REVIEW ARTICLE

Pharmacological Review of *Caralluma* r.br: A Potential Herbal Genus

Sireesha Malladi[1], Venkata Nadh Ratnakaram[2], K. Suresh Babu[3], M. Sreenivasulu[1]

[1]Department of Science and Humanities, Vignan's Foundation for Science, Technology and Research, Guntur, Andhra Pradesh, India, [2]Department of Chemistry, GITAM University, Bengaluru, Karnataka, India, [3]Department of Chemistry, Mallareddy Engineering College, Hyderabad, Telangana, India

Abstract

In history, medicinal plants were proven as a source of active compounds with therapeutic applications, and at present, they are an important collection for the discovery of novel drug leads. *Caralluma* is a genus used as traditional medicine. The present article thoroughly reviewed about the classification of *Caralluma* into subgenera, number of its species, its distribution in different parts of the world, and pharmacological activities exhibited by different species of *Caralluma*.

Key words: Biological activities, *caralluma*, medicinal herb, phytochemicals

INTRODUCTION

Medicinal herbs are a versatile source for therapeutic applications and play a vital role in maintaining the proper health as well as in managing various disease conditions of both animals and humans all over the world. India is one of the prominent places for plant-based medicines in the world. It is estimated that about 25,000 plant based medical formulations are effectively used in folk medicine. They are also known to be very famous to rural communities of India. India is a huge depository for the medicinal plants that were became very popular in traditional medical treatments.[1] Several plant species are used by the various systems of medicines such as Ayurveda, Siddha, and Unani to treat a range of diseases.[2] As allopathic medicines possess toxic nature and side effects, the use of plant-based medicine is becoming popular. This lead to a sudden enhancement in the production of herbal drugs.[3]

Plant-derived compounds are recently gaining much interest due to their wide range of applications.[4] Medicinal plants become a prominent resource of folk medicines, food supplements, modern medicines, new drug leads, nutraceuticals, pharmaceutical intermediates, and chemical units for synthetic drugs.[5] A number of remarkable outcomes were found through the usage of natural products to treat diseases, most particularly polypharmacological applications and synergistic effects of plant extracts.[6] Botanists, ethnopharmacologists, microbiologists, and natural product chemists are investigating for new phytochemicals which could be used in the treatment of different infectious diseases[7] specifically in the radiance of the emerging drug-resistant microorganisms, and there is a need to develop more and more efficient antimicrobial agents. The present article describes about *Caralluma* genus and pharmacological activities of its different species.

ASCLEPIADACEAE

Asclepiadaceae was considered formerly as a plant family, but now it is constituted as a subfamily with name Asclepiadoideae under Apocyanaceae family.[8] The name "Asclepiadoideae" is originated from the word "*Asclepias*" which means milkweeds.[9] Worldwide, Asclepiadoideae subfamily includes 348 genera with 2900 plant species. In

Address for correspondence:
Dr. Venkata Nadh Ratnakaram, Department of Chemistry, GITAM University, Bengaluru Campus, Nagadenahalli, Doddaballapur Taluk, Bengaluru – 561 203, Karnataka, India. Phone: +91-9902632733.
E-mail: doctornadh@yahoo.co.in

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India, Asclepiadoideae can be represented, especially, by 43 genera which includes 243 species. Of 43 genera, 5 are endemic.[10]

