental fields of Institute for Biological Research Sinisa Stankovic, Belgrade, Serbia during pre-flowering stage. **4aα,7α,7aβ-nepetalactone (79.89%)** has been the key compound and 4aβ,7α,7aβ-nepetalactone (6.3%), α-pinene (3.3%), δ-cadinene **(52)** (2.1%), germacrene D (1.8%) have been the other major compounds present in the oil. Thirty nine compounds have been reported from the essential oil (isolated from fresh aerial parts with hydro distillation for 3 hours) of ***Nepeta septemcrenata*** (collected during full flowering stage in March, 2006 from Kathrine, Egypt) when analysed with GC-MS. These form 98.3% of the total oil. The oil mainly comprises of **4aα,7α,7aβ-neptalactone (24.2%)**, 4aα,7α,7aα-nepetalactone (19.9%), 1,8-cineole (8.5%), elemol **(53)** (13.8%), linalool (5.6%), while β-bisbolene, terpine-4-ol and α-terpinol have been present in low concentration.[65] Dabiri and Sefidkon (2003)[8] collected aerial parts of ***Nepeta racemosa*** at flowering stage (from central parts of Iran in September 2000). The oil has been extracted from air-dried aerial parts with hydro-distillation using Clevenger-type apparatus for 6 hours. The oil has been analysed with GC and GC-MS and twenty two compounds have been recognized which form 99.3% of the total oil composition. 1,8-cineole (9%), 4aα,7α,7aα-nepetalactone (24.4%), 4aα,7α,7aβ-nepetalactone (25.6%) and **4aβ,7α,7aβ-nepetalactone (33.6%)** have been the key compounds present in the essential oil. The volatile essential oil extracted (with hydrodistillation for 3 hours) from air-dried aerial parts of ***Nepeta sintenisii*** (collected from Charat, Iran in the month of june, 2002 at an elevation of 2250 m) showed the presence of forty constituents when analysed with GC-MS. The oil mainly comprises of monoterpenes (27.7%) and sesquiterpenes (43.6%), while **4aβ,7α,7aβ-netalactone (23.4%)**, elemol (16.1%), E-β-farnesene (9.5%), 1,8-cineole (8.2%), germacrene-D (3.5%), β-bisabolene **(54)** (4.2%) and cis-sabinene hydrate **(55)** (6.5%) have been the major compounds present in the oil.[7] Ricci *et al.* (2010)[79] with the help of GC-FID, GC-MS and ^{13}C NMR recognized ***trans,trans*-nepetalactone (50.38%)**, *trans,cis*-nepetalactone **(56)** (21.74%), *cis,trans*-nepetalactone **(57)** (6.66%) and nepetalactol **(58)** (0.49%) as key component in the essential oil (isolated with hydrodistillation for 4 hrs and extracted with dichloromethane) of ***Nepeta cataria*** leaves (collected from Serra Azul Street, 308 Piracicaba, SP, Brazil).



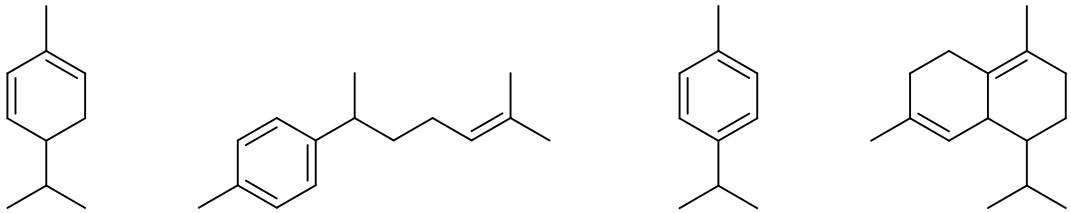
(36) **(37)** **(38)** **(39)** **(40)**



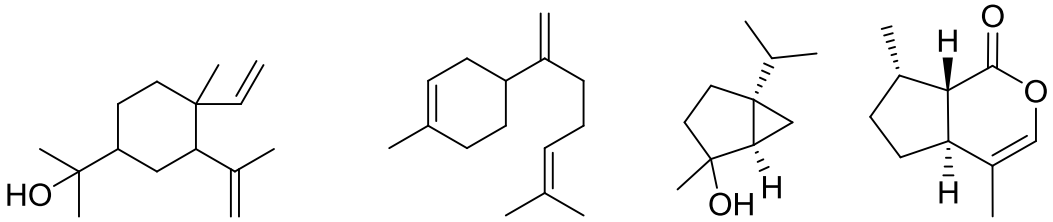
(41) **(42)** **(43)** **(44)**



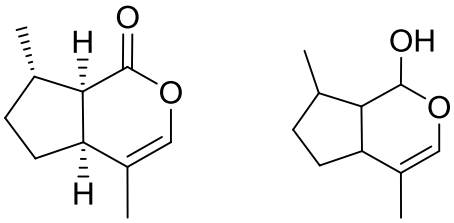
(45) **(46)** **(47)** **(48)**



(49) **(50)** **(51)** **(52)**



(53) **(54)** **(55)** **(56)**



(57) **(58)**

Species with other than nepetalactone as principal constituents:

GC-MS evaluation of essential oil of ***Nepeta binaludensis*** collected from cultivated fields revealed the presence of twenty-three components

which form 99.4% of the total oil. The oil has been extracted from dried aerial parts with hydro-distillation procedure using Clevenger-type apparatus for 3 hours. **1,8-cineole (63%)** has been the major constituent present in the oil. 4aα,7α,7aα-nepetalactone (19%), alcohol fenchyl **(59)** (5.3%), β-pinene (4.5%), α-terpineol (2.2%) and ρ-cymene-8-ol **(60)** (1.4%) have been the other key compounds found in the oil.[92] Sonboli *et al.* (2004)[95] collected aerial parts of ***Nepeta crispa*** in July, 2003 at flowering stage from Alvand Mountains, Hamadan, Iran. The oil was isolated from air-dried aerial parts with hydro-distillation using Clevenger-type apparatus for 3 hours. The analysis of oil with GC and GC-MS revealed the presence of twenty three compounds which form 99.8 % of the total oil composition. The oil contained sesquiterpene hydrocarbons, monoterpene hydrocarbons and oxygenated monoterpenes in 2.2%, 13.7% and 83.9% concentration respectively, whereas **1,8-cineol (47.9%)**, 4a*α*,7*α*,7a*β*- nepetalactone (20.3%), β-pinene (6.9%), α-terpineol (4.8%), 4-terpineol (2.8%) and α-pinene (2.5%) have been the major compounds reported in the oil. The examination of essential oils of ***Nepeta Crispa*** (collected from Alvand Mountains, province of Hamadan) and ***Nepeta menthoides*** (collected from Sabalan Mountains, province of Ardabil) obtained from the leaves and flowers (with hydro-distillation using Clevenger-type apparatus for 3 hours) showed the presence of 89.5% monoterpenoids, 0.9% sesquiterpenoids, 0.6% phenyl propanes in former species, while the latter species contained 87.2% monoterpenoids, 0.1% sesquiterpenoids, 0.9% phenyl propanes. The composition of the oil has been analysed with GC and GC-MS. 1,8-cineole has been the major constituent present in both the species. **1,8-cineole (71.0%)**, β-pinene (5.0%), α-terpineol (4.1%), δ-terpineol **(61)** (2.8%) and 4-terpineol (2.3%) have been the major components reported in the essential oil of *N. Crispa*, whereas **1,8-cineole (41.1%)**, dihydromyrcen-1-ol **(62)** (9.2%), 4-terpineol (7.1%), geranyl acetate (6.1%), α-terpineol (5.7%), β-pinene (5.6%) and sabinene **(63)** (2.4%) have been the key components found in the essential oil of *N. menthoides* . The study of essential oil revealed that these species have no traces of nepetalactone. [94] Essential oil obtained from the air-dried aerial parts of ***Nepeta pogonosperma*** (collected in May, 2008 from its wild locality in Qazvin provience, Iran) by hydro-distillation using Clevenger-type apparatus has been analysed with GC-MS by Ali *et al.* (2012).[103] Forty-one compounds have been characterised which represent 97.5% of the total oil. β-pinene (3.5%), linalool (4.5%), terpinen-4-ol (4.8%), (E)-α-bisabolene **(64)** (5.4%), α-terpineol (5.4%), 4aα,7α,7aα-nepetalactone (14.5%) and **1,8-cineole (31.2%)** have been the prime constituents present in the oil.

