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REVIEW

Phytochemical, pharmacological properties and diseases of a medicinal plant *Coleus forskohlii* Briq.- A review

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Coleus forskohlii is an Indian ancient root drug recorded in Ayurvedic materia medica. Forskolin a diterpene compound is the active principle of this plant. Minor diterpenoids, deacetylforskolin, 9-deoxyforskolin, 1, 9-deoxyforskolin, 1, 9-dideoxy-7-deacetylforskolin, and four other diterpenoids, have been reported to be present in the roots of *C. forskohlii.* Forskolin is the last compound to be formed in the biogenetic sequence. This review article has attempted in research updates on phytochemistry, biogenesis, pharmacological properties and diseases of the medicinal plant *C. forskohlii* The plant, *Coleus forskohlii* suffers from many diseases like leaf spots, leaf blight, stem blight and wilt as has been reported from time to time by different workers. But through extensive survey of diseases of the plant for two consecutive years, in and around Burdwan district, West Bengal, the wilt disease caused by *Fusarium oxysporum* (ITCC No.6933.08) has been found to be the most wide spread and severe in the area under investigation which poses a total crop loss in the fields under cultivation. As a result of the disease, the plant and its products suffer a lot leading to a great economic loss to our country.

Keywords : *Coleus forskohlii,* biogenesis, diseases, pharmacological properties, phytochemistry

INTRODUCTION

It has been estimated that about 80% of the world's population depends on traditional medicine for their health needs. In many developed countries, traditional herbal remedies are making a comeback as alternatives to modern medicine. The existence of traditional medicine depends on plant diversity and the related knowledge of their use as herbal medicine. As the medicinal plants have great significance to the health of community and individuals. India has rich history within the uses of medicinal plant and their derivatives for medicinal purpose large numbers of medicinal plants are employed in traditional medicine since time of yore. India is well known as 'big box of medicinal plant' and is one of the twelve mega biodiversity hot spot regions of the world and one fifth of all plants found in India are used for medicinal purpose (Schippmann *et al.* 2002).Nearly 25,000 effective plant based formulations are used in folk medicine by rural communities in India. According to a report there was about US $ 62 billion sales of herbal medicines in the world and it is expected to increase up to US $ 3 trillion by 2020. Exports from India have increased from Rs. 460 crores in 1995 to 1200 crores in 2000 (Singh *et al.* 2011). Medicinal plants are important for pharmacological research and drug development, not only when constituents are used directly as therapeutic agents, but also as starting materials for the synthesis of drugs or as models for pharmacologically active compounds (Mukherjee, 2003). The world market for plant derived chemicals viz., pharmaceuticals, fragrances, flavours and colour ingredients exceed several billion dollars per year. Classic examples of phytochemicals in biology and medicine include taxol, vincristine, vinblastine, colchicine as well as the Chinese antimalarial - artemisinin and the Indian ayurvedic drug –forskolin. Moreover uses of herbal medicine for the treatment of various

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disorders are extremely important in developing countries where cost of conventional medicine is burden to population. Quite 30% of entire plant species are useful in medicinal purpose (Vaishnavi, 2022).