CARALLUMA GENUS

Caralluma genus belongs to Asclepiadoideae and is widely distributed in Asia (countries such as Afghanistan, India, Iran, Pakistan, and Sri Lanka), Africa, Arabian Peninsula, Canary Islands, and Southeast Europe.[11,12] The word "*Caralluma*" is originated from the Arabian word "qarh al-luhum" and it means wound in the flesh or abscess.[13] *Caralluma* is considered as the synonym of *Boucerosia*, but both are differing in floral arrangement.[13] *Caralluma* plant species are morphologically erect, creeping as well scrambling succulent herbs with tetragonal branches.[11] Certain Indian succulent plants species containing very elongated flowering were grouped under one genus, and it was named as *Caralluma* by R. Brown.[14] In 1834, Wight and Arnott[15] divided the genus *Caralluma* into two new genera *Hutchinia* and *Boucerosia*. *Boucerosia* was characterized by the plant species with flowers in terminal umbels and widely distributed in Arabian, Indian, and Mediterranean areas of the world. *Hutchinia* was characterized by creeping underground succulent plant species and a few erect plant species containing flowers as terminal umbels. All the genera were compiled under genus *Caralluma* by Brown in 1892.[16] More controversy was created due to the addition of a number of similar succulents in the same genus. Later, in 1895, Schumann[17] divided the genus into three subgenera such as *Boucerosia, Lacruma, and Eucaralluma* (*Caralluma*). In 1990, the *Caralluma* genus was again divided by Gilbert into four subgenera such as *Boucerosia*, *Caralluma*, *Desmidorchis,* and *Urmalcala.* Plowes[18] divided the *Caralluma* genus into 17 genera, and of them, only four genera (such as *Apteranthus, Boucerosia, Caralluma,* and *Caudanthera*) are distributed in India. The species of the genus *Caralluma* are included under three subgenera such as *Boucerosia*, *Desmidorchis,* and *Urmalcala*.[19] In India, *Caralluma* exists in the form of 12 species with seven varieties, in which 11 species are mostly found in South India.[10] Many taxonomists tried to solve the difficulties in classifying different Indian taxa of *Caralluma* but unable to clear the ambiguity.

Caralluma is one of the prominent genera and it grows well in dry regions such as India, Africa, and the Middle East.[20] In folkloric medicine, as well as in Unani and Ayurvedic systems of medicine, the plants of *Caralluma* are being used for the treatment of diabetic patients and rheumatism.[21] Tribals consider some of them as food during famines[22] and also as a part of traditional medicinal system.[23] In India and Pakistan, *Caralluma* species have been used as emergency foods for the past few centuries.[24] A spectrum of biological activities of *Caralluma* species can be expected due to the existence of pregnane glycosides,[25] stigmasterol, and other phytochemicals in them.[26] At present, *Caralluma* is gaining much importance from researchers because it possesses an array of immunostimulating activities due to the presence of various phytochemicals.[27]

Caralluma acutangula

The results of Al-Faifi *et al*.[28] revealed that alcoholic extracts of *C. acutangula* exhibited excellent anticancer activity on hepatocellular carcinoma cell and MCF7 (breast cancer cell) when compared to standard drugs (Doxorubicin and 5-Fluorouracil).

Caralluma adscendens

Uddandapu *et al*.[29] studied about phytochemical and antibacterial studies as well as physicochemical parameters of *C. adscendens* along with 15 other medicinal plants**.** Antimicrobial property of the methanolic extract of *C. adscendens* was tested against four pathogenic bacteria such as *Escherichia coli*, *Proteus vulgaris*, *Klebsiella pneumoniae,* and *Staphylococcus aureus* and minimum inhibitory concentration (MIC) values were also determined. *C. adscendens* has shown comparatively good antimicrobial activity against *K. pneumonia* and *S. aureus*. *C. adscendens* was found to exhibit antibacterial and antifungal, where the aqueous and ethanolic extracts of the plant were studied against five bacterial strains (*E. coli, P. vulgaris, Pseudomonas aeroginosa*, *S. aureus,* and *Salmonella typhi*).[30] Polar solvent extracts (ethanolic and aqueous) were found to be more effective against *E. coli* and *S. typhi,* out of the tested bacteria. On the other hand, no antifungal activity was observed with both polar and non-polar extracts against the tested fungi, namely *Candida albicans*, *Aspergillus niger,* and *Mucor.*