Sefidkon *et al.* (2002)[85] evaluated the essential oil with GC and GC-MS taken out from air-dried aerial parts of ***Nepeta fissa*** C.A. Mey (collected from Tehran Province in Jun, 2000 at full flowering season) with hydro-distillation using Clevenger-type apparatus for 4 hours. Forty two compounds forming 99.3% of the total oil composition have been characterised and spathulenol (4.1%), bicyclogermacrene **(65)** (4,9%), α-pinene (5.8%), β-pinene (6.0%), valencene **(66)** (6.6%), γ-muurolene **(67)** (7.9%), caryophyllene oxide (12.3%) and **β-caryophyllene (17.4%)** have been the major compounds. Sajjadi and Eskandari (2005)[87] studied the essential oil with GC-MS extracted (by hydrodistillation for 3 hours) from air-dried aerial parts of ***Nepeta oxyodonta***. The plant material has been collected in June from Charmahal and Bakhtiari province, Iran from height of 2700m. Total fifty-eight compounds have been characterised and δ-candinene (2.8%), α-pinene (3.2%), 1,8- cineole (3.3%), caryophyllene oxide (5.3%), T-cadinol (5.6%), germacrene-D-4-ol **(68)** (6.8%), α-cadinol **(69)** (7.3%), germacrene-D (7.4%), β-bourbonene (8.1%), spathulenol (8.5%) and **(E)-caryophyllene (12.6%)** have been the principal compounds. Essential oil obtained from the young leaves (solvent extraction, percolation) of ***Nepeta cataria*** (collected in July 2006 from medicinal plant garden of Tehran University, Iran) has been analysed using GC and GC-MS by Saeidnia *et al.*

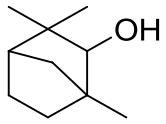
(2008).[105] Four compounds have been identified which represent 97.53% of the total oil. The oil has been rich in monoterpenes, while **α-citral (51.95%)**, nerol **(70)** (32.24%), β-citronellol (9.03%) and geraniol **(71)** (4.31%) have been the major components of the oil. No isomer of nepetalactone has been found in the oil. The evaluation of essential oils of ***Nepeta elliptica*** and ***Nepeta laevigata*** (collected from on June 2009 from high Himalayas of J & K, India) isolated from air-dried aerial parts (inflorescences) with hydro-distillation (using Clevenger-type apparatus for 3 hours) showed the presence nineteen and twenty-four compounds forming 83.4% and 86.7% of the total oil composition respectively. The chemical composition of both oils have been analysed with capillary GC-FID and GC-MS. *N. elliptica* essential oil contained 68.8% sesquiterpene hydrocarbon, 12.2% oxygenated sesquiterpene, while α-terpineol (1.7%), spathulenol (2.6%), zingiberene **(72)** (2.8%), elemol (3.5%), γ-cadinene (3.3%), β-bisabolene (3.2%), germacrene D (3.6%), β-caryophyllene (5.5%), α-humulene **(73)** (11.8%), bicyclogermacrene (13.1%) and **β-elemene (23.4%)** have been the major components. Further, the essential oil of *N. laevigata* contained 20.7% oxygenated monoterpenes, 40.9% sesquiterpene hydrocarbon, 25.1% oxygenated sesquiterpene, whereas 4aα,7α,7aα-nepetalactone (2.0%), caryophyllene oxide (3.2%), α-humulene (3.5%), spathulenol (3.9%), β-bourbonene (4.5%), α-bisabolol **(74)** (5.3%), α-bisabolol oxide B **(75)** (12.4%), β-caryophyllene (10.8%), germacrene D (19.4%) and **β-Citronellol (16.5%)** have been the prime components.[106] GC-MS examination of essential oil of ***Nepeta raphanorhiza*** collected in April, 2010 from Pulwama region of Kashmir Valley showed the presence of sixteen components which form 97.5% of the total oil. The oil has been extracted from the fresh aerial plant parts with hydro-distillation procedure using Clevenger-type apparatus for 3 hours. The oil contained 65.3% sesquiterpene hydrocarbons and 19.5% of monoterpenes hydrocarbons. Sesquiterpenes mainly composed of α-humulene (2.0%), α-bisbolene (9.4%), β-caryophyllene (12.7%) and **(Z)-β-farnesene (49.2%)**, whereas monoterpene hydrocarbons have δ-3-carene **(76)** (12.3%) as main compound. Sabinene (2.5%), caryophyllene oxide (3.4%) and germacrene-D-4-ol (5.8%) has been also found in the oil. Literature revealed that most of the Himalayan *Nepeta* species from Jammu and Kashmir showed either no or very low content of nepetalactone in their essential oil.[37]

Farjam (2012)[108] investigated the essential oil of ***Nepeta pungens*** collected from Sepidan mountain, Fars, Iran in August, 2011. The oil has been extracted from air-dried leaves using Clevenger-type apparatus for 4 hours. GC and GC-MS analysis of the oil revealed the presence of forty nine compounds which constitute 97.2% of the total oil composition. Nerylacetate **(77)** (2.5%), β-sesquiphellandrene **(78)** (2.8%), β-ocimene (3.9), sabinene (3.9%), spathulanol (4.2%), citronellal (4.9%), bornylacetate **(79)** (5.3 %), eucalyptol (1,8-Cineole) (5.8 %), limonene (12.0 %) and **geranyl acetate (17.0 %)** have been the key compounds reported in the oil. Air-dried aerial parts of ***Nepeta deflersiana*** (collected in May, 2007 from the vicinity of Sana'a-Yeman) have been subjected to hydro-distillation using Clevenger-type apparatus for 3 hours. The obtained essential oil has been analysed by using GC and GC-MS which showed the presence of fifty-one compounds mainly oxygenated monoterpenes (31.4%) and oxygenated sesquiterpenes (28.2%). **Hexadecanoic acid (8%)**, caryophyllene oxide (6.4%), 2-methoxy-p-cresol (5.6%), camphor **(80)** and eugenol **(81)** (4.7% each) have been the main constituents reported in the total oil.[109] Bisht *et al.* (2010)[80] examined chemical composition of essential oil isolated with steam distillation from fresh flowering aerial parts of six Himalayan *Nepeta* species viz. *Nepeta clarkei* Hook. F. (collected from Malari, Chamoli at height of 2800m), *Nepeta discolor* Royle ex Benth. (collected from Malari, Chamoli at height of 2800m), *Nepeta elliptica* Royle ex Benth. (collected from Clips, Nainital at height of 2700m), *Nepeta erecta* Benth. (collected from Hemkund at height of

