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Review

A review of plants of genus *Leucas*

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Plants of genus *Leucas* (Lamiacae) are widely used in traditional medicine to cure many diseases such as cough, cold, diarrhoea and inflammatory skin disorder. A variety of phytoconstituents has been isolated from the *Leucas* species which include lignans, flavonoids, coumarins, steroids, terpenes, fatty acids and aliphatic long chain compounds. Anti-inflammatory, analgesic, antidiarrhoeal, antimicrobial, antioxidant and insecticidal activities have been reported in the extracts of these plants and their phytoconstituents. An overview of the ethnobotanical, phytochemical and pharmacological investigations on the *Leucas* species is presented in this review.

Key words: *Leucas*, ethnomedicinal plants, bioactive constituents.

INTRODUCTION

Plants are indispensible sources of medicine since time immemorial. Studies on natural product are aimed to determine medicinal values of plants by exploration of existing scientific knowledge, traditional uses and discovery of potential chemotherapeutic agents. Phytochemicals are used as templates for lead optimization programs, which are intended to make safe and effective drugs (Balunas and Kinghorn, 2005). Plants of genus *Leucas* (Lamiacae) have been widely employed by the traditional healers to cure many diseased conditions which insinuated that this genus have immense potential for the discovery of new drugs or lead molecules. The genus *Leucas* comprises of about 80 species (Hedge, 1990). The highest species diversity has been found in East Africa (Ryding, 1998). In India, 43 species are available (Mukerjee, 1940). Plants of genus *Leucas* are generally shrubs, subshrubs, annual herbs or perennial herbs with woody root and/or stem-base. Leaves are opposite, entire or with spiky lobes, oval shaped with tapered end, petiolated or sometimes without intervening stalk.

The axillary or terminal inflorescence is usually with indeterminate augmentation. Bracteoles are roughly erect. The calyx shape varies within the genus (often tuberlar shape) some times calyx enlarges into fruits.

Calyx comprises of five connate sepals (one upper, two lateral and two lower) and 5 - 20 secondary lobes.

Whitish hairs are generally present on the outer surface of the upper lip of the corolla, though yellowish cream color or red hair can also be present in some species (Bentham, 1835; Ryding, 1998). The investigated parts of the *Leucas* species include roots, seeds, stem, leaves, and whole plants. The present review not only covers phytochemical progress made on the plants of genus *Leucas* over the past few decades but also incorporates their uses, in different formulations and in the treatment of various diseases by the traditional healers across the globe.

Traditional use of selected species

The plants of genus *Leucas* have been used by the tribal in various parts of Asia and Africa. Widely employed different species, their parts and mode of application/administration in various diseases are presented in Table 1.

Key classes of compounds common in *Leucas*

The investigation for the phytochemistry of genus *Leucas* possibly began with Shirazi (1947) who worked on *Leucas aspera*. So far, a variety of interesting but limited compounds have been isolated/identified from the plants

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Table 1. Traditional uses of *Leucas* species.

Species	Part	Mode	Indications	Country	References
L. abyssicica	R, T		Tonsillitis, eye disease	Ethiopia	Wondimu et al., 2007
L. alluaudii	L	Juice	Abscess, vomiting	Republic of Congo	Chifundera, 2001
	L	Fresh juice with honey	Gonorrhoea, sterility, spermatorrhea, nocturnal emission, impotency, aphrodisiac and increases sperm in semen	India	Behera and Misra, 200
	L, R	Juice	Ringworm infection	Nepal	Dangol and Gurung, 1991
	L	Juice with lime	Bubo and jaundice	India	Harsha et al., 2002
	L	Pills with garlic and pepper	Jaundice	India	Reddy et al., 1991
	L	Juice with garlic	Squeezed into the nostril to relieve headaches	India	Natarajan et al., 1999
L. aspera	L	Leaf extract stored overnight in hollow chilly fruit case	Madras eye condition	India	Sandhya et al., 2006
	WP, R	Paste	Antidote to snakebite, in fever, headache and insect-stings, asthma	India	Singh et al., 2002
	L	Warmed leaf juice	Earache and arthritic pain	Bangladesh	Yusuf et al., 2006
	L	Juice instilled into eyes	Burning sensation and redness of eyes	India	Tiwari and Yadav, 2003
	L	Boiled leaves vapors	Inhaled to relieve cough and colds	India	Ganesan et al., 2007
	L	Paste	Skin diseases, dhobis itch and ringworm	India	Mahishi et al., 2005
	L	Crushed leaf	Snake bite, one side headache	India	Revathi and Parimelazhagan, 2010
L. biflora	WP	Paste with coconut oil	Skin diseases	India	Ayyanar and Ignacimuthu, 2005
L. calostachys	L	Fresh leaves	As a food substitute	Ethiopia	Abbink, 1993
	L	-	Chest pain, pneumonia, stomach spasm	Africa	Iwu, 1993
	L, WP	Juice, aqueous extract	Malaria	Kenya	Muregi et al., 2004
L. capensis	L	Paste used as adjuvant in traditional veterinary	Diarrhea and gallsickness	South Africa	Vardhana, 2008
L. capitata	F, L	Juice, syrup	Cold, cough, snake bite, scabies	India	Dold and Cocks, 2001
L. cephalotes	L, R	Aqueous paste	Snake bite	India	Selvanayagam et al., 1995
	F	Syrup	Cough and cold	India	Chauhan, 1999
	L	Paste Decoction	Chewed or massaged over gums and teeth to cure mouth ulcer headache	India	Shukla et al., 2010

Table 1. Contd.