Antioxidant activity or radical scavenging activities of *C. adscendens* var. *fimbriata* extracts were studied against a variety of synthetic and natural free radicals (trolox equivalent antioxidant capacity, ferric reducing antioxidant power, total antioxidant activity, 2,2-diphenyl-1-picrylhydrazyl, $OH^{\cdot}$, and NO).[31] The total phenolics and flavonoids were correlated with antioxidant activity. Methanol and water extracts were proved to contain strong antioxidant capability compared to other extracts due to the presence of high flavonoids and total phenol content in them. Based on their studies, these extracts were suggested as an alternative to synthetic antioxidants in nutraceuticals and food preparations. Antioxidant activity and hypolipidemic activity of various extracts of *C. adscendens* Roxb were studied by Tatiya *et al*.[32] Butanolic extract of *C. adscendens* Roxb had effectively decreased the blood glucose levels in addition to the minimization of low-density lipoprotein, cholesterol, total cholesterol/high-density lipoprotein (HDL) and triglycerides and also improved the HDL in diabetic rats which were used for test.

Hypolipidemic activity of the aqueous extract of *C. adscendens* var. *fimbriata* in hyperlipidemic rats (induced

by triton as well as methimazole) was studied by using various animal models.[33] *In vitro* anthelmintic activity of different extracts of *C. adscendens* var. *fimbriata* against *Pheretima posthuma* (Annelida) and *Ascaridia galli* (nematode) was carried out by Noorulhuda *et al*.,[34] and their studies proved the presence of significant activity for the aqueous extract of *C. adscendens* var. *fimbriata* in comparison with other extracts. Significant antimutagenicity of ethanolic extract of *C. adscendens* against the tested strains was reported by Gowri and Chinnaswamy.[35] *Ames Salmonella histidine* reversion method was used to determine the antimutagenic activity of *C. adscendens* (*Roxb*) in species of *Salmonella typhimurium* (TA98, TA100, and TA153). A review on *C. adscendens* Roxb phytopharmacology was carried out by Tambe *et al*.[36] Wound healing capacity of three different extracts (using petroleum ether, ethyl acetate, and methanol) of *C. adscendens* (Roxb) was reported in rats by Tambe *et al*.[37] These studies were carried out using excision, incision as well as dead space wound models. In these studies, significant wound healing potential was observed for methanolic extracts of *C. adscendens* with a high rate of wound contraction.

Caralluma arabica

C. arabica was investigated for its antioxidant activity in H_2O_2-induced rat liver containing oxidative stress. The freeze-dried extracts were subjected to total antioxidant capacity (TAC) as well as glutathione (GSH) assays under the presence of H_2O_2 (0.1%). Treatment with H_2O_2 causes *in vitro* oxidative stress, and it was evident from depletion of GSH and decrease of TAC levels, but prior treatment with plant extracts increased H_2O_2-induced GSH depletion as well as TAC levels. Based on these results, it was concluded that *C. arabica* may be used to minimize oxidative stress and its corresponding problems in the human health.[38] Antioxidant activity, anticancer as well as anti-inflammatory potential of *C. arabica* (for ethanol, n-hexane, ethyl acetate, n-butanol, and aqueous extracts) were studied by Khasawneh *et al*.[39] In these studies, ethyl acetate and ethanol extracts have shown the highest antioxidant activity due to their high phenolic content. Good anti-inflammatory activity as well as good cytotoxic activity (against MCF7 breast cancer cell line) was exhibited by ethyl acetate extract.