3250 m), *Nepeta govaniana* Benth. (collected from Bhundiar, Chamoli at height of 2600m) and *Nepeta leucophylla* Benth (collected from Nainital at height of 2400 m). The oils have been analysed by using GC and GC-MS technique. The major compounds present in six Himalayan *Nepeta* species have been given in table no. 4. GC-MS and GC-FID analysis of oil extracted with Clevenger-type apparatus for 3 hours from the fresh plant material (aerial parts) of ***Nepeta govaniana*** (collected in July, 2010 from Gulmarg region of Kashmir Valley) showed the presence of seventeen components which form 87.3% of the total oil composition. The oil contains sesquiterpene hydrocarbons and oxygenated sesquiterpenes which form 80.5% and 6.5% composition, respectively. β-bourbonene (3.6%), β-caryophyllene (6.1%), germacrene D (9.4%) and **pregeijerene (56.9%)** have been the major constituents of sesquiterpene hydrocarbon present in the oil, whereas oxygenated sesquiterpenes have torreyol **(85)** (5.1%) as principal compound and other minor components include elemol, germacrene-D-4-ol, α-cadinol and α-eudesmol.[117] Thirteen components have been identified (which forms 97.55% of the total oil composition) from the essential oil of ***Nepeta cilicia*** (collected from Basconus Mountain at an altitude 1450 m in month of June) when analysed by GC-MS. The oil has been isolated from air-dried flowering parts and leaves using hydro-distillation method with Clevenger-type apparatus for 3 hours. **Limonene (44.75%)**, β-pinene (13.6%), β-caryophyllene (11.2%), caryophyllene oxide (9%), germacrene D (5.2%) and α-pinene (3.5%) have been the prime components of the oil. Less than 9% of the total oil composition consists of other compounds.[112] The examination of essential oil of ***Nepeta depauperata*** using GC-MS showed the presence of thirty three compounds which form 82.52% of the total oil composition. The oil has been obtained from the air-dried aerial parts with hydro-distillation using Clevenger-type apparatus for 3 hours. Plants have been collected from northern slopes of Khabr Mountain, Kerman Province, Iran at flowering season from height of 3500m in Jun, 2002. β-eudesmol **(86)** (2.16%), δ-cadinene (2.80%), 1,8-cineole (3.97%), α-candinol (5.41%), caryophyllene oxide (10.27%), β-caryophyllene (12.93%) and **spathulenol (31.84%)** have been the principal constituent present in the oil.[27]

Ghannadi *et al* (2003)[121] isolated the essential oil of ***Nepeta macrosiphon*** **Boiss** from air-dried flowering aerial parts by Likens-Nickerson's simultaneous distillation-extraction procedure. The plant material has been collected from northern slopes of Dalakhani mountain, Songhur, Iran at height of 2300 m. GC-MS analysis of the oil revealed the presence of forty-five compounds which constitute 95.1% of the total oil composition. Torreyol (2.0%), myrtenol **(87)** (2.0%), δ-cadinene (2.3%), germacrene A (2.4%), α-cadinene **(88)** (3.0%), citronellyl acetate **(89)** (3.8%), γ-eudesmol **(90)** (3.9%), linalool (4.1%), verbenone **(91)** (4.4%), aromadendrene **(92)** (4.8%), α-cadinol (4.9%), bicyclogermacrene (5.7%), α-muurolene **(93)** (6.0%), caryophyllene oxide (8.1%), germacrene D (9.2%) and **spathulenol (14.1%)** have been the prime compounds present in the oil. GC-MS analysis of essential oil of ***Nepeta sintenisii*** taken out from the air-dried leaves (with Clevenger-type apparatus for 6 hours) showed the presence of twenty one components which form 97.82% of the total oil. Plants have been collected in Jun, 2010 from Darkesh protected area, Bojnourd, North Khorassan Province Iran at the flowering stage. Germacrene-D (2.27%), β-bisabolene (3.65%), nepetalactone (4.93%), E-β-farnesene (22.67%) and **α-terpinolene (47.86)** have been the main compounds present in the oil.[123] Fresh aerial parts of ***Nepeta septemcrenata*** [collected from the wadi gebal in Sant cathrin (Sinai), Egypt on August, 2002] have been subjected to hydro-distillation using Egptian Pharmacopoeia apparatus and analysed by GC-MS. The obtained essential oil have sixteen key compounds [ten oxygenated compounds (70.67%) and six hydrocarbons (24.29%)] forming 94.96% of total oil composition. **1,2 benzene-dicarboxylic acid dibutyl ester (33.16%),** 4-methyl-2,6-ditertbutyl phenol **(94)** (23.30%), thujone **(95)** (5.45%), hexadecanoic acid (3.64%) and 2-decyn-1-ol **(96)**

(3.25%) have been the principal oxygenated compounds, whereas 4-nonyne **(97)** (9.00%), n-heneicosane **(98)** (6.69%), 3-octyne **(99)** (5.14%) and 2-methyl-pentadecane **(100)** (2.36%) have been the main hydrocarbons present in the essential oil.[81]



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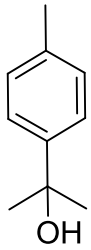

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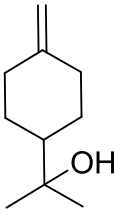

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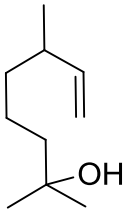

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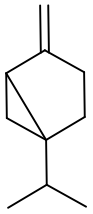

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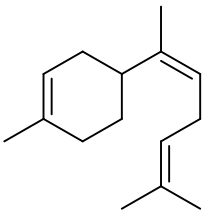

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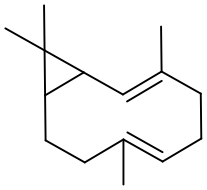

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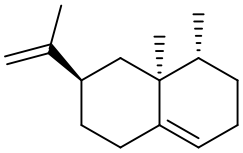

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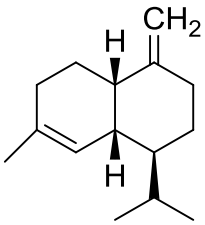

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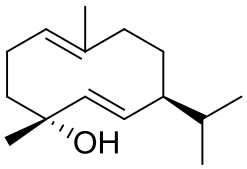

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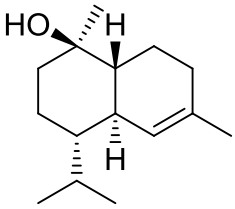

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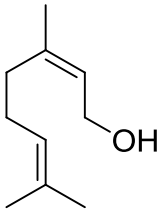

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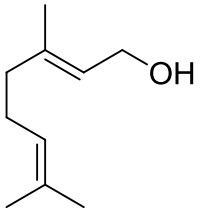