	L	Decoction prepared with equal amount of *B. diffusa* L.	Once a daily for week for the treatment of burning sensation and painful urination	India	Punjani, 2010
L. ciliate	Fr, R, WP	Decoction, broth	Flu, numbness of limbs, diarrhea, dyspepsia, hemorrhoids, gall, fracture, pneumonia, health protection	China	Long and Li, 2004
L. decurvata	L	Sap	To relieve eye inflammation	South Africa	Watt et al., 1962
L. deflexa	WP	Plant macerate	Rabies, anaplasmosis and in agalactia	Republic of Congo	Chifundera, 1998
		Aqueous decoction	Eye ailments	Former Zaire	Yamada, 1999
	L	Oral	Diarrhoea (child), ascariasis	Ethiopia	Giday et al., 2009
L. hirta	L		Antiseptic, in septic wounds, fever, cough, snake bite, and liver disorders	India	Manjunatha et al., 2006
L. indica	In, R	Paste	Insect and snake bite	Bangladesh	Partha and Hossain, 2007
	L	Paste with cow milk	Cough	India	Udayan et al., 2007
L. jamesii	L	Juice of boiled and fresh leaves	Cholera, stomachic, diarrhoea	Kenya	Kiringe, 2006
L. lanata	L	Past	Bleeding and in septic wounds	India	Sharma and Dhoundiyal, 1997
	L		Pus absorbent	India	Singh, 2008
	L	Paste with shoots of *O. rosea*	Carbuncles	India	Shah et al., 2008
	L, F	With cold water or milk	Cold , cough, dysentery	India	Verma and Chauhan, 2007
L. lavandulaefolia	AP	Juice	Cough and cold	India	Saha et al., 1997c
L. linifolia	L	Juice Juice with rhizome of *C. domestica*	Dog, insect and snake bite Gastric trouble	India	Acharyya and Sharma, 2004
L. martinicensis	WP	Decoction with *H. spicigeriais*	Malaria	Ghana	Asase et al., 2005
L. martinicensis .	L, AP	Decoction	Inflammations, rheumatism, kidney disorders	Brazil	Agra et al., 2007
	WP	Decoction	Relieves coughing in cattle	Tanzania	Minja, 1999; Ramathal and Ngassapa, 2001

Table 1. Contd.

	L	Aqueous juice	Gonorrhea and anti-vomiting	Tanzania	Kokwaro, 1993
	L	Leaf extract with water or milk	Headache, fever	India	Samuel and Andrews, 2010
	WP	Decoction	Urinary schistosomiasis	Mali	Bah et al., 2006s
L. mollissima	L		Insect repellent	India	Uniyal and Shiva, 2005
L. plukenetii	L	Juice	Pharyngitis and throat trouble	India	Bhattacharjya and Borah, 2008
	L	Juice	Tonsillitis	India	Purkayastha et al., 2005
L. stricta	L	-	Vegetable	India	Bedi, 1978
L. urticaefolia	L, F, Fr, R	Decoction Infusion Roasted root	Fever Cold and cough To relieves swelling	India	Katewa and Galav, 2005
L. zeylanica	R	Necklet made up of root bear on arms and legs	To treat convulsion caused by fever	Bangladesh	Yusuf et al., 2006
	L,F		Fever, jaundice, scorpion and snake bite	India	Jain et al., 2010

of this genus which include phenolics, steroids,triterpenes, tannins and alkaloids.

Phenolic compounds

Plant phenolics are a structurally diverse set of compounds responsible for organoleptic properties of plants. These are found to possess a wide range of therapeutic activity. They occur in plants in the form of simple phenolic acids or as complex structures associated with the oxygenated heterocyclic ring, such as benzoic acid derivatives, stilbenes, tannins, lignans, anthocyanins, flavonoids and coumarins Harborne et al., 1999). In plants of the genus *Leucas*, phenolics are found in abundance; (chemical structures of some phenolics from the genus are presented in the Figure 1. Organic acids namely methoxybenzyl benzoate (1) and 4-hydroxy benzoic acid (2) along with a new peroxy acid urticic acid (3) have been isolated from the chloroform fraction of methanolic extract of whole plant of *Leucas urticifolia* (Fatima et al., 2008). Mishra et al. (1995) reported 4-(24′-hydroxy-1′oxo-5′-n-propyltetracosanyl)-phenol (4) from the shoots of *Leucas aspera*. Lignans, another important class of plant phenolics, are formed as a result of dimerization of phenylpropanoid units at the central carbons of their side chains and generally occur in the root, stem, bark, fruit and seed parts of the plant (Ayres and Loike, 1990). Sadhu et al. (2003) isolated eight lignans namely nectandrin B (5), (-)-chicanine (6), meso-dihydroguaiaretic acid (7), macelignan (8), myristargenol B (9), erythro-2-(4-allyl-2,6-dimethoxyphenoxy)-1-(4-hydroxy-3-methoxy phenyl) propan-1-ol (10), machilin C (11), (7R,8R)- and (7S,8S)-licarin (12) from the methanol extract of the whole plant of *Leucas aspera*.

Flavonoids, another important class of phenolics featuring the linkage of two benzene rings by a chain of 3 carbon atoms, so as to form pyran or pyrone ring, play predominant role in plant physiology and serve as light screens, antioxidants, enzyme inhibitors, precursors of toxic substances and pigments (Harborne et al., 1975; McClure, 1986). In the genus *Leucas*, many reports reveal the occurrence of flavonoids in