Caralluma attenuata

Mounika *et al*.[40] studied the anthelmintic and antitubercular activities of aqueous methanolic extract of *C. attenuata* after preliminary phytochemical screening. Considerable antitubercular activity and anthelmintic potentiality were observed at 50 µg/mL and 300 µg/mL concentrations, respectively. Kumar *et al*.[41] investigated on antioxidant effect and antidiabetogenic activities of ethanolic extract of *C. attenuata* in streptozotocin-induced diabetic rats. *C. attenuata* was suggested as an antidiabetic agent because its extracts were able to reduce the blood glucose levels. In addition, an increase in food intake, body weight, and glucose tolerance limits was also observed. Hypoglycemic activity of *C. attenuata* in alloxan-induced white albino diabetic rats was studied by Kalaivani and Hristy.[42] Their results have shown that there is a marked decrease in blood sugar levels after treating with ethanol extract of *C. attenuata* and also it has shown notable changes in the concentrations of different biomolecules such as hemoglobin, insulin, glycosylated hemoglobin, protein, hexokinase, urea, pyruvate kinase, fructose 1,6 biphosphatase, and glucose-6-phosphatase levels. Based on their studies, it was proposed that *C. attenuata* extracts induce hypoglycemic activity in diabetic rats due to suppression of gluconeogenesis as well as stimulation of glucose oxidation through pentose phosphate pathway. Antihyperglycemic activity of chloroform, ethanol, and butanol extracts of *C. attenuata* on glucose-supplied diabetic rats and alloxan-induced diabetic rats was studied by Venkatesh *et al*.[43] Butanol extracts were found to exhibit significant antihyperglycemic activity.

Caralluma cicatricose

Hepatoprotective activity of methanol extracts of *C. cicatricose* was assessed in CCl_4-induced liver-damaged rabbits. *C. cicatricose* improved serum protein levels and exhibited a dose-dependent reduction with respect to blood glucose level, hepatic enzymes levels, and blood urea nitrogen. From reports of histopathological studies on the liver of rabbits, it is evidenced that there is a reduction in injury induced by CCl_4. Based on their results, it was suggested that *C. cicatricose* can be used as a natural hepatoprotective agent.[44]

Caralluma dalzielii

Ethanolic extract of *C. dalzielii* was studied for ameliorative effect in fructose-induced diabetic Wistar rats by taking five groups of rats. The test was carried out using glibenclamide as a positive control and distilled water as negative control. *C. dalzielii* extracts notably reduced the total cholesterol in Wistar rats.[45] Phytochemical constituents and acute toxicity of the alcohol extract of *C. dalzielii* were studied.[46] Anti-inflammatory and analgesic activities were studied in mice and rats (chemical and thermal-induced pain models and carrageenan-induced acute inflammation) using these extracts. Based on the results, it was concluded that these extracts can be used in the removal of pain and inflammation.[46]

Caralluma edulis

Nutritional assessment and antioxidant activity of *C. edulis* were investigated along with other plants by Shad *et al*.,[47] and among the tested six plant species, comparatively *C. edulis* was found to contain maximum antioxidant activity. Ethanolic extracts of *C. edulis* were proved to possess a potent

antidiabetic activity by the studies in diabetic rats induced by streptozotocin.[48] The extract has shown an increased effect in cellular antioxidant defense mechanism to sustain oxidative damage.

Caralluma europaea

Seventy-four volatile compounds (58 compounds are non-aromatic and 16 compounds are aromatic) were isolated from the essential oils which were extracted from stems and fruits of *C. europaea* using hydrodistillation. These compounds were found to possess antimicrobial potential against pathogenic microbes.[49] Headspace gas chromatography method was used to determine the volatile components present in flowers of *C. europaea.* Of the identified 41 compounds, the major compounds are monoterpenoids (linalool - 18.4%, α-terpinene - 19.1%, and terpinolene - 23.3%) and carbonylic compounds (hexanoic acid - 1.7%, heptanal - 2.0%, and octanoic acid - 2.4%) along with minor compounds such as indole and dimethyl sulfide.[50]

Caralluma fimbriata

A study on quantitative and qualitative analysis of phytochemical as well as nutritional analysis of the aqueous extract of *C. fimbriata* was carried out by Padwal *et al*.[51] *C. fimbriata* extract was proved to be very useful to prevent and manage the oxidative stress in kidneys, based on the evaluation of renoprotective effect of its aqueous alcohol extracts on Wistar rats.[52] Ethanolic extracts of *C. fimbriata* were found to possess a significant antimutagenicity as these extracts inhibited the reversion created by direct mutagens such as hydroxylamine, ethidium bromide, and sodium azide.[53] *S. typhimurium* was used in these studies for determination of antimutagenicity. Aqueous extracts of *C. fimbriata* were found to be active against pathogenic bacteria (*Bacillus subtilis, E. coli*, and *S. aureus*) and concluded that it can be used to treat diseases such as diarrhea, throat, ear and intestinal tract infections, skin diseases, and fever.[54]