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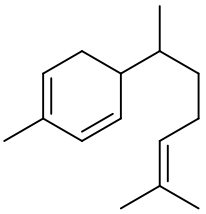

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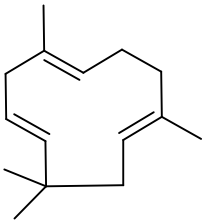

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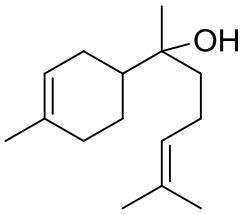

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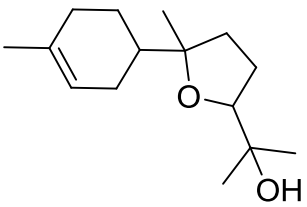

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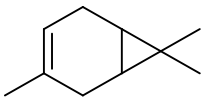

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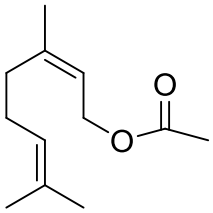

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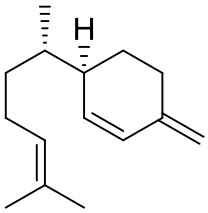

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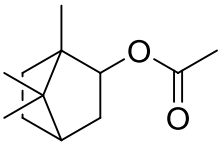

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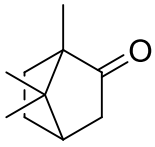

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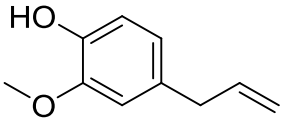

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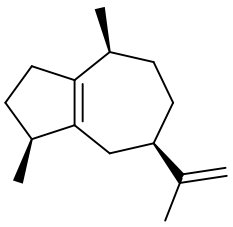

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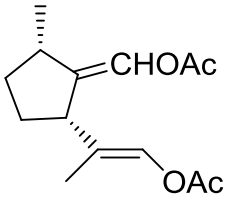

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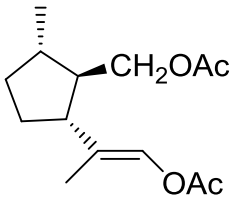

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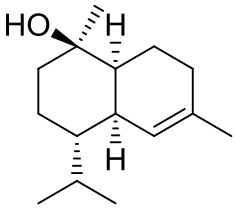

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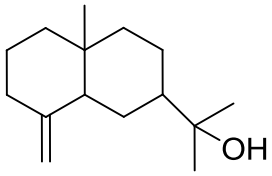

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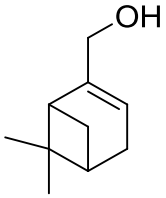

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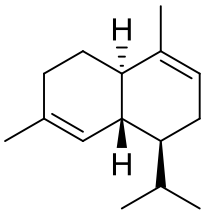

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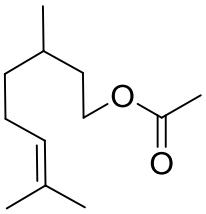

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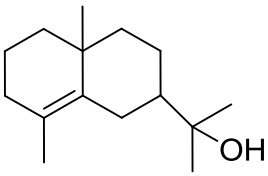

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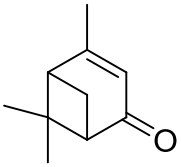

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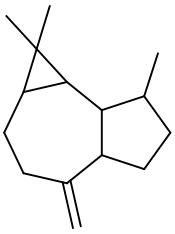

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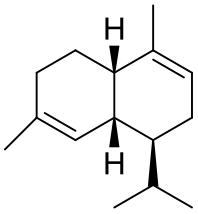

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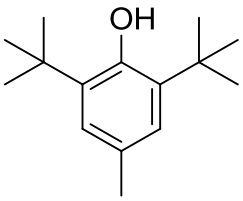

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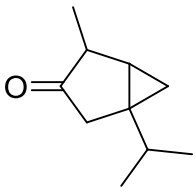

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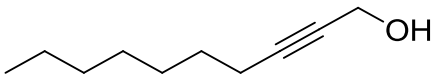

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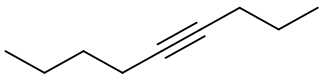

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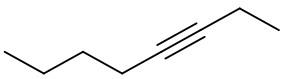

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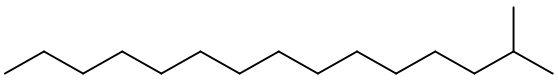

(100)

CONCLUSION

The composition of the essential oil has been varying according the region, soil type and environmental condition from where the plant species have been collected.[126,127] It has been found from the literature that the most of species growing in the Himalayas region have been contained compounds other than nepetalactone as major constituents in their essential oils as compare to the species growing in other part of the world (Iran, Tehran, Serbia, Egypt, Turkey, Brazil, USA etc.), which have both nepetalactone along with its derivatives and other than nepetalactone compounds as the major ingredient of their essential oils. The essential oil isolated from different plant parts viz. stem, leaves, flowers (fresh or dry) collected at different age and vegetative cycle stage have no major effect on the composition of the oil. It has been also found from the literature that the oil of different species of *Nepeta* have been mostly isolated from aerial parts mainly collected during full flowering stage with hydrodistillation using Clevenger type apparatus gives good results. For the sustainable growth and development, a gradual shift from the use of synthetic drugs and agrochemicals to the natural ones have been witnessed as the latter have proven to be non-toxic, cheap and easily available. Active ingredients isolated from genus

Nepeta has been reported to show wide array of biological activity in medicinal and agriculture field. Depending upon the multiple uses of secondary metabolites obtained from genus *Nepeta*, their structure-activity relationship and activity screening goes unabated. The present review would be supportive in the enhancement of today's research in the development of new biologically potent compounds derived from plants which would find many applications in medicinal and agricultural fields.

ACKNOWLEDGEMENTS

Authors are grateful to DST (Department of Science and Technology), Govt. of India, New Delhi for financial assistance under INSPIRE programme (INSPIRE Code IF120715).

Table 1: Species which contained nepetalactone as principal constituents

Sr. No.	Species	Principal Compounds (%)																
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Ref.
1	***N. assurgens*** **(aerial parts)**	**44.6**	2.8						21.3						3.1/ 5.3	3.8 /-	**22/ 98.4**	42
2	***N. cadmea**** **i (herbal parts)** **ii (herbal parts)**	**74.96** **44.51**															**84/ 94 -**	43
3	***N. caesarea**** **i** **ii**	**91.2-95.3** **92-95**																44 45
4	***N. cephalotes**** **i** **ii (aerial parts)**	**35.1** **90.1**							11.4						-/ 18.2 -/ 7.5		**10/ 78.58** /-	46 47
5	***N. crassifolia*** **(aerial parts)**	**92.6**															**21/ 99.49**	48
6	***N. x faassenii*** **(dry leaves)**	**67.8**				-/ 2.3			6.6				4.8		2.7 /-		**109 /95.9**	49
7	***N. govaniana***	**25.9**									17.5 /-		20.5					50
8	***N. mirzayanni*** **(aerial parts)**	**61.0**								-/ 7.8							**22** /-	47
9	***N. persica*** **(aerial parts)**	**80**															**14/ 97.3**	51
10	***N. racemosa***	**64.9**	7.4	1.7														52
11	***N. teydea*** ** **a) leaves (before flowering)** **b) leaves and flowers**	**89.54** **-**													- -/ 7.87	- **12.64** /-		53
12	***N. argolica ssp Argolica***		**68-94.5**														**62** /-	54