The genus *Coleus* was first described by Loureiro in 1790 and the generic name was derived from the Greek word 'COLEOS' meaning sheath. All the species of *Coleus* have four didynamous, dedinate stamens, and the filaments of the stamens unite at their base to form a sheath around the style. The species name *forskohlii* was given to commemorate the Finnish botanist, Forskel. The genus *Coleus* consists of 150 species and the following species viz., *C. amboinicus, C. forskohlii, C. spicatus* and *C. malabaricus* occur naturally. *Coleus forskohlii* Briq. [syn: *Coleus barbatus* (Andr.) Benth.]. is a plant of Indian origin (Khatun *et al.* 2011a) belonging to mint family Lamiaceae (Fig. 1A) and grows perennially over tropical and subtropical regions of India, Pakistan, Sri Lanka, East Africa and Brazil at 600-1800 m elevation. In India, the crop is cultivated in the parts of Gujarat, Maharashtra, Rajasthan, Karnataka and Tamil Nadu and is being grown in an area of more than 2500 hectares for its tuberous roots. The common name of *Coleus* are Pashan Bhedi in Sanskrit, Patharchur in Hindi, Makandiberu in Kannada, *Coleus* in English, Garmalu in Gujarati, Maimnul in Marathi. Traditionally, the roots have been used as condiments in pickles, for preparation of pickles and also for medicinal purposes by the ayurvedic schools of medicines (Bhowal and Mehta, 2017). Root juice is given to children suffering from constipation (Singh *et al.* 2011). Kothas, the native tribes of Trichigadi in Nilgiri, South India consider the decoction of tuberous roots as tonic (Shukla *et al*. 2017). The crop has a great potential in future due to the expected increase in demand for forskolin widely used in glaucoma, cardiac problems and also used in the treatment of certain types of cancer (Wang *et al.* 2019). It has ethnomedicinal uses for relief of cough, eczema, skin infections, tumors and boils have been recorded (Kanne *et al.* 2015). Its roots (Fig. 1B) are the source of a labdane diterpene compound called forskolin having a unique property to stimulate adenylate cyclase. Forskolin is also a potent vasodilatory, hypotensive and inotropic agent (Salehi *et al.* 2019). Like certain drugs used for asthma, the novel feature of forskolin is its unique mechanism of generating cyclic adenosine monophosphate (AMP) in the cells through the direct activation of the catalytic unit of adenylate cyclase enzyme, which made the pharmaceutical industry to recognize the plant as most medicinally and economically important (Pateraki *et al.* 2017). Because of continuous collection of roots from the wild sources, this plant has been included in the list of endangered species (Tripathi *et al.* 2014). Recently, its cultivation has picked up as a crop because of its economic potential. The crop is cultivated through 55-day-old rooted cuttings which are generally planted on ridges at a spacing of 60 × 45 cm (row to row 60 cm and plant to plant 45 cm). Transplanting is done into planting holes having a depth of 10-12 cm and diameter of 8-10 cm. The crop responds well to organic and inorganic fertilizers. A combination of 40 kg N, 60 kg P_2O_5 and 50 kg K_2O per ha is optimum dose of chemical fertilizers. The crop is ready for harvest in 4 to 5 months after planting. The plants are uprooted, the tubers separated, cleaned and sun dried. On an average, a yield of 800 to 1000 kg/ha of dry tubers may be obtained. However, if proper cultivation practices are applied, a yield of up to 2000 to 2200 kg/ha of dry tubers can easily be obtained.

Phytochemistry

The major constituent which has been reported from *C. forskohlii* are diterpenoids and essential oils. The tuberous root extracts of *C. forskohlii* contain minor diterpenoids i.e., deactylforskolin, 9-deoxyforskolin, 1, 9-deoxyforskolin, 1, 9-dideoxy-7-deacetylforskolin in addition to forskolin (7 â- acetoxy - 8, 13-epoxy1á, 6 â, 9 á - trihydroxylabd-14-en-11-one) which is the principle bioactive constituent of *Coleus forskohlii* 10, 241,6-diacetoxy-9-deoxyforskolin, forskolin I, forskolin J, and forskolin L was isolated and reported from the Chinese species (Xu and Kong, 2004). Two more diterpenoids i.e., 6-acetyl-1-deoxyforskolin and 6-acetyl-1, 9-dideoxy forskolin were also reported (Xu and Kong, 2006). Further studies report the presence of various forskolin derivatives like forskolin E, forskolin F or coleonol D, forskolin G, and forskolin H (Xu et al., 2006).