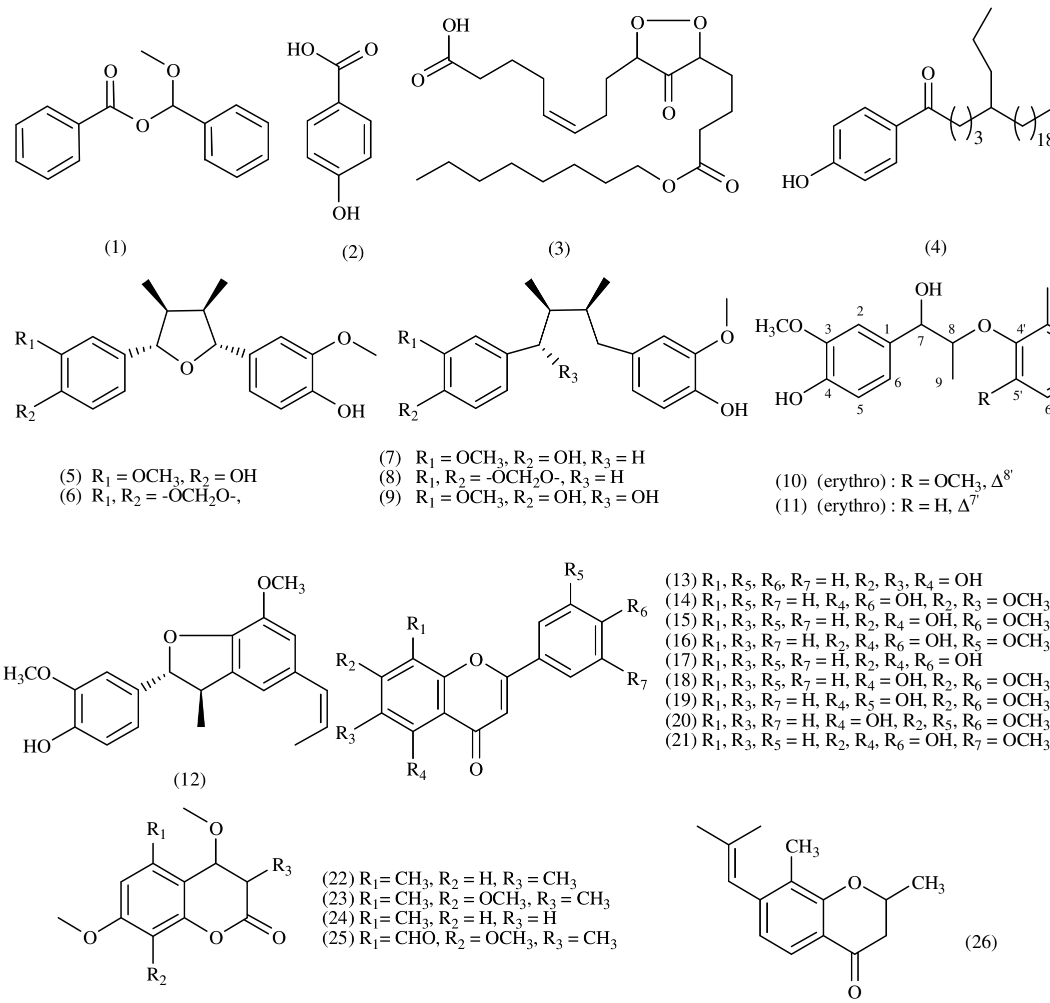


Figure 1. Structures of some phenolic compounds isolated from *Leucas* species.

the conjugated form (that is with sugar). However, free flavonoid 'baicalein' (13) was reported in the ethereal fraction of hydro methanolic extract of *L Leucas. aspera* flower (Manivannana and Sukumar, 2007) and a flavone – cirsimaritin (14) were reported in *Leucas mollissima* Wall. var. Chinensis Benth (Ku et al., 2000). Sadhu et al. (2003) reported acacetin (15), chrysoeriol (16) and apigenin (17) from the *Leucas aspera*. 5-hydroxy-7,4′-dimethoxyflavone (18), pillion (19), gonzalitosin I (20) and tricin (21) were reported from *Leucas cephalotes* (Miyaichi et al., 2006). Coumarins, another class of plant phenolics, comprised of phenlypropanoid system, are found to be physiologically effective for animals as well as men (Kennedy and Thornes, 1997). Natural coumarins such as coumarsabin (22), 8-methoxycoumarsabin (23), siderin (24) and a novel compound coumarleucasin (25) from acetone extract of *Leucas inflata* roots have been isolated. The presence of chromone is also found in some species. A novel compound 'leucasone' (26) of this category has been reported from the *Leucas inflata* (Al Yousuf et al., 1999).

Steroids

Sterols, structurally comprised of perhydrocyclopenta-(O)phenantherene ring system, are widely distributed in higher plants (Harborne et al., 1999). Presence of ubiquitous phytosterol such as β-sitosterol (27), stigmasterol (28), campesterol (29), ursolic acid (30) and their derivatives have been reported in plants of genus *Leucas* (Figure 2) (Al Yousuf et al., 1999; Bahadur and Sen, 1969; Chaudhury and Ghosh, 1969; Fatima et al., 2008; Miyaichi et al., 2006; Pradhan et al., 1990; Sadhu et al., 2006). A novel steroid 'leucisterol' (31) was reported from the methanol extract of whole plant of *Leucas urticifolia*. The skeleton of this compound is similar to stigmasterol, the difference lying in the side chain (that is presence of a hydroxyl group at C-20 atom, a double bond at C-22 atom and S configuration at C-24

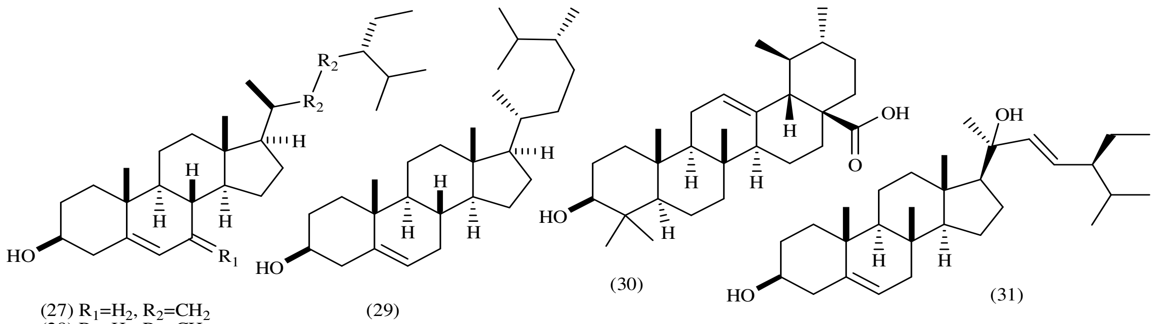


Figure 2. Structures of some phytosterols from *Leucas* species.

atom) (Fatima et al., 2008).