Sr. No.	Species	Principal Compounds (%)															
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Ref.
13	*N. atlantica* (whole plant)		**71.4**							8.2/-		-/ 2.5					**26/ 99.9**	55
14	*N. cataria**																	
	i (whole plant)	-	**77.4**			-			-	-				4.1 /-			**26/ 99.7**	55
	ii (leaves)	6.0	**70.4**			-/ 2.5			-	-				-			**22/ 93.0**	56
	iii	11.9	**28.8**			-			13.5 /-	5.7 /-				-			-	57
15	*N. coerulea*	11.9	**21.5**	3.7	19.3													58
16	*N. granatensis* (whole plant)		**39.4**						24.0						6.3 /2.3		**26/ 98.9**	55
17	*N. meyeri* (aerial parts)	8.83	**83.4**														**14/ -**	59
18	*N. nuda* *																	
	i. *ssp nuda***																	
	a) leaves oil	-	**24.7**						16.7	- /16.3								60
	b) verticillaster oil	-	**75.7**						-	-								
	ii. *ssp. albiflora*	37.6	**37.6**							-/ 4.4								61
19	*N. nepetella ssp Aragonensis*	3.5	**57.7**															58
20	*N. parnassica***																	40
	a) vegetative stage	1.5	**22.0**			7.9			21.1	- /4.8					9.5 /3.5	5.0 /-	**35/ 94.8**	
	b) flowering stage	17.3	8.9			2.0			**34.6**	-					11.4 /6.4	4.3 /-	**46/ 98.7**	
21	*N. racemosa*		**31.5-91.6**															62
22	*N. rtanjensis**																	
	i (aerial parts)		**86.4**	6.3									-		1.4 /-		**19/ 95**	63
	ii (aerial parts)		**79.9**	-									1.8		3.3 /-		**8/ 96.2**	64

Sr. No.	Species	Principal Compounds (%)																
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Ref.
23	***N. septemcrenata*** **(aerial parts)**	19.9	**24.2**						8.5		- /13.8			-/ 5.6		2.5 /2.7	**39/ 98.3**	65
24	***N. transcaucasica*** **(aerial parts)**	28	**39**										15				**27/ 97.69**	66
25	***N. tuberose*** **(whole plant)**		**76.8**						1.2								**26/ 100**	55
26	***N. bornmuelleri*** **(aerial parts)**			**64.0**					7.1								**28/ -**	47
27	***N. eremophila*** **(aerial parts)**			**73.3**					13.1								**26/ -**	67
28	***N. persica*** ** **a) flower** **b) leaf** **c) stem** **d) root**		33.0 28.3 24.9 7.6	**58.5** **62. 3** **66.2** 27.1											3.6 /- - 4.6 /- **40.4** /-			68
29	***N. racemosa*** **(aerial parts)**	24.4	25.6	**33.6**					9								**24/ 99.3**	8
30	***N. saccharata*** **(aerial parts)**			**66.9**									12.9				**18/ 98.2**	69
31	***N. sintenissii*** **(aerial parts)**			**23.4**					8.2		- /16.1	9.5 /-	3.5			2.3 /2.5	**40/ 96.5**	7
32	***N. argolica***	26.5	12.9	14.5	**29.4**													70
33	***N. grandiflora***		2.4		**41.0**													71
34	***N. kotschyi*** **(aerial parts)**				**92.0**				2.6								**11/ 97.7**	72
35	***N. crassifolia***	16.3	7.7	9.6		**27.2** /-			9.0									73
36	***N. betonicifolia*** **(aerial parts)**					-/ **42**			3.2				6.0				**33/ 97.9**	69
37	***N. crassifolia***	5.9				-/ **81.1**												57

Sr. No.	Species	Principal Compounds (%)																
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Ref.
38	***N. nuda***					-/ **18.10**					-/ 14.38		15.68					74
39	***N. angustifaliathe***						**75.37** /-										**29**/ -	75
40	***N. cataria** **i** **ii (aerial parts)**						>**77** /- **27.5** /-		- 10.8	- 5.5 /-	- 2.5 /-	- 2.6 /-	9.2	- -/ 3.6	- 2.5 /-	- 5.3 /-	- **47**/ **91.2**	41 76
41	***N. mahanensis*** **(aerial parts)**						**37.6** /-		27.2				6.5				**18**/ -	67
42	***N. nepetella*** **(leaves and flowers)**						**76.5** /-											77
43	***N. mussini***						-/ **70**											41
44	***N. tuberosa subsp. tuberose*** **(inflorescences)**							**69** /-		5.0 /-								78
45	***N. cataria*** **(leaves)**							-/ **50.38**									**4**/ **79.27**	79
46	***N. elliptica*** **(aerial parts)**							-/ **83.4**										80

*sub heading i, ii, iii etc. represent the essential oil composition of same plant (having same compound as major component of the oil) investigated from different localities by same or different worker.

** sub heading a), b), c) etc. represent the essential oil composition of different parts of same plant investigated by same worker.

*** species in the above table have been alphabetically enlisted according to the major constituent due to which repetition in the name of species may be observed. (because same species from different locality may have different major constituents)

A: 4aα,7α,7aα-nepetalactone; B: 4aα,7α,7aβ-nepetalactone; C: 4aβ,7α,7aα-nepetalactone; D: 4aβ,7α,7aβ-nepetalactone; E: 4aα,7β,7aβ-nepetalactone/4aα,7β,7aα-nepetalactone; F: nepetalactone/ epinepetalactone; G: 5,9-dehydronepetalacone/(7R)-trans,trans-nepetalactone; H: 1, 8-cineole; I: (E or Z) α or β-caryophyllene/ β-caryophyllene oxide; J: β-elemene/ β-elemol; K: (Z)-β-farnesene/farnesol; L: germacrene-D; M: limonene/ linalool; N: α-pinene/ β-pinene; O: α-terpineol/4-Terpineol; P: total compounds/representing % of total oil.

Species with sr. no. (1-11) have 4aα,7α,7aα-nepetalactone, sr. no. (12-25) have 4aα,7α,7aβ-nepetalactone, sr. no. (26-31) have 4aβ,7α,7aα-nepetalactone, sr. no. (32-34) have 4aβ,7α,7aβ-nepetalactone, sr. no. (35) have 4aα,7β,7aβ-nepetalactone, sr. no. (36-38) have 4aα,7β,7aα-nepetalactone, sr. no. (39-42) have nepetalactone, sr. no. (43) have epinepetalactone, sr. no. (44) have 5,9-dehydronepetalacone and sr. no. (45-46) have trans, trans-nepetalactone as the key constituent in their essential oil.