Priya *et al*.[55] proved the *in vitro* anticancer potential of the methanolic extract of *C. fimbriata* against A549 lung cancer cell line, and dose fixation was suggested to be above 100 μg/mL. A relationship between inhibition on growth of cancer cell lines and dose/duration was established. A study on antidiabetic and hepatoprotective effect was carried out for methanolic extract of *C. fimbriata* in streptozotocin-induced diabetic rats. The treated rats were recovered from diabetic condition, hepatotoxicity, and renal toxicity. Hence, the methanol extract of *C. fimbriata* can be effectively used in the treatment of diabetes and its related complications.[56] Effect of dry extract of *C. fimbriata* on appetite and lipid profile was studied in Wistar rats nurtured with cafeteria/hypercaloric diet. It was concluded that *C. fimbriata* can be used in treating obesity as their dry extracts have effectively reduced the gain in body weight and also alterations in lipid profile in rats fed with cafeteria diet.[57] Methanolic extract of *C. fimbriata* was found to inhibit the hyperplastic obesity.[58] Antiobesogenic and antiatherosclerotic activities of the alcoholic extract of *C. fimbriata* were studied using diet-induced obesity rat models. An increase in serum leptin levels was observed, and lipid profile alterations with respect to weight gain were inhibited. *C. fimbriata* was proved to be significant in suppressing appetite as well as a potent antiobesogenic agent on rats fed with cafeteria diet.[59] A review on phytochemistry, traditional uses, and pharmacological properties of *C. fimbriata* was carried out by Devi and Dhamotharan[60] and Naingade *et al*.[61] Of the three extracts (using solvents petroleum ether, chloroform, and aqueous methanol) of *C. fimbriata*, high analgesic activity was exhibited by aqueous methanol extracts when tested against albino mice.[62]

Caralluma indica/Boucerosia indica

B. indica extracts were subjected to qualitative phytochemical testing and antimicrobial screening. Polar solvent (methanol and aqueous) extracts were found to be more effective against the tested pathogenic bacteria compared to acetone/petroleum ether extracts.[63]

Caralluma lasiantha/Boucerosia lasiantha

C. lasiantha (syn. *B. lasiantha*) belongs to the subfamily Asclepiadoideae and its local name is Kundeti Kommulu (in Telugu)/Sirumankeerai (in Tamil).[64] Recent publications report about its biological activities such as antibacterial,[65] hyperglycemic,[66] cytotoxic,[67,68] antioxidant,[69] and immunostimulating.[70] Its vital role in the Indian Traditional Medicine was reviewed by Malladi *et al*.[71]

Caralluma nilagiriana

Chloroform, methanolic, and aqueous extracts of *C. nilagiriana* were found to contain higher antimicrobial potential against *K. pneumoniae* compared to other microbes (*E. coli, S. aureus, P. aeroginosa,* and *S. typhi*) and even more than the standard tetracycline. Similarly, the methanolic extract has shown greater activity against *P. aeroginosa* compared to standard.[72]

Caralluma penicillata

In vitro evaluation of antileishmanial, antiplasmodial, and antitrypanosomal activity of the methanolic extract of *C. penicillata* along with other 24 medicinal plants was carried out by Mothana *et al*.[73] From the results, it was evident that *C. penicillata* has shown a significant antiplasmodial activity against *Plasmodium falciparum and* moderate antitrypanosomal activity against *Trypanosoma brucei*. Ethanolic extract of *C. penicillata* was evaluated for anti-inflammatory activity as well as gastritis protection

Table 1: Pharmacological activities exhibited by different species of *Caralluma genus*