Terpenes

Terpenes constitute one of the largest and structurally diverse class of plant secondary metabolites responsible for flavor, fragrance and bioactivity of the plants (Humphrey and Beale, 2006). Plants of genus *Leucas* are found to be rich in terpenes. Chemical structures of some of these terpenes are presented in Figure 3. Vagionas et al. (2007) reported the presence of monoterpenes in the essential oil obtained from *Leucas glabrata* by GCMS analysis. The study revealed high content of menthone (32), pulegone (33), piperitone (34), piperitenone (35) and presence of α-thujene (36), myrcene (37), α-phellandral (38), g-terpinene (39), terpinen-4-ol (40), nerolidol (41), carvone (42), carvacrol (43), caryophyllene (44), cumin alcohol (45), a-farnesene (46), menthol (47), E-nerolidol (48) in the oil. However, the essential oil fraction from the leaves and flowers of *Leucas aspera* were found to contain high amount of a-farnesene, α-thujene and menthol (Gerige et al., 2007; Mangathayaru et al., 2006), whereas, high content of β-cubebene (49), α-pinene (50), trans-caryophyllene, limonene (51), α-terpineolene (52) were found in the essential oil from *Leucas milanjiana* (Moody et al., 2006). The essential oil fraction of *Leucas deflexa* leaf was reported to have a high amount of sesquiterpene hydrocarbons namely germacrene-D (53), β-caryophyllene and α-humulene (54) (Mve-Mba et al., 2006).

A new type of diterpenes, leucasperones A and B (55-56); leucasperols A and B, (57-58) have been reported from *Leucas aspera* (Sadhu et al., 2006). Maslinic acid (59), an oleanane-type triterpene, has also been reported from the plant. Miyaichi et al. (2006) reported new diterpenes Leucasdins A, B and C (60-62); two protostane-type triterpenes named Leucastrins A and B (63-64), and oleanolic acid (65) from the methanol extract of whole plant of *Leucas cephalotes* Spreng. Oleanolic acid-3-acetate (66) was found in the methanolic extract of *Leucas mollissima* Wall. var. Chinensis Benth (Ku et al., 2000). A lactone triterpene 3β,16α-dihydroxyolean-28→13β-olide (67) was isolated from the benzene fraction of *Leucas aspera* root extract (Pradhan et al., 1990).

Glycoside

Two new flavonoidal glucosides leufolin A and B (68-69) were reported from the ethylacetate fraction of methanolic extract of whole plant *Leucas urticifolia*, which exhibited significant *in vitro* butyrylcholinesterase enzyme inhibitory activity (Noor et al., 2007). A novel phenylethanoid glycoside, 3-O-methyl poliumoside (70) and angoroside C (71), 2-(3-hydroxy-4-methoxyphenyl)-ethyl-O-α-L-rhamnopyranosyl-(1→3)-O-α-L-rhamno-rhamnopyranosyl-(1→6)-4-O-E-ferul -oyl-β-D-glucopyranoside (72), incanoside D (73), martynoside (74), acteoside (75) were reported in the methanolic extract of the whole plant of *Leucas indica*.

Among these, phenylethanoid glycoside, 3-O-methyl poliumoside, was found to exhibit potent free radical scavenging activity due to the presence of large number of hydroxyl group present in the structure (Mostafa et al., 2007). A flavonoidal glycoside, baicalin (76), from the fresh flower of *Leucas aspera*, showed significant biphasic RBC membrane stabilization activity against hypotonicity induced hemolysis (Manivannana and Sukumar, 2007). Further, the isopimarane-type diterpenoidal glycosides ‘leucasperosides A, B, C’ (77-79) and linifolioside (80) reported in *Leucas aspera* and *Leucas linifolia*, exhibited inhibitory activity against PGE1 and PGE2 induced contractions in the guinea pig ileum (Mahato and Pal, 1986; Sadhu et al., 2006). Flavonoidal glycoside apigenin 7-O-(6″-O-(p- coumaroyl)- β-D-glucoside) (81) has been isolated from the *Leucas aspera* (Sadhu et al., 2003) while cosmosin (82), anisofolin A (83) and luteolin 4′-O-β-D-glucurono-pyranoside (84) were reported from *leucas cephaloates* (Miyaichi et al., 2006). Chandrashekar et al. (2005) reported the isolation of chrysoeriol-6″-(O′Ac)-4′-β-glucoside