Table. 1 :The chemical compounds isolated from *Coleus forskohlii*

Name of the compound	Plant part use	Reference
Abietane diterpenoids	R	Mothana *et al.* (2014)
Abietatriene (dehydroabietane)		
7β-Acetyl-12-deacetoxycyclobutatusin	L	de Albuquerque *et al*. (2007)
(+)-Allylroyleanone (plectranthone J)	L	Kanne *et al.* (2015)
Barbatusin	L	Mitra *et al.* (2020)
Barbatusol	S	Albaidhani and Mattar (2024)
Cariocal	S	Kanne *et al.* (2015)
Coleon C	WP	Liu *et al.* (2007)
(16R)-Coleon E	L	Fernandes *et al.* (2011)
Coleon F	L	
Coleon O	L	
Coleon S	L	Yao *et al.* (2002)
Coleon T	L	Yao and Xu (2001)
Cyclobutatusin	L	Fernandes *et al.* (2011)
Demethylcryptojaponol (11 - hydroxysugiol)	R	Xu *et al.,* (2005)
20-Deoxocarnosol	S	Pullaiah (2022)
14-Deoxycoleon U	R	Xu *et al.* (2005)
Ferruginol	S	Pullaiah (2022)
6β-Hydroxycarnosol	S	
3β-Hydroxy-3-deoxybarbatusin	L	Amezcuaa *et al.* (2022)
Plectrin	L	
(16R)-Plectrinon A	L	Schultz *et al.* (2007)
Plectrinon B	L	Amezcuaa *et al.* (2022)
6,7-Secoabitane diterpene I	S	Kanne *et al.* (2015)
6,7-Secoabitane diterpene II	S	
Sugiol	WP	Li *et al.* (2006)
8,13-Epoxy-labd-14-en-11-one-diterpenoids		
1-Acetoxy coleosol	R	Kanne *et al.* (2015)
6-Acetyl-1-deoxyforskolin	WP	Xu and Kong (2006)
1-Acetylforskolin	R, WP	Kanne *et al.* (2015) Wu *et al.* (2005)
6-Acetyl-1,9-dideoxyforskolin	WP	Xu and Kong (2006)
Coleol	R	Kanne *et al.* (2015)
Coleonol E	R	
Coleonol F	R	
Coleosol	R	

7-Deacetylforskolin	R	
Deacetyl-1-deoxyforskolin	R	
Deoxycoleonol	R	
9-Deoxyforskolin	R	
1,6-Diacetoxy-9-deoxyforskolin	R,WP	Yang *et al.* (2007)
1,6-Di-O-acetylforskolin	R,WP	Wu *et al.(*2005), Yang *et al.* (2007)
1,9-Dideoxy-7-deacetylforskolin	R	Wu *et al.(*2005)
1,9-Dideoxyfoskolin	R	
1,9-Dideoxycoleonol B	R	
Forskolin	R	Zhang *et al.* (2005)
Forskolin E	R, WP	Xu *et al.* (2006)
Forskolin F	R, WP	
Forskolin G	R, WP	Xu and Kong (2004) Yang *et al.* (2006) Shen *et al.* (2002) Shan *et al.* (2006)
Forskolin H	R, WP	Xu and Kong (2004) Yang *et al.* (2006), Shen *et al.* (2002)
6β-Hydroxy-8,13-epoxy-labd-14-en-11-one	R	Xu and Kong (2004)
Isoforskolin	R	Kanne *et al.* (2015)
11-Oxomanoyloxide	R	
Coleonol	R	
Coleonone	R	
13-Epi-9-deoxycoleonol	R	
3-Hydroxyforskolin	WP	Shan and Kong (2006)
3-Hydroxyisoforskolin	WP	
Manoyl oxide	R	Kanne *et al.* (2015)
Coleolic acid	WP	Liu *et al.* (2007)
Coleonic acid	WP	
Forskoditerpene A	WP	Shan *et al.* (2008)
12-Hydroxy-8,13E-labdadien-15-oic-acid	WP	Xu and Kong (2006)
13-Epi-sclareol	R	Sashidhara *et al.* (2007)
Forskoditerpenoside A	WP	Shan *et al.* (2007)
Forskoditerpenoside B	WP	
Forskoditerpenoside C	WP	Shan *et al.* (2008)
Forskoditerpenoside D	WP	
Forskoditerpenoside E	WP	