Key compounds (other than compounds given in table from A to O) present in different species given in above table:

1: ***N. assurgens*** [(Z)-β-ocimene (3.7%)]; **5:** ***N. crassifolia*** [linalyl acetate (2.6%)]; **6:** ***N. x faassenii*** [(Z)-β-ocimene (2.6%)]; **9:** ***N. persica*** [Spiro[5.6]dodecane(14.2%)]; **10:** ***N. racemosa*** **[**(Z)-β-ocimene (9.5%), (E)-nerolidol (8.8%)]; **11:** ***N. teydea*** **b)** [camphor (5.94%), 1,8-cineole + limonene (14.67%)]; **13:** ***N. atlantica*** [dihyderonepetalactone (3.1%)]; **14:** ***N. cataria*** **i** [dihyderonepetalactone (5.0%), terpinene (4.2%)]; **iii** [citronelly acetate (5.2%)]; **16:** ***N. granatensis*** [α-phellandrene (5.8%), ρ-cymene (3.8%), dihyderonepetalactone (2.8%)]; **20:** ***N. parnassica*** **a)** vegetative stage [trans-verbenol (6.4%), verbenone (4.5%)], **b)** flowering stage [δ-cadinene (2.8%), ρ-mentha-1,5-diene-8-ol (2.6%)]; **23:** ***N. septemcrenata*** [β-bisabolene (3.7%)]; **25:** ***N. tuberose*** [dihyderonepetalactone (5.9%)]; **28:** ***N. persica*** **b)** leaf [β-ocimene (3.6%)] **d)** [α-amorphene (5.3%), γ-cadinene (2.9%), cis-calamenene (2.5%)]; **30:** ***N. saccharata*** [sabinene (6.5%), trans-caryophyllene (3.3%)]; **31:** ***N. sintenissii*** [cis-sabinene hydrate (6.5%), β-bisabolene (4.2%), β-sesquiphellandrene (2.8%)]; **36:** ***N. betonicifolia*** [triplal (5.2%), 1-nor-bourbonanone (4.0%)]; **39:** ***N. angustifaliathe*** [spiro(5,6) dodecane (3.47%), 2,4-dimethyl-1,3-pentadiene (2.7%)]; **40:** ***N. cataria*** **ii** [spathulenol (2.8%)]; **44:** ***N. tuberosa subsp. tuberose*** [geranyl acetate (17%)]; **45:** ***N. cataria*** [trans-cis nepetalactone (21.74%), cis-trans nepetalactone (6.66%)].

Table 2: Species which contained constituents other than nepetalactone as principal constituents

Sr. No.	Species	Principal Compounds (%)																	
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	Ref.
1	***N. septemcrenata*** **(fresh aerial parts)**	**33.16**																**16/ 94.96**	81
2	***N. curviflora**** **i** **ii (aerial parts)**		**41.6**/ 9.5 **50.2**/ 6.4			11.0 /- 5.3 /-												- **35/ 93.2**	82 83
3	***N. daenensis***		**27.1**/ 2.8			-/ 11.4					14.5 /-							**23** /-	84
4	***N. fissa*** **(aerial parts)**		**17.4**/ 12.3								5.8/ 6.0		4.1/ -			2.7/ -		**42/ 99.3**	85
5	***N. nuda*** **L. subsp. *albiflora* (aerial parts)**		**23.9** /-	6.4 /-		-/ 2.75					-/ 10.01		7.35 /-					**24/ 93.46**	86
6	***N. oxyodonta*** **(aerial parts)**		**12.6** /5.3	3.3 /-		-/ 7.4					3.2		8.5 /-		-/ 8.1	7.3 /-		**58/ 96.1**	87
7	***N. cilicia*** **(leaves & flowers)**		15.7/ **40.7**															**23/ 96.6**	88
8	***N. betonicifolia***		-/ **39.2**										9.7 /-					**42/ 90.7**	89
9	***N. nuda*** **L. ssp. *nuda***		5.4/ **21.8**										13.8 /-						90
10	***N. baytopii*** **(aerial parts)**		5.6 /4.4	**23.2** /-		-/ 4.5					3.1/ 3.8		3.9/ 2.8			5.3 /-		**46/ 92.2**	76
11	***N. binaludensis**** **i** **ii (aerial parts)**			**42** /- **63** /-					-/ 4.0 -		-/ 3.0 - /4.5						- 19.0 /-	- **23/ 99.4**	91 92

Sr. No.	Species	Principal Compounds (%)																	
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	Ref.
12	***N. congesta*** **(aerial parts)**			**29.9** /-		-/ 20.3							-/ 10.3						93
13	***N. crispa**** **i (leaves & flowers)** **ii (aerial parts)** **iii (aerial parts)**			**71** /- **47.9** /- **62.8** /-							-/ 5.0 2.5 /- -						- -/ 20.3 10.3 /-	**12/ 91.0** **23/ 99.8** **28** **/-**	94 95 67
14	***N. denudata***			**48.0** /-							-/ 4.6							**21/ 85.7**	46
15	***N. discolor*** **(fresh flowering aerial parts)**		18.8/-	**25.5** /-															80
16	***N. fissa*** **(aerial parts)**		9.2/ 8.2	**24.3** /-		3.1/ 5.4					-/ 3.2		3.0/ 3.2					**49/ 92.5**	76
17	***N. flavida***			**38.9** /-					-/ 25.1									**68/ 96.4**	6
18	***N. gloeocephala*** **(aerial parts)**			**35.2** /-							7.1/ 21.8		-/ 7.8					**29/ 99.98**	96
19	***N. haussknechtii*** **(aerial parts)**			**36.7** /-														**27/ 94.2**	97
20	***N. heliotropifolia***		11.3/ 14.2	**19.0** /-		5.1 /-							8.3 /-					**25/ -**	98
21	***N. involucrate*** **(aerial parts)**			**23.1** /-		-/ 15.1					-/ 12.2							**48/ 97.2**	99

Sr. No.	Species	Principal Compounds (%)																
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	Ref.
22	***N. ispahanica****																		
	I			**66**														-	91
				/-															
	ii (aerial parts)			**71.7**														**27**	67
				/-														/-	
23	***N. italica***			**80.8**														**28**	100
				/-														/-	
24	***N. menthoides****																		
	i (leaves & flowers)			**41.1**			6.1				-/						-	**27/ 89.5**	94
				/-			/-				5.6								
	ii (aerial flowering parts)			**33.8**			-				-						23.2	**29/ 97.6**	101
				/-													/-		
25	***N. pannonica***			**28.9**														**60**	102
	(aerial parts)			/-														/-	
26	***N. pogonosperma***			**31.2**					-/		-/			-/	5.4		14.5	**41/ 97.5**	103
	(aerial parts)			/-					4.5		3.5			4.8	/-		/-		
27	***N. rivularis***			**38.5**							-/		-/					**22**	67
	(aerial parts)			/-							10.7		14.8					/-	
28	***N. royleana***			**75**															50
				/-															
29	***N. schiraziana****																		104
	a) stem		11.7	**45.6**		-/												**14**	
			/-	/-		17.4												/-	
	b) flower		10.6	**34.4**		-/												**14**	
			/-	/-		15.8												/-	
	c) leaves		14.2	**38.5**		-												**18**	
			/11.7	/-														/-	
30	***N. sulfuriflora***			**61.5**														**28**	100
				/-														/-	
31	***N. cataria***			-/	9.03													**4/ 97.53**	105
	(young leaves)			**51.95**	/-														