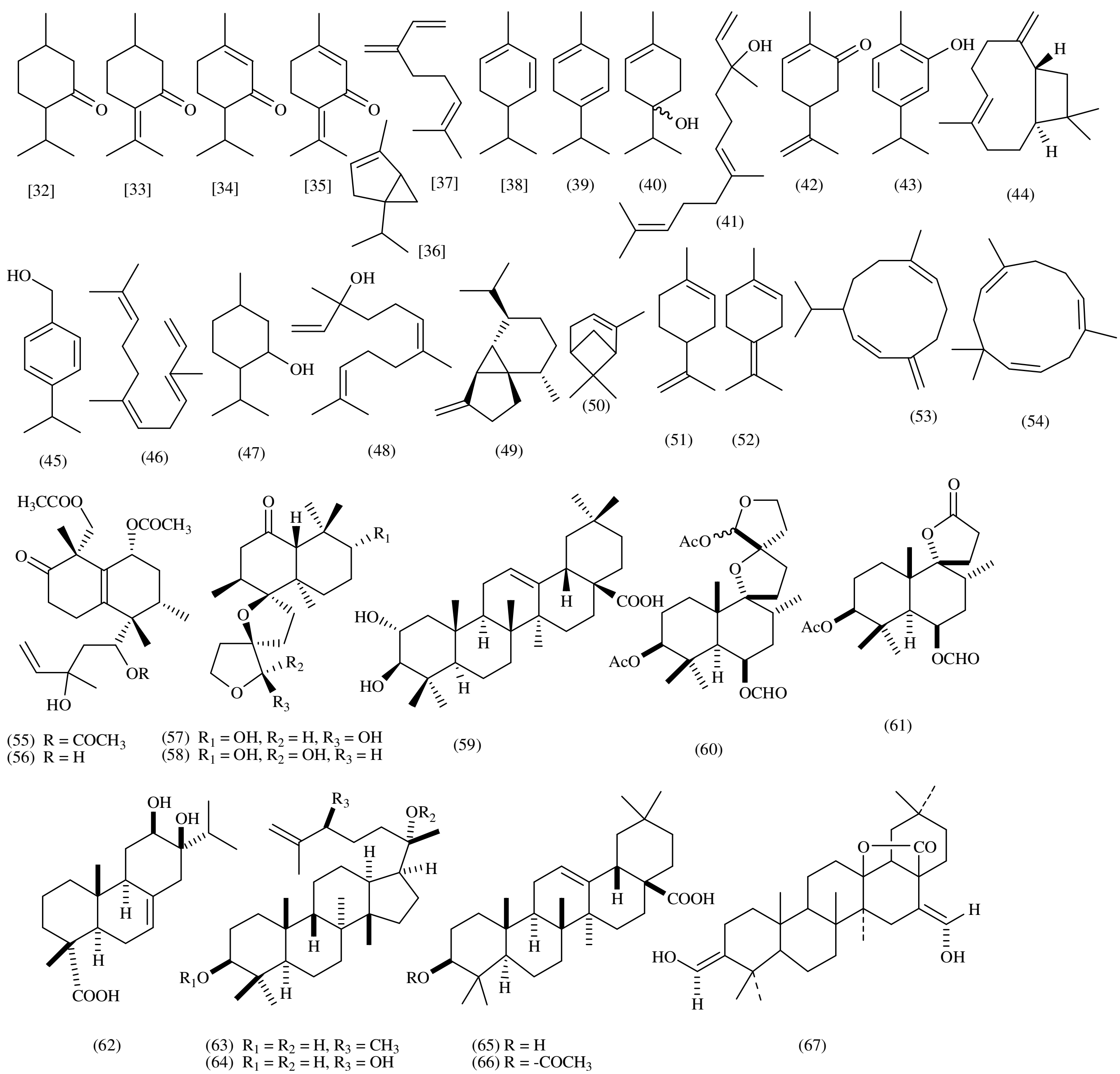


Figure 3. Structures of some terpenes obtained from *Leucas* species.

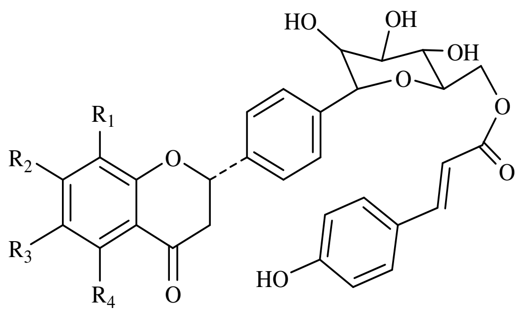
(85) from ethanolic extract of the aerial parts of *Leucas lavandulaefolia* Rees. Chemical structures of glycosides reported from *Leucas* species are presented in Figure 4.

Fatty acids

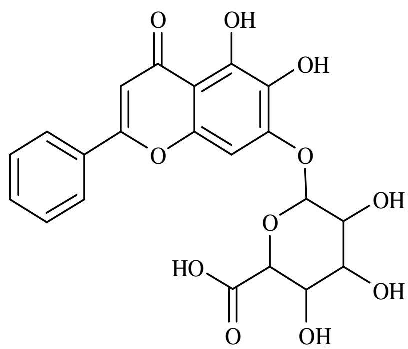
Leucas cephalotes and *Leucas uriicaefolia* seeds were found to have a high content (28% w/w) of laballanic acid (86) Figure 5 (Aitzetmuller et al., 2006; Sinha et al., 1978). Varying concentrations of oleic acid (87) and linoleic acid (88) were found in *Leucas aspera* which was contingent upon crop variation (Chen et al., 1979; Mahato and Pal, 1986).

Miscellaneous

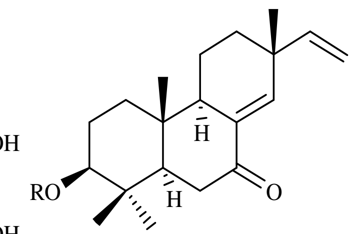
Leucas aspera is widely used in countryside as foods and also for nutritional requirement. It is reported to have high content (21.3%) of protein (Chen et al., 1979; Prakash, 1988). *Leucas aspera* and *Leucas cephalotes* contain



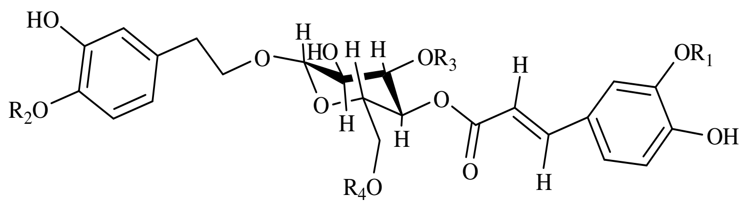
(68) $R_1 = R_3 = H, R_2 = R_4 = OH$
(69) $R_1 = R_3 = OH, R_2 = R_4 = H$



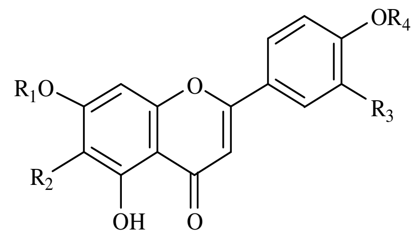
(76)