Note : L = leaf, R = root, S = stem, WP = whole plant

Table 2: Pharmacological activities reported from *Coleus forskohlii*

Activity	Action	References
Antiglaucoma/Reduction in Intra Ocular Pressure (IOP)	Forskolin suspension (1%for skolin) obtained from *C. forskholii* lowers the IOP in rabbits, monkeys,and humans by reducing the net aqueous inflow.	Majeed *et al.* (2015)
Asthma	Forskolin the active constituent of *C.forskholii* was studied as bronchodilator for its potential use in asthm a. It blocked bronchospasm and bronchitis in guinea pigs caused by histamine and leukotriene C-4	Bivalacqua *et al* (2000)
Antiobesity	The antiobesity effects of were investigated in ovariectomized rats and the administration of *C. forskholii* extracts reduced body weight, food intake and fat accumulation in those rats.	Han *et al.* (2005)
Antiplatelet	The antiobesity effects of were investigated in ovariectomized rats and the administration of *C. forskholii* extracts reduced body weight, food intake and fat accumulation in those rats	Kamohara (2016)
Antimicrobial	A study on antimicrobial efficacy of *C. forskholii* against Staphylococcus aureus shown both bacteriostatic and bacteriocidal activity at Minimum Inhibitory Concentration (MIC) values ranging from 60 to 300µg/ml.	Snowden *et al.* (2014)
Anti-inflammatory	Forskolin administered through i.p. route significantly inhibits Carrageenan-induced paw edema in a dose -dependent manner in rats. Similar effects were also observed in adjuvant induced polyarthritis and Croton oil-induced ear inflammation in rats.	Menon and Latha (2011)
Antihypertensive	Studies shown that forskolin increases the heart rate, and lowers the blood pressure in dogs and cats and also in spontaneously hypertensive and renal hypertensive rats. Another study reports that coleonol (distereoisomer of forskolin) isolated from a 50% ethanol extract of *C. forskholii* have lowered the blood pressure of anesthetized cats and rats, as well as spontaneously hypertensive rats, due to the relaxation o f the vascular smooth muscle.	Moser *et al.* (2023) Bhowal and Mehta, 2017
Antimetasatic and Antiproliferative	Forskolin was proved as a potent inhibitor of cancer metastasis in mice injected with malignant cells. As little as 82mcg administered to mice inhibited metastatsis by 70%. 13-epi-sclareol showed antiproliferative activity in breast and uterine cancer cells *in vitro.* Coleon C when investigated on eight human tumor cell li nes for its antiproliferative activity. It was observed that the A375 was the most sensitive of all the cell lines and it was concluded that coleon C could effectively inhibit tumour cell proliferation and growth by inducing apoptosis with low toxicity. Barbatusin is reported to inhibit Lewis lung carcinoma and lymphocytic leukemia P 388 in mice.	Xue *et al.* (2020) Sashidhara *et al.* (2007) Xing *et al*., (2008)
Antidepressant	Forskolin indicates a strong antidepressant when studied using the forced swimming method in rats. Forskolin (0.01 -0.1 mg/kg) dose-dependently decreased ratings of immobility, with effects similar to those of amitriptyline treatment. The maximum effects of forskolin were observed at 0.01 mg/kg dose which is 150 more times potent than that (15 mg/kg) of amitriptyline.	Owona *et al.* (2016)
Antidyspeptic	The aqueous extract of *C. forskholii* decreases gastric secretion indicating antidyspeptic activity, and protects agai nst stress induced gastric ulcers.	Pullaiah (2022)