Name of the plant	Biological activity	References
Caralluma adscendens	Antibacterial	[96]
	Antifungal	[96]
	Hypolipidemic	[33]
	Antimutagenic	[35]
	Analagesic	[97]
	Antioxidant and hypolipidemic	[32]
	Antibacterial and antifungal	[35]
	Wound healing potential	[37]
	Immunostimulating	[70]
	Anti-inflammatory	[98]
	Hyperglycemic	[99]
Caralluma adscendens var. *attenuata*	Antioxidant	[69]
	Antiadipogenesis	[100]
	Antiproliferative properties	[67]
	Immunostimulating	[70]
Caralluma adscendens var. *fimbriata*	Antioxidant capacity	[31]
	Antiadipogenesis	[100]
	Antiproliferative properties	[67]
	Anthelmintic	[34]
Caralluma adscendens var. *Gracilis*	Antioxidant, antimicrobial, and cytotoxic	[101]
Caralluma arabica	Antioxidant	[38]
	Antioxidant and lipoxygenase inhibitory	[39]
	Antigastric ulcer and cytoprotective	[102]
	Antinociceptive and anti-inflammatory	[20]
	Antihyperglycemic	[103]
Caralluma attenuata	Anthelminthic and antitubercular	[40]
	Antidiabetic	[104]
	Cytotoxic	[68]
	Antidiabetogenic and antioxidant	[41]
	Hypoglycemic	[42]
	Hyperglycemic	[105]
	Antihyperglycemic	[43]
	Anti-inflammatory and antinociceptive	[21]
Caralluma cicatricose	Hepatoprotective	[44]
Caralluma dalzielii	Ameliorative effect	[45]
	Analgesic and anti-inflammatory	[46]
	Antidiabetic	[106]
Caralluma diffusa	Cytotoxic	[68]
Caralluma edulis	Antioxidant	[47]
	Antidiabetic	[48]
	Antioxidant	[107]
Caralluma fimbriata	Antimutagenic	[53]
	Renoprotective	[52]
	Antimicrobial	[54]

(Contd...)

Table 1: (*Continued*)

Name of the plant	Biological activity	References
	Atoprotective and antidiabetic	[56]
	Anticancer	[55]
	Antiobesity	[57]
	Antinociceptive	[62]
	Antiobesogenic and antiatherosclerotic	[58]
	Effect on food intake, appetite, and anthropometry	[108]
Caralluma flava (Desmidorchis flava)	Antiproliferation	[109]
	Antioxidant	[110]
Caralluma russelliana	Antitrypanosomal	[87]
Caralluma stalagmifera	Antioxidant	[69]
	Antiadipogenesis	[100]
	Antiproliferative properties	[67]
	Immunostimulating	[70]
	Anti-inflammatory and antiarthritic	[111]
Caralluma stalagmifera var. *longipetala*	Antiadipogenesis	[100]
	Antioxidant	[69]
	Antiproliferative properties	[67]
	Immunostimulating	[70]
Caralluma tuberculata	Hypoglycemic and hypolipidemic	[80]
	Neuroprotective	[112]
	Antihypertensive	[82]
	Antioxidant	[81,113]
	Antifungal, antioxidant, cytotoxic, phytotoxic	[86]
	Phytotoxic and antioxidant	[84]
	Sedative, muscle relaxant, and antinociceptive	[85]
	Antifungal, antibacterial, and phytotoxic	[114]
	Antiproliferative	[115]
	Antiplasmodial and antitrypanosomal	[87]
	Anti-inflammatory	[116]
Caralluma umbellata	Nephroprotective and antioxidant	[88]
	Antibacterial	[89]
	Cytotoxic	[68]
	Antiadipogenesis	[100]
	Antioxidant	[69]
	Antiproliferative properties	[67]
	Nephroprotective	[90]
	Antioxidant	[91]
	Hepatoprotective	[92]
	Anti-inflammatory	[93]
	Antinociceptive and anti-inflammatory	[94]
	Anti-inflammatory and antinociceptive	[117]
Caralluma lasiantha	Antihyperglycemic	[66]
	Antioxidant	[69]

(Contd...)