(77) R= Glc-Glc'-Glc''
(78) R= Glc-Glc'
(79) R= Glc⁻(Rha) Glc'
(80) R = Glc-Rha



(70) $R_1 = CH_3, R_2 = H, R_3 = Rha, R_4 = Rha$
(71) $R_1 = CH_3, R_2 = CH_3, R_3 = Rha, R_4 = Ara$
(72) $R_1 = CH_3, R_2 = CH_3, R_3 = Rha, R_4 = Rha$
(73) $R_1 = CH_3, R_2 = CH_3, R_3 = (Glc^2Rha), R_4 = H$
(74) $R_1 = CH_3, R_2 = CH_3, R_3 = Rha, R_4 = H$
(75) $R_1 = H, R_2 = H, R_3 = H, R_4 = Rha$



(81) $R_2, R_3 = H, R_4 = CH_3, R_1$ = -(6''-*O*-*p*-coumaroyl)glucopyranoside
(82) $R_2, R_3, R_4 = H, R_1 = Glc$
(83) $R_2, R_3, R_4 = H, R_1$ = (3,6-di-*O*-*p*-coumaroyl)glc
(84) $R_1, R_2 = H, R_3 = OH, R_4 = GlcUA$
(85) $R_1, R_3 = H, R_2 = O'Ac, R_4 = Glc$

Figure 4. Structures of some glycosides isolated from *Leucas* species.

significant amounts of total carotenoid and β-carotene (89) (Rajyalakshmi et al., 2001). Asperphenamate (90) and alkaloid nicotine (91) have also been reported in *Leucas aspera* (Mangathayaru et al., 2006; Sadhu et al., 2006). Long chain compounds nonatriacontane (92) (Mishra et al., 1995) 1-dotriacontanol (93), 1-hydroxytetratriacontan-4-one (94), 32-methyl-tetratriacontane (95) were reported in *Leucas aspera* (Mishra et al., 1992). Aliphatic ketols namely 28-hydroxy-pentatriacontan-7-one (96), 7-hydroxy-dotriacontan-2-one (97), 5-acetoxy-triacontane (98) were isolated from the shoots of *Leucas aspera* (Mishra et al., 1993). n-Hentriacontane (99), l-dotriacontanol, phytol (100) and a new diterpene fatty acid ester known as trans-phytyl palmitate (101) were reported from the *Leucas nutans* (Hasan et al., 1991). Amyl propionate (102) and isoamylpropionate (103) were present in high concentration in the essential oil fraction of the leaf and flower parts of *Leucas aspera* (Mangathayaru et al., 2006).

Accumulation of heavy metals reported in plants adversely affect the quality, safety and their medicinal value. Higher concentration of zinc (201 µg/g), iron (809 µg/g), and strontium (133 µg/g), have been reported from *Leucas linifolia* grown in the North Eastern region of India Mohanta et al., 2003; Rai et al., 2001).

Pharmacological activity

Plants have always been an attractive source of drugs. Nevertheless, intricate ways of molecular interactions and bioactivity mechanisms of the extracts or their bioactive constituents provide a challenge to the scientists (Colegate and Molyneux, 2008). Plants of the genus *Leucas* display a wide range of pharmacological activities. A brief overview of their activities has been presented here.

Anti-inflammatory activity

The whole plant extract of *Leucas aspera* was reported to have anti-inflammatory activity and caused degranulation of mast cells (Reddy et al., 1986). Significant anti-inflammatory activity of the yellow colored chromatographic fraction of *Leucas aspera* extract was observed in the chronic and acute models of inflammation. It was observed that, the activity was due to the inhibition of histamine and serotonin (Saha et al., 1997b). Similar observations were made for the alcoholic and aqueous extracts of the plant (Saundane et al., 2000). Srinivas et al. (2000) showed that a dose of 50 mg/kg of *Leucas aspera* dried leaf powder, in 2% gum