Antioxidant	Studies were carried out for the antioxidant properties of *C. forskholii* and it was observed that the t ubers possessed significant potential of both enzymatic and non -enzymatic antioxidants that could protect against oxidant and free radical injuries, in addition to having their medicinal properties.	Khatun *et al.* (2011b)
Antidiabetic	Forskolin stimulates glucose-induced insulin secretion *in vitro* . This appears to reflect a general stimulatory influence of forskolin on adenylate cyclase activity, obviating its specific suitability as an antidiabetic treatment.	Klemen *et al.* (2023)
Antimycotic	Antifungal studies were carried out on different fungi like *Aspergillus flavus, Trichoderma rubrum,* and *Microsporum gypseum* and it was observed that chloroform extract shows maximum inhibitory activity.	Sonia *et al.* (2011)
Hepatoprotective	Forskolin and 1, 9-dideoxyforskolin are efficacious agonist of the pregnane X receptor (PXR, NR1I2) and thus there is activation of PXR which mediates the hepatoprotective effect.	Jeff *et al.* (2006)
Hypothyroidism	Forskolin and 1, 9-dideoxyforskolin are efficacious agonist of the pregnane X receptor (PXR, NR1I2) and thus there is activation of PXR which mediates the hepatoprotective effect.	Staudinger *et al.* (2006)
Immune System Enhancement	Forskolin exhibits potent imm une system enhancement (primarily through activation of macrophages and lymphocytes) in several model.	Pavlikova and Arukwe (2011)
Psoriasis	Clinical studies were conducted in four patients with psoriasis and it was observed when they were given forskolin, there were improvement in psoriatic symptoms. The abili ty of forskolin to regulate cAMP levels in skin cells has been shown to have therapeutic benefit for sufferers of psoriasis.	Ohtsuki *et al.* (2017)
Relaxative effects	forskoditerpenosides A and B isolated from the ethanol extract of the whole plant of *C. forskholii* showed relaxative effects on isolated guinea pig tracheal spirals in vitro.	Shan *et al.* (2006)
Urinary Tract Infection (UTI)	Forskolin when injected directly into t he bladder or administered intravenously to type 1 fimbriated uropathogenic *Escherichia coli* infected mice, it induced exocytosis of bladder epithelial cells fusiform vesicles in which E. coli is incorporated and thus reduced the number of intracellular *E. coli* and exposed the bacteria to the antibiotics.	Bishop *et al.* (2007)
Vasculogenic properties	Investigations on forskolin for vasculogenic impotence were carried out and it was observed that forskolin can be used as an addition to a standard 3 -agent pha rmacotherapy for erectile dysfunction. Other in vivo and *in vitro* studies were carried out which elicits a possible role of forskolin in treating this condition.	Xue *et al.* (2020)
Cardiovascular action	The most potent water soluble forskolin derivative so far produced is 6 -(3-dimethylaminopropionyl)forskolin hydrochloride or NKH477. It is published a report on how continuous infusion of NKH477 successfully weaned a neonate from cardiopulmonary bypass, after correction of a complex congenital cardiac anomaly. NKH477 [Colforsin daropate HCl (Adehl® Inj.)] is available in Japan, where it is used in the treatment of heart failure	Paul *et al.* (2013) Iranami et al (2002)

Fig.1: (A) Healthy *Coleus forskohlii* in the field **(B)** Tuberous roots of *C. forskohlii*

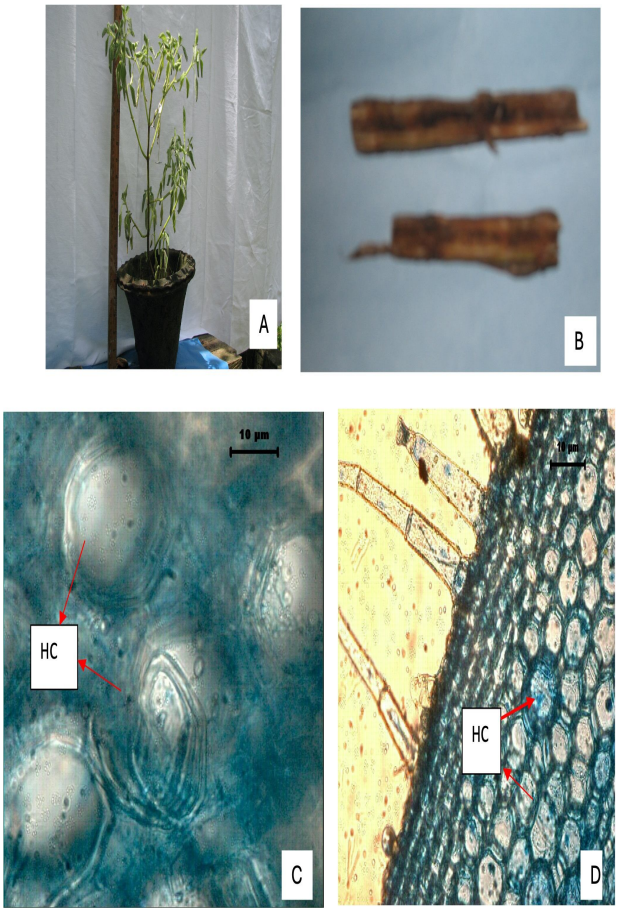

Fig.2.(A) Wilt disease of *C.forskohlii* **(B)** Browning of stem tissue in wilted *Coleus* plant **(C)** Hyphal clogging (HC) of the pathogen in the vessels and (**D**) In the cortical cells of a wilted *Coleus* plant, Bar=10µm.