Table 1: (*Continued*)

Name of the plant	Biological activity	References
	Antiadipogenesis	[100]
	Antiproliferative	[67]
	Cytotoxic	[68]
	Immunostimulating	[70]
Boucerosia diffusa	Antiangiogenic	[79]
Boucerosia indica	Antimicrobial	[63]
Caralluma nilagiriana	Antibacterial	[72]
Boucerosia truncato-coronata	Antioxidant	[78]
	Antiangiogenic	[79]
Caralluma pauciflora	Cytotoxic,antimicrobial, and antioxidant	[101]
Caralluma penicillata	Anti-inflammatory and gastritis protection	[74]
	Antiplasmodial, antitrypanosomal, and antileishmanial	[73]
Caralluma sinaica	Anticancer and antifolate activities	[76]
	Antidiabetic	[77]
Caralluma longidens	Antimicrobial	[95]
Caralluma quadrangula	Antimicrobial	[75]
	Antidiabetic	[118]
Caralluma negevensis	Anticancer	[13]
Caralluma acutangula	Anticancer	[28]

property against indomethacin in guinea pigs. The extract was also tested for acute anti-inflammatory activity, and single dose of extract was equally active as that of indomethacin but shorter in time duration. Repeated doses of the ethanolic extract of *C. penicillata* were reported as less significant against chronic inflammation than indomethacin with respect to ulcerogenic effect. At the same time, combination of extract and indomethacin minimized the gastritis property of indomethacin depending on ulcer index.[74]

Caralluma quadrangular

Extracts of *C. quadrangular* have shown antimicrobial activity against four strains (*P. aeruginosa, E. coli*, *Micrococcus luteus,* and *C. albicans*) but not against *B. subtilis*. Higher activity was reported with acetone and ethanolic extracts compared to the extracts using distilled water, ethyl alcohol, Tris-HCl, and *Zamzam* water.[75]

Caralluma sinaica

Methanolic extracts of *C. sinaica* exhibited strong antifolate and anticancer activities compared to the extracts of other five plants studied by the authors. *In vitro* antitumor activities were carried against human breast, CNS, and lung cancer cell lines for all the six plants, whereas antifolate studies were carried out using commercial dihydrofolate reductase.[76] Ethanolic extracts of *C. sinaica* have decreased the blood glucose levels more significantly compared to standard (glibenclamide) in streptozotocin-induced diabetic rabbits.[77]

Boucerosia truncato coronata/Caralluma truncato-coronata

Comparable antioxidant potential was observed for the ethanolic extracts of *B. truncate coronata* plants cultured both *in vivo* and *in vitro*.[78] Extracts of *B. truncate coronata and Boucerosia diffusa* were tested for antiangiogenic activity using *in vivo* chick chorioallantoic membrane assay. Ethanolic and chloroform extracts of *B. diffusa* have shown high antiangiogenic activity, whereas methanolic extract of *B. truncato coronata* exhibited good antiangiogenic activity.[79]

Caralluma tuberculata

Hypolipidemic and hypoglycemic effects of *C. tuberculata* was studied with respect to the safety of the kidney and liver of diabetic rats. No harmful effect was observed.[80] Based on significant effect on normalization of blood glucose and good antioxidant potential in streptozotocin-induced diabetic rats, *C. tuberculata* was recommended for diabetic patients to suppress oxidative stress-instigated complications.[81] Antihypertensive effect of aqueous methanolic extract of *C. tuberculata* was studied in both normotensive and hypertensive Sprague Dawley rats.