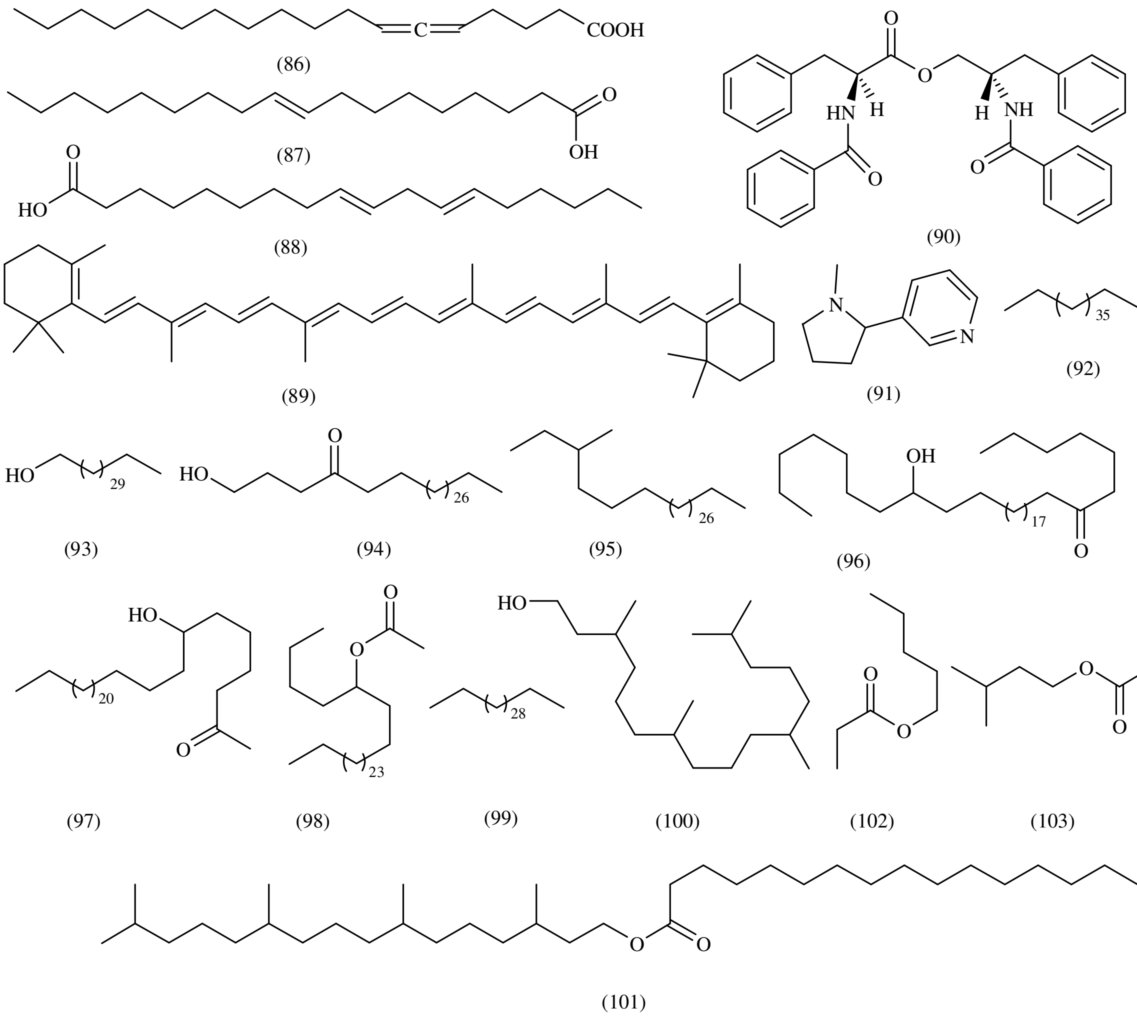


Figure 5. Structures of some fatty acid, nitrogenous and aliphatic compounds isolated from *Leucas* species.

acacia showed significant anti-inflammatory activity which was found to be better than acetylsalicylic acid in the carrageenin induced paw edema model and less active than phenylbutazone, when tested in cotton pellet induced granuloma in rat model. Goudgaon et al. (2003) reported that, the anti-inflammatory activity of *Leucas aspera* is mainly due to its alkaloidal component and the tannins present have no role.

In later studies of bioactivity guided isolation of active compounds from *Leucas aspera*, Sadhu et al. (2003, 2006) reported that, methanol extract of the whole plant at 3×10^{-5} g/ml concentration possess inhibitory activity against both PGE1- and PGE2-induced contractions in guinea pig ileum and the isolated compound (3-O-β-D-glucosyl(1→2)-β-D-glucoside) was found to be mainly responsible for this activity. Manivannana and Sukumar (2007) reported that, the bioactive constituents (baicalein and baicalin) of *Leucas aspera* flowers exhibited significant RBC membrane stabilizing activity. No anti-inflammatory effect was observed with the ethanolic extract (95%) of the whole plant of *Leucas inflata* collected from UAE (Wasfi et al., 1995). However, the acetone extract of the roots of this plant was found to possess anti-inflammatory activity in the preliminary studies (Al Yousuf et al., 1999). Extract of *Leucas mollissima* Wall also exhibited potent anti-inflammatory activity which was mainly due to its bioactive constituent apigenin-7-O-β-D- (6″-p-coumaroyl)glucoside (Ku et al., 2000).

Central nervous system activity

Methanol and acetone extracts of *Leucas inflata* possess dose dependant antinociceptive activity which may be mediated by their central and peripheral actions (Al- et Yousuf al., 2002). In similar study, ethanolic extract of *Leucas aspera* root showed significant peripheral antinociceptive activity at a dose of 400 mg/kg (Rahman et al., 2007). Mukherjee et al. (2002) reported a yellow colored fraction from the methanol extract of *Leucas lavandulaefolia* which exhibited dose related effects on general and exploratory behavior and muscle relaxant activity in rats and mice.

Cough, cold and antidiarrhoeal activities

Saha et al. reported that the semisolid mass from the yellow colored band obtained from methanol extract of *Leucas lavandulaefolia* chromatographed over alumina showed significant, dose dependant, anti-tussive activity. This effect was comparable to codeine phosphate. He suggested that this activity was mediated by the CNS (Verma and Chauhan, 2007). Mukherjee et al. (1998) reported that, the ethanol extract of aerial part of *Leucas lavandulaefolia* significantly reduced the incidence and severity of diarrhoea in the castor oil-induced diarrhoea in rats.

Antidiabetic activity

Saha et al. (1998) have established that, the methanol extracts of whole plant of *Leucas lavandulaefolia* possess a dose-related strong hypoglycaemic activity and have similar potency to that of glibenclamide at an oral dose of 400 mg/kg. Further, activity of the extract had gradual onset and a longer duration of action.

Antimicrobial activity

Vagionas et al. (2007) reported that menthone, pulegone and piperitone rich essential oil of *Leucas glabrata* possessed significant antimicrobial activity against selected gram positive and negative bacteria and fungi strains at a concentration of 0.45 to 1.14 mg/ml (MIC). The aqueous extract of the leaves of *Leucas aspera* was found to be inactive against fungal strains- *Aspergillus flavus* (Sandosskumar et al., 2007), *Trichophyton rubrum*, *Aspergillus niger* (Gupta and Banerjee, 1972). No inhibition against *Escherichia coli* and *Pseudomonas* aeruginosa were detected with 80% ethanolic extract (Valsaraj et al., 1997). However, significant antimicrobial activity was reported for the alkaloidal fraction and the total methanol extract the *Leucas aspera* flowers (Mangathayaru et al., 2005b). The methanol extract of *Leucas zeylanica* and 80% ethanolic extract of *Leucas* aspera leaves were found to exhibit potent inhibitory activity against *Staphylococcus aureus* and *Bacillus subtilis* (Rajakaruna et al., 2002; Valsaraj et al., 1997). Interestingly, the volatile oil obtained from the leaves of this plant exhibited high sensitivity for *Pseudomonas aeruginosa*, *Haemophilus influenza*, *S. aureus*, *Candida albicans* but practically no sensitivity against *Bacillus subtilis*, *Proteus*. *vulgaris*, *Neisseria gonorrhea*, *Tricoderma vibriae* and A. *niger* (Gerige et al., 2007). The difference in the antimicrobial activity may be due to variation in the constituents and/or compositions of the different extracts.