Shukla *et al*. (2017) isolated and reported 1-acetyl forskolin, Isoforskolin or coleonol B, and 1, 6-di-Oacetylforskolin. Shan *et al.* (2007) extracted two diterpene glycosides namely forskoditerpenoside A and forskoditerpenoside B from the ethanol extract of the whole plant of *C. forskohlii.* Later, three new minor labdane diterpene glycosides, forskoditerpenoside C, forskoditerpenoside D, forskoditerpenoside E and a nobel labdane diterpene forskoditerpene A were isolated from the ethanolic extract of the whole plant of *C. forskholii* (Shan *et al.* 2008). Coleonol E and Coleonol F are reported from Indian species (Etsassala *et al*., 2021). Coleol and coleosol were isolated from the roots of *C. forskohlii* (Bhowal and Mehta, 2017). In the Kenyan species coleon O and plectrin were reported from their leaves (Etsassala *et al.* 2021). A study on whole plant extract conducted by Shan and Kong (2006) reports the presence of 3-hydroxy forskolin and 3-hydroxyisoforskolin. The chemical compounds isolated from *Coleus forskohlii* are given in Table1.

Biogenesis

Forskolin is biosynthesized from acetate-mevalonate pathway. In the postulated biosynthetic pathway 8,13- epoxy-labd-14-en-11-one is the first mono oxygenated labdane type diterpene to be formed on biosynthetic pathway

leading from the labdane diterpene skeleton, subsequent addition of oxygen gives 1,9-dideoxy forskolin, 9-deoxyforskolin and forskolin with other terpenes. Forskolin is the last compound to be formed in the biogenetic sequence. Molecular cloning and functional expression of geranylgeranyl pyrophosphate synthase (GGPP) from *C. forskohlii* have been demonstrated. Engprasert *et al.* (2004) proposed that forskolin was synthesised from Isopentenyl diphosphate (IPP), a common biosynthetic precursor via a non-mevalonate pathway. GGPP synthase is thought to be involved in the biosynthesis of forskolin, which is primarily synthesized in the leaves and subsequently accumulates in the stems and roots.

Mechanism of action

Forskolin being the major chemical constituent of the tuber, herbal preparations of it act on various multiple pharmacologic mechanisms. The blood pressure lowering antispasmodic effects of extracts of *C. forskohlii* roots based on the extensive screening of Indian plants for biological activity at the Central Drug Research Institute, Lucknow (Lokesh et al. 2018). It was found that the methanol extracted from the root tuber is helpful in lowering blood pressure and positive inotropic activities in animal models. Singh and compared physico-chemical properties of coleonol, forskolin and their derivatives and reported that the two compounds do not have the same structure and are stereoisomers that is, they differed only in the configuration of the acetate (-OAc) group at carbon 7, in forskolin it was â while in colenol it was á (Lokesh *et al.* 2018). The pharmacological studies of forskolin and coleonol indicated that they had identical properties (Sharma and Vasundhara, 2011). The principle mechanism by which forskolin exerts its hypotensive activity is by stimulation of adenylate cyclase and thereby increasing cellular concentrations of the second messenger cyclic AMP (cAMP) (Kavitha *et al.* 2010). The mechanisms of interaction of forskolin were studied in detail (Salehi *et al.* 2019). Forskolin directly activates almost all hormonesensitive adenylate cyclases in intact cells, tissues and even solubilised preparation of adenylate cyclase (Sharma and Vasundhara, 2011). The unique feature of this activation is that the site of action for forskolin is the catalytic subunit of the enzyme or a closely associated protein (Chao *et al.* 2022). Of the 9 types of adenylate cyclase in humans, forskolin can activate all except type IX, which is found in spermatozoa (Iwatsubo *et al.* 2003). Stimulation of adenylate cyclase is thought to be the mechanism by which forskolin relaxes a variety of smooth muscles. This action of forskolin proved the potential use of the molecule, not only as an invaluable research tool for understanding cyclic AMP dependent physiological processes, but also as a potential therapeutic agent for diseases like cardiac insufficiency, hypertension, glaucoma, thrombosis, asthma and metastatic condition (Lokesh *et al.* 2018). Forskolin, by increasing cAMP level in turn, inhibits basophil and mast cell degranulation and histamine release, (Sapio *et al.* 2016) lowers blood pressure (Madhavi *et al.* 2011) and intraocular pressure, (Vetrugno *et al.* 2012) inhibits platelet aggregation, (Clark *et al.* 2019) promotes vasodilation, (Xue *et al.* 2020) bronchodilation, (Salehi *et al.* 2019) and thyroid hormone secretion and stimulates lipolysis in fat cells (Henderson *et al.* 2005).