A marked decrease in systolic blood pressure, mean blood pressure, diastolic blood pressure, and heart rate was observed at all doses compared to control in normotensive models. Significant antihypertensive effect was shown in hypertensive models. A high decrease in blood pressure was observed in hypertensive models than in normotensive models. Based on the results, it was concluded that aqueous methanolic extract of *C. tuberculata* can be used as an effective antihypertensive agent.[82]

Bibi *et al*.[83] authored a review article on *C. tuberculata*. Different extracts (using solvents such as n-hexane, ethyl acetate, chloroform, and methanol) of *C. tuberculata* were studied for phytochemical composition and, antioxidant as well as phytotoxic potential. Methanolic extract was proved to exhibit high phytotoxic activity, whereas $CHCl_3$ extract has exhibited good antioxidant potential.[84] *C. tuberculata* extracts were used to study sedative, muscle relaxant, and antinociceptive activities. Chloroform and ethyl acetate fractions have exhibited significant sedative and muscle relaxation effects compared to n-hexane fraction.[85] Significant activities (free radicals scavenging, phytotoxic, antifungal, and cytotoxic) were reported for the methanolic extracts of *C. tuberculata*.[86] Good antiplasmodial and antitrypanosomal activities were exhibited by petroleum ether fraction of MeOH extract of *C. tuberculata,* whereas moderate cytotoxicity was shown by chloroform fraction of MeOH extract.[87]

Caralluma umbellata

Bharathi *et al*.[88] reported significant nephroprotective and antioxidant activities for the methanolic extracts of *C. umbellata. C. umbellata* extracts from non-polar end to polar end (using different solvents such as hexane, benzene, diethyl ether, chloroform, acetone, and methanol) were evaluated for their antibacterial activity. Based on the antibacterial activity of *C. umbellata Haw* against *E. coli*, *B. subtilis*, and *Bacillus cereus*, the scientific basis for its use in the traditional treatment of stomach disorder was explained.[89]

Total phenol content as well as *in vitro* antioxidant activity of aqueous alcoholic extract of *C. umbellata* was studied by Kumar and Sandhya[90] and concluded that the presence of phenolic content is the main reason for good antioxidant activity of *C. umbellata. In vitro* antioxidant activities of aqueous and methanolic extracts of *C. umbellata* were also studied by Kalyani and Anuradha.[91] Prevention of lipid peroxidation and good scavenging activity of extracts were reported. Hepatoprotective effect of *C. umbellata* on acetaminophen-induced hepatic damage rats was estimated and found to contain significant activity.[92] Good anti-inflammatory effect was reported for Carumbelloside-II and III (from *C. umbellata*) and good anti-inflammatory activity was also reported for Carumbelloside-II. The traditional use of *C. umbellata* in healing of pain and inflammation was substantiated based on these results.[93,94]

Caralluma longidens

Methanolic extract of *C. longidens* was evaluated for antimicrobial activity against clinical pathogens, and MICs were also determined. Of all the microbes, *K. pneumoniae, S. typhi, S. aureus*, *C. albicans,* and *Candida krusei* were more sensitive towards these extracts compared to others such as *Corynebacterium ulcerans, Proteus rettgeri, Pseudomonas fluorescens*, and *A. niger*.[95]

In continuation to the above pharmacological activity collection, efforts of various researchers on their study pertaining to different species of *Caralluma* are compiled in Table 1.

PHYTOCHEMICAL AND PHARMACOLOGICAL ACTIVITIES

Enthusiastic researchers in this field can extend their investigation in relating the pharmacological activities exhibited by *Caralluma* species to their corresponding phytochemicals such as flavone glycoside, luteoline-4′-O-neohesperiodoside,[21] pregnane glycosides,[101,118] acylated pregnane glycosides,[119] acylated steroidal glycosides,[115] and pregnane steroid.[120,121]

Advancement of new routes[122-125] and novel approaches[126-133] of synthesis are helping the synthesis of molecules of therapeutic importance. However, researchers are striving further due to resistance gained by strains toward these drugs. Plant-based products are gaining momentum in the market in view of the lack of any side products.[134] Hence, based on the screening of phytochemicals, they can be used directly or new molecules can be produced using them as precursors.

CONCLUSION

Caralluma genus is a potential source for phytochemicals with medicinal usage. Thorough literature collection shows that few species are explored for pharmacological activities so far. However, many other species (such as *Caralluma flava*, *Caralluma negevensis*, *Caralluma pauciflora*, *Caralluma retrospiciens*, *Caralluma russeliana*, and *Caralluma wissmannii*) have to be further explored.

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