Antioxidant activity

The essential oil content of *Leucas glabrata* did not show significant antiradical activity when tested by the DPPH method (Jain et al., 2010). In similar experiments, Shyur et al. (2005) reported that the methanol extract of the whole plant of *Leucas mollissima* showed insignificant free radical and superoxide anion scavenging activity. However, significant activity was found in the ethanolic extract of *Leucas aspera* root (IC_{50} = 7.5 µg/ml) (Rahman et al., 2007).

Hepatoprotective activity

The ethyl acetate extract of the whole plant of *Leucas cephalotes* did not show ameliorative effect on liver in CCl_4-intoxicated rats or mice (Singh et al., 1978). The chloroform extract of *Leucas lavandulaefolia* whole plant, obtained after defatting with petroleum ether was found to have hepatoprotective activity in D(+)galactosamine-intoxicated rat model (Chandrashekar et al., 2007). The cold methanolic extract of the whole plant of *Leucas aspera* was found to exhibit significant hepato protection in CCl_4 induced liver damage (Mangathayaru et al., 2005a).

Cytotoxicity

Brine shrimp lethality assay is a rapid and inexpensive method used to correlate the cytotoxic and anti-tumor properties of natural and synthetic compounds. Various studies using this model showed that, the hydroalcoholic extract of *Leucas aspera* whole plant exhibited cytotoxicity (LC_{50} = 1,900 µg/ml) (Krishnaraju et al., 2005) and this activity was more in the root extract (LC_{50} = 52.8 µg/ml) (Rahman et al., 2007).

Insecticidal and replant activity

Leucas aspera leaves are used as mosquito repelant and as insecticide by countrified Indians (Kirtikar and Basu, 1990). These claims were vindicated by extensive studies which indicated that *Leucas aspera* leaf extract exhibited significant larvicidal activity against first, second, third and fourth instar larvae of *Culex quinquefasciatus* (Muthukrishnan et al., 1997). *Leucas aspera* leaf extract (4% solution) showed 90% death of the fourth instar larvae (Murugan and Jayabalan, 1999) and 100% death after 24 h were recorded for the third instar larvae of *Anopheles stephensi* (Vinayagam et al., 2008). The petroleum ether extract of the leaves of *Leucas aspera* exhibited LC_{50} between 100 to 200 ppm against the fourth instar larvae of *C. quinquefasciatus*, *A. stephensi* and *Aedes aefypti* (Sakthivadivel and Daniel, 2008). Maheswarn et al. (2008) reported that the highest larvicidal activity against I-IV instar of *C. quinquefasciatus* and *A. aefypti* was found in the hexane extract followed by chloroform and ethanol extracts. *A. stephensi* larval treatment with *Leucas aspera* leaf extract resulted in significant fall of its carbohydrate and DNA profile (Vinayagam et al., 2008). Further, the highest mortality was seen during the moulting, melanization and tanning processes which are controlled by hormones (Mawangi and Rembold, 1988). Hence, the above findings suggest that the larvicidal activity of the plant may be due to disturbance in hormonal and metabolic process of larvae. The seed oil obtained from *Leucas cepbalotes* and *Leucas urticifolia* failed to show repellent/antifeedant activity against adult *Tribolium castaneum* Herbst insect (Khan et al., 1983).

Miscellaneous activity

Mukeherjee et al. reported that, yellow colored chromatographic fraction of the methanol extract of *Leucas lavandulaefolia,* showed effects on general behavior pattern of experimental mice and also exhibited tranquilizing effect (Mukherjee et al., 2002). In other study, Saha et al. (1997a) used methanol extract of *Leucas lavandulaefolia* for the evaluation of wound healing activity in the excision and the incision wound models in rats. They also observed significant contracting ability, wound closure time, tensile strength and regeneration of tissues at the wound sites. The observed wound healing power of methanol extract of *Leucas lavandulaefolia* was comparable to that of nitrofurazone used as standard drug. However, the methanol extract of *Leucas lavandulaefolia* did not show significant antiviral activity against HSV-1 at a concentration non-toxic to the cell line (Vero) (Vijayan et al., 2004). In another study, the protective role of *Leucas aspera* against the snake (cobra) venom poisoning was studied in mice. This study revealed that *Leucas aspera* alcoholic extract treatment significantly improved the survival time which may be due to the stabilization of mast cells and inhibition of the secretion of platelet activating factor and histamine (Reddy et al., 1993).

Conclusion

The following manifestations can be made on the basis of this comprehensive perusal of literature, that the plants of genus *Leucas* are being used traditionally, due to their immense therapeutic potential to treat/cure various diseases. Phenolics and triterpenes are present in plants and exhibit significant biological activity. Many studies demonstrated significant anti-inflammatory activity of the extracts and some isolated constituents obtained from the plants of this genus. This vindicated the use of certain species in the chronic and acute inflammatory diseases including psoriasis, dermatitis and other skin disorders. A variety of phytoconstituents has been isolated from the different species of the genus *Leucas*. However, only a few species have been explored exhaustively for their chemical constituents and pharmacological activities. Thus, there remains a tremendous scope for further scientific exploration of this genus, to establish their therapeutic efficacy and commercial exploitation.

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