Uses in ayurved and other uses

In traditional Ayurvedic systems of medicine, *C. forskohlii* has been used for treating heart diseases, abdominal colic, respiratory disorder, insomnia, convulsions, asthma, bronchitis, intestinal disorders, burning sensation, constipation, epilepsy and angina (Lokesh *et al.* 2018). The roots are also used in treatment of worms and to alleviate burning in festering boils. When mixed with mustard oil, the root extract is applied to treat eczema and skin infections. Traditionally, the roots have been used as condiments in pickles, for preparation of pickles and also for medicinal purposes by the ayurvedic schools of medicines (Lokesh *et al.* 2018). Root juice is given to children suffering from constipation (Kanne *et al.* 2015). Kothas, the native tribes of Trichigadi in Nilgiri, South India consider the decoction of tuberous roots as tonic (Bhowal and Mehta, 2017).

The plant is also used for veterinary purposes (Wynn and Fougère, 2009). Forskolin is also used in the preparation of medicines preventing hair

greying and restoring grey hair to its normal colour. Though grouped as a medicinal plant, it also contains essential oil in tubers, which has very attractive and delicate odour with spicy note (Lokesh *et al.* 2018). Essential oil has potential uses in food flavouring industry and can be used as an antimicrobial agent (Lunz and Stappen, 2021). The roots yield an essential oil which has antimicrobial properties and is therefore, put to use in cosmetics.

Pharmacological properties

C. forskohlii has been used as a potential drug for hypertension, congestive cardiac failure, respiratory disorders, painful urination, colic, convulsions and insomnia (Kanne *et al*. 2015). It has been shown to have anti-inflammatory property as well (Menon and Latha, 2011). Clinical studies of the plant and the forskolin constituent support these traditional uses but also indicate that it may have therapeutic benefit in asthma, angina, psoriasis, and prevention of cancer metastases. The pharmacological studies carried out so far on *C. forskohlii* are given in Table 2.

Diseases of C. forskohlii

Like other crop plants *C. forskohlii* plant is susceptible to many diseases like leaf spots, leaf blight, root rot and wilt and root knot. Of these root- rot/wilt and root knot are the major diseases, affecting complete damage to tubers.

Leaf spot disease

Leaf spot lesions are initially brown and punctiform, becoming elliptic, subcircular to irregular and pale brown in colour. They were well delimited with a dark brown rim (up to 5 mm in diameter), distributed on the lamina, sometimes coalescing and leading to extensive necrosis and yellowing. A dematiaceous fungus (*Corynespora cassiicola*) was consistently found sporulating in the centre of the lesions (Fernandes and Barreto, 2003). Leaf spot caused by *Botryodiplodia theobromae* has also been reported (Ramprasad, 2005).

Blight Disease

Blight disease is common during monsoons or during period of high humidity. Symptoms include water soaked leaf spots that increased rapidly in size becoming light tan to brown and later necrotic. Severe infection results in defoliation and death of the plants. *Rhizoctonia solani* has been reported to cause the leaf blight of *C. forskohlii* (Singh *et al.* 2011). Ramprasad (2005) reported stem blight caused *Phytophthora nicotianae* var. *nicotianae*.

Root-rot/wilt disease

Root rot/ wilt is the major disease of *C. forskohlii* causing heavy losses (>50%) in south India. Root rot is a disease caused by a variety of fungi/ bacterium species that love standing water. Disease show various symptoms like yellowing and wilting of leaves, brown to black roots, oozing, putrefaction and decaying of roots and unhealthy plants. The disease has been reported to be caused by the following: The fungal pathogen causing the disease has been identified as *Fusarium chlamydosporum* (Singh *et al.* 2009). The symptoms include gradual yellowing marginal necrosis and withering of leaves followed by loss in vigour and premature death. Such plants show discoloration of roots and complete decaying of tap and lateral root system. The bark of such plants is easily peeled off. Such affected plants are finally killed due to severe root and collar rots. The infected tubers show rotting and emit bad odour. *Fusarium solani* causing root-rot of *C. forskohlii* has also been reported by Bhattacharya and Bhattacharya (2008). *Ralstonia solanacearum* was reported to be causing vascular wilt of *C. barbatus* (Coelho and Assis, 2002; Chandrashekara and Prasannakumar 2010). The symptoms include initially brown later on becomes black roots due to decaying, oozing and putrefaction of roots. Root-rot caused by *Macrophomina phaseolina* has also been reported in *C. forskohlii*. The symptoms observed are yellowing and drooping of the leaves, blackening of the stem, rotting of the roots and basal stem and peeling of stem bark and root epidermis. The presence of black sclerotia is observed on the rotted portion (Kamalakannan *et al.* 2006).