Sr. No.	Species	Principal Compounds (%)																	
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	Ref.
32	***N. elliptica*** **(aerial parts)**		5.5 /-		-/ **23.4**	-/ 3.6							2.6 /-		3.2 /-			**19/ 83.6**	106
33	***N. raphanorhiza*** **(aerial parts)**		3.2 /3.4			**49.2** /-							-/ 2.5		9.4 /-			**16/ 97.5**	37
34	***N. laevigata*** **(aerial parts)**		10.8 /3.2		16.5 /-	-/ **19.4**							3.9 /-		-/ 4.5			**24/ 86.7**	106
35	***N. ucraininca***					-/ **39.7**							5.6 /-		-/ 5.8			**41/ 89.5**	107
36	***N. pungens*** **(aerial parts)**			5.8 /-	4.9 /-		**17.0** /-		12 /-				4.2 /3.9			-/ 3.9		**49/ 97.2**	108
37	***N. deflersiana***		-/ 6.4				-/ **8.0**		-/ 2.6									**53/ 90.1**	109
38	***N. nuda*** **L. ssp albiflora* (collected from Tannourine)**		-/ 7.3				-/ **10.1**					-/ 7.2			7.8 /-				82
39	***N. clarkei*** **(fresh flowering aerial parts)**					-/ 13.0		**25.3** /-											80
40	***N. leucophylla*** **(fresh flowering aerial parts)**							**25.4** /-											80
41	***N. erecta**** **i (fresh flowering aerial parts)** **ii (aerial parts)**		- -/ 9.6					-/ **66.7** -/ **70.6**										- **34/ 94.6**	80 110
42	***N. govaniana*** **(fresh flowering aerial parts)**							-/ **35.2**				20.7 /-							80

Sr. No.	Species	Principal Compounds (%)																
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	Ref.
43	*N. clarkei****		-/ 14.1															**20/ 95.3**	111
44	*N. cilicia* (flowering parts and leaves)		11.2 /9.0			-/ 5.2			**44.75**/-		3.5 /13.6							**13/ 97.55**	112
45	*N. betonicifolia* (aerial parts)		-/ 9.2	20.8 /-					-/ **40.5**									**34/ 89.6**	113
46	*N. satureioides*		6.6/ 6.4			3.4 /-			-/ **23.8**									**45/ 97.4**	114
47	*N. sessilifolia* (aerial parts)								-/ 14.2	**14.7** /-								**33/ 97.4**	97
48	*N. floccosa*									-/ **33.1**									50
49	*N. discolar*										**18.5** /12.6								50
50	*N. glomerulosa*										**18.3** /-								115
51	*N. laxiflora*			11.8 /-							**19.7** /-							**57** /-	116
52	*N. govaniana** i (aerial parts) ii (aerial parts)		6.1 /- -			-/ 9.4 -						**56.9** /- **38.0** /-			-/ 3.6 -			**17/ 87.3** **>50** /-	117 118
53	*N. pratti*											-/ **45.21**						**15/ 76.8**	119
54	*N. bracteata* (aerial parts)		11.2 /12.3										**14.0** /-					**28** /-	47
55	*N. cilicica* (aerial parts)						-/ 14.0						**15.1** /-					**75/ 96.8**	120
56	*N. depauperata* (flowering aerial parts)		12.93/ 10.27	3.97 /-									**31.84**/-			5.41 /-		**33/ 82.5**	27

Sr. No.	Species	Principal Compounds (%)																
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	Ref.
57	***N. macrosiphon**** **i (flowering aerial parts) ii (aerial parts)**		-/ 8.1 9.6 /-			-/ 9.2 -			-/ 4.1 -/ 5.6				**14.1** /- **28.8** /-			4.9 /- 13.6 /-		**45/ 95.1 73/ 96.9**	121 122
58	***N. sessilifolia***												**25.75**/-					**57/-**	116
59	***N. sintenissii*** **(aerial parts)**					22.67/ 2.27								**47.86**/-	3.65 /-			**21/ 97.82**	123
60	***N. asterotrichus***			17.4 /-					-/ 12.5					-/ **22.8**				**15 /-**	124
61	***N. makuensis*****												9.0/-					**28/ 92.9**	125

*sub heading i, ii, iii etc. represent the essential oil composition of same plant (having same compound as major component of the oil) investigated from different localities by same or different worker.

** sub heading a), b), c) etc. represent the essential oil composition of different parts of same plant investigated by same worker.

*** The major constituent of Species *N. clarkei* with sr. no. 43 and *N. makuensis* with sr. no. 61 have kaur-16-ene (36.6%) and viridiflorol (17.5%).

**** species in the above table have been alphabetically enlisted according to the major constituent due to which repetition in the name of species may be observed. (because same species from different locality may have different major constituents)

A: 1,2 benzene-dicarboxylic acid dibutyl ester; B: β-caryophyllene/ β-caryophyllene oxide; C: 1, 8-cineole (eucalyptol)/ α-citral; D: β-citronellol/ β-elemene; E: (E-Z)-β-farnesene/ germacrene-D; F: geranyl acetate/ hexadecanoic acid: G: iridodial β-monoenol acetate diastereomers and iridodial β-monoenol acetate / isoiridomyrmecin; H: limonene/ linalool; I: linalool acetate/ neral; J: α-pinene/ β-pinene; K: pregeijerene/ pulegone; L: spathulenol/sebinene; M: α-terpinolene/ terpinen-4-ol, N: (α/β)-bisabolene/β-bourbonene; O: α-cadinol/β-ocimene ; P: 4aα,7α,7aα-nepetalactone/4aα,7α,7aβ-nepetalactone; Q: total compounds/representing % of total oil.

Species with sr. no. (1) have 1,2 benzene-dicarboxylic acid dibutyl ester, sr. no. (2-6) have β-caryophyllene, sr. no. (7-9) have β-caryophyllene oxide, sr. no. (10-30) have1, 8-cineole (eucalyptol), sr. no. (31) have α-citral, sr. no. (32) have β-elemene, sr. no. (33) have (E-Z)-β-farnesene, sr. no. (34-35) have germacrene-D, sr. no. (36) have geranyl acetate, sr. no. (37-38i) have hexadecanoic acid (38 ii have α-bisabolene), sr. no. (39-40) have iridodial β-monoenol acetate diastereomers and iridodial β-monoenol acetate, sr. no. (41-42) have isoiridomyrmecin, sr. no. (43) have kaur-16-ene, sr. no. (44) have limonene, sr. no. (45-46) have linalool, sr. no. (47) have linalool acetate, sr. no. (48) have neral, sr. no. (49-51) have α-pinene, sr. no. (52) have pregeijerene, sr. no. (53) have pulegone, sr. no. (54-58) have spathulenol, sr. no. (59) have α-terpinolene, sr. no. (60) have terpinen-4-ol, sr. no. (61) have viridiflorol as the principal constituent in their essential oil.