The most characteristic symptoms of wilt disease of *Coleus* are found in the stem and roots of the infected plants (Fig. 2A). The fungus penetrates

the root system and establishes itself. In the outer surface of the roots, white cottony mycelia remain adhered just like a mantle. At the upper portion of the root a blackish spot develops, it gradually girdles the stem where the colour gradually turns greyish and progresses up and down. At first, partial wilting occurs but later the shoots loose their turgidity and droop down because of the disturbances occurred due to infection in the vascular system of the roots and stems (Fig.2B). Leaves become yellowish, later turn greyish and ultimately droop. At this stage, decay of the roots started. In cross section of the stem, clogging of vascular system by the mycelia of wilt fungus generally happens (Fig.2 C and D).

Root knot disease

The disease is caused by microscopic, parasitic, soilinhabiting nematodes also known as eelworms, belonging to the genus *Meloidogyne*. These nematodes burrow into the soft tissues of root tips and young roots and cause nearby root cells to divide and enlarge. Four different types of *Meloidogyne* species are common: *M. javanica, M. incognita, M. hapla* and *M. arenaria.* Affected crops may show slow/stunted growth, yellowing of leaves, wilting of the plant despite adequate soil water content and finally leading to collapse of individual plants. Severely infested seedlings produce few roots and usually die rapidly. Heavy infection of older plants causes the plant to wilt unexpectedly and die off early. Swelling or galls develop on the roots of the infected plant, as the result of nematode induced expansion of root cells. The galls vary in size from slight thickenings to lumps 5 to 10 cm across. All root knot galls damage the vascular tissues of roots and thus interfere with normal movement of water and nutrients. They also increase the susceptibility of the root system to invasion by disease causing fungi and bacteria. Root knot disease in *C. forskohlii* has been reported to be caused by *Meloidogyne incognita* and *Meloidogyne arenaria. Meloidogyne incognita* has been reported to cause a yield reduction of upto 86% (Senthamari *et al.* 2006), while severe looses also occur in *C. forskohli* because of *Meloidogyne arenaria* infestations (Bhandari *et al.* 2007).

Complex disease

Collar rot complex of *C. forskohlii* involving *F.chlaydosporum* and *Rhizoctonia bataticola* (*Macrphomonia phaseolina*) as reported by Kulkarni *et al.* (2007). Complex disease of *C. forskohlii* has also been reported involving both fungal and nematode pathogens (Senthmarai *et al*. 2008).

CONCLUSION

C. forskohlii is a medicinal plant containing a large number of bioactive compounds. During the review study I found that herbal medicine are most effective for various diseases. Herbal products have low toxic effects than conventional preparation. Herbal products helps in natural healing there are future scope for different preparation using Herbal Ingridents. Medicinal Plants provide basic raw material for medicine which have high demand now a day's. *C. forskohlii* is an effective to various disorders or diseases like glaucoma, asthma, urinary tract infection, etc. The roots contain a wide spectrum of diterpenoid compounds. Many of them have cardiovascular and antiproliferative actions. *C. forskohlii* is the only source of forskolin, the analogues of which are of immense value in the treatment of cardiovascular diseases. And there is future scope to prepare a formulation using this plant as its high medicinal value. Cultivation of this herb is therefore, gaining prominence. The spreading of diseases on this medicinal plant may causes a set back to the industry associated with the formulation of its medicinal products. So, this review work may encourage other researcher to study these diseases further and their proper management.

DECLERATION CONFLICT OF INTEREST

The author has no conflict of interest in publishing the article

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