Key compounds (other than given in above table from A to P) present in different species:

3: *N. daenensis* [bicyclogermacrene (9.6%), bicycloelemene (8.1%), myrcene (5.6%)]; 4: *N. fissa* [γ-muurolene (7.9%), valencene (6.6%), bicyclogermacrene (4.9%), δ-cadinene (3.0%)]; 5: *N. nuda* L. subsp. *albiflora* [isopulegone (12.6%), cis-sabinol (10.1%), β-myrcene (2.95%), calarene (2.65%), α-campholene aldehydes (2.56%); 6: *N. oxyodonta* [germacrene-D-4-ol (6.8%), T-cadinol (5.6%), δ-cadinene (2.8%)]; 7: *N. Cilicia* [αcopaene (7.3%), βcubebene (6.6%)]; 8: *N. betonicifolia* [caryophyllenol-II (5.1%), humulene epoxide-II (4.7%), isocaryophyllene oxide (4.3%)]; 9: *N. nuda* L. ssp. *nuda* [*allo*-aromadendrene (9.0%)]; 10: *N. baytopii* [nepetalactone (12.8%), α-terpineol (3.1%), β-Gurjunene (2.5%)]; 11: *N. binaludensis* i [nepetalactone (25%), α-terpineol (4.0%)], ii [alcohol fenchyl (5.3%)]; 13: *N. Crispa* i [α-terpineol (4.1%), δ- terpineol (2.8%)], ii [α-terpineol (4.8%), 4- terpineol (2.8%)], iii [4aβ,7α,7aβ-nepetalactone (9.2%)]; 14: *N. denudate* [myrtenol (5.0%), trans- pinocarveol (4.5%)]; 15: *N. discolour* [ρ-cymene (9.8%)]; 16: *N. fissa* [nepetalactone (17.6%), α-terpineol (2.8%)]; 18: *N. gloeocephala* [(E)-β-ocimene (7.1%), (Z)-β-ocimene (6.9%)]; 19: *N. haussknechtii* [elemol (11.4%)]; 20: *N. heliotropifolia* [myrtenol (5.9%), *trans*-pinocarveol (4.2%), α-terpineol (4.1%)]; 24: *N. menthoides* i [dihydromyrecen-1-ol (9.2%), 4-terpineol (7.1%), α-terpineol (5.7%)]; 25: *N. pannonica* [4aα,7β,7aα-nepetalactone (14.3%)]; 26: *N. pogonosperma* [α-terpineol (5.4%)]; 27: *N. rivularis* [γ-terpinene (5.1%)]; 31: *N. cataria* [nerol (32.24%), geraniol (4.31%)]; 32: *N. elliptica* [bicyclogermacrene (13.1 %), α-humulene (11.8%), elemol (3.5%), γ-cadinene (3.3%), zingiberene (2.8%)]; 33: *N. raphanorhiza* [δ-3- carene (12.3%), germacrene-D-4-ol (5.8%)]; 34: *N. laevigata* [α-bisabolol oxide B (12.4 %), α-bisabolol (5.3%), α-humulene (3.5%)]; 35: *N. ucrainica* [palmitic acid (10.8%)]; **36: *N. pungens*** [boranylacetate (5.3%), β-sesquiphellandrene (2.8%), nerylacetate (2.5%)]; **37: *N. deflersiana*** [2-methoxy-p-cresol (5.6%), camphor (4.7%), eugenol (4.7%), phytol (3.5%), epi-α- muurolol (3.4%), 6,10,14-trimethylpentadecane-2-one (3.3%), β-eudesmol (3.2%), eudesm-11-en-4α-ol (2.9%), Humulene epoxide II (2.8%)]; **38: *N. nuda* L. ssp albiflora i** [collected from Tannourine- (E,Z)-nepetalactone (4.4%)] and [coolected from Laklouk- , pulegone (10.8%), (E,Z)- nepetalactone (8.0%), β-farnesene (7.1%0), β-caryophylene

(6.9%)]; **39:** ***N. clarkei*** [*β*-sesquiphellandrene (22.0%), α-guaiene (10.0%)]; **40:** ***N. leucophylla*** [dihydroiridodial diacetate (18.2%), iridodial dienol diacetate (7.8%)]; **43:** ***N. clarkei*** [**kaur-16-ene (36.6%),** pimara-7,15-dien-3-one (19.7%), methylabietate (5.3%), manoyl oxide (4.4%)]; **46:** ***N. satureioides*** [(Z,E)-farnesol (14.7%), linalyl acetate (11.1%), Lavandulol acetate (6.6%)]; **48:** ***N. floccose*** [geranial (32.4%)]; **49:** ***N. discolar*** [linalyl acetate (12.3%), myrcene (10.7%)]; **52:** ***N. govaniana*** i [torreyol (5.1%), α-muurolene (3.6%)] ii [cis-trans iridolactone (14.0%), gejerenene (6.8%), two nepetalactone (4.8%)]; **53:** ***N. pratti*** [menthone (19.9%)]; **54:** ***N. bracteata*** [bicyclogermacrene (11.4%)]; **55:** ***N. cilicica*** [δ-cadinene (5.5%), α- copaene (4.5%)]; **56:** ***N. depauperata*** [δ-cadinene (2.80%)]; **57:** ***N. macrosiphon*** i [α-muurolene (6.0%),bicyclogermacrene (5.7%), aromadendrene (4.8%), verbenone (4.4%), γ-eudesmol (3.9%), citronellyl acetate (3.8%), α-cadinene (3.0%)], ii [bicyclogermacrene (10.1%)]; **58:** ***N. sessilifolia*** [lavandulyl acetate (16.7%)]; **59:** ***N. sintenissii*** [nepetalactone (4.93%)]; **60:** ***N. asterotrichus*** [4aβ,7α,7aβ-nepetalactone (14.8%), γ-terpinene (10.6%)]; **61:** ***N. makuensis*** **[viridiflorol (17.5%)**, T-cadinol (10.7%)].

Table 3: Major compounds present in the essential oils of four *Nepeta* species

N. atlantica	*N. cataria*	*N. granatensis*	*N. tuberose*
4aα,7α,7aβ-nepetalactone (71.4%)	**4aα,7α,7aβ-nepetalactone (77.4%)**	**4aα,7α,7aβ-nepetalactone (39.4%)**	**4aα,7α,7aβ-nepetalactone (76.8%)**
dihydronepetalactone **(45)** (3.1%)	dihydronepetalactone (5.0%)	eucalyptol (1,8-cineole) (24.0%)	dihydronepetalactone (5.9%)
β-caryophyllene (8.2%)	terpinene **(46)** (4.2%)	α-pinene (6.3%)	menthol **(47)** (1.6%)
farnesol **(48)** (2.5%)	limonene (4.1%)	α-phellandrene **(49)** (5.8%)	α-pinene (1.3%)
α-curcumene **(50)** (1.3%)	Thymol (1.3%)	ρ-cymene **(51)** (3.8%)	eucalyptol (1,8-cineole)(1.2%)

Table 4: Major compounds present in six Himalayan *Nepeta* species:

Species Name	Major compounds
N. clarkei	α-guaiene **(82)** (10.0%); germacrene D (13.0%); *β*-sesquiphellandrene (22.0%) **iridodial *β*-monoenol acetate diastereomers (25.3%)**
N. discolor	*ρ*-cymene (9.8%); *β*-caryophyllene (18.6%); **1,8-cineole (25.5%)**
N. elliptica	**(7*R*)-*trans*,*trans*-nepetalactone (83.4%)**
N. erecta	**isoiridomyrmecin (66.7%)**
N. govaniana	pregeijerene (20.7%); **isoiridomyrmecin (35.2%)**
N. leucophylla	iridodial dienol diacetate **(83)** (7.8%); dihydroiridodial diacetate **(84)** (18.2%) **iridodial *β*-monoenol acetate (25.4%)**

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