Indian Journal of Natural Products and Resources
Vol. 15(3), September 2024, pp 347-356
DOI: 10.56042/ijnpr.v15i3.6285

Cordia macleodii (Griff.) Hook. f. & Thomson (Boraginaceae) – A comprehensive review

R. L. S. Sikarwar* and B. A. Chopade

A. K. S. University, Sherganj, Satna, Madhya Pradesh 485001, India

Received 18 October 2023; revised received 03 June 2024; accepted 25 June 2024

Cordia macleodii (Griff.) Hook.f. & Thomson belongs to the family Boraginaceae of flowering plants and is locally known as Dahiman or Dahipalash. It is a highly medicinal and critically endangered plant distributed mainly in dry deciduous forests of India and used by tribal communities of different states of India for making various agricultural and household implements and treating various ailments and diseases. The presence of valuable phytochemicals such as glycosides, flavonoids, saponins, phenols, terpenoids, and fixed oils made this plant more promising for developing modern herbal drugs. These bioactive compounds have been isolated from tree bark, stem andleaves. The plant possesses various pharmacological activities such as antimicrobial, hepato-protective, antioxidant, antivenom, wound-healing, antidepressant, and antihypertensive, with great significance in pharmaceutical industries for developing new herbal drugs. The present review gives an account of taxonomy, ethnobotany, pharmacognosy, phytochemical constituents, pharmacological activities, and conservation status.

Keywords: Chemical constituents, *Cordia macleodii*, Ethnomedicinal uses, Pharmacognosy, Pharmacological activities

IPC code; Int. cl. (2021.01)− A61K 36/00, A61K 36/30

Introduction

The genus *Cordia* L. belongs to the family Boraginaceae of flowering plants. It contains about 300 species of shrubs and trees that are distributed worldwide, mostly in warmer regions[1,2]. About 16 species of the genus *Cordia* have been reported from India[3,4]. It is endemic to the Indian subcontinent and widely used by several tribal communities of different states of India to treat various ailments and diseases and make household and agricultural implements. *Cordia macleodii* is declining fast from natural habitats due to over-exploitation and habitat degradation. A lot of work has been done on different aspects of this valuable plant, including ethnobotany, phytochemistry, pharmacognosy, and pharmacological activities. Therefore, a review study of *C. macleodii* has been undertaken.

Vernacular names

Vernacular names of the *C. macleodii* in different languages are given in Table 1.

The tree's vernacular name, Sitapatra (Sita's letter, in Sanskrit and Bengali), comes from the mythological princess Sita, who wrote letters (Patra) to her husband, Lord Rama, on the leaf of this tree. Scratches on the upper surface of the leaf elicit permanent black marks[5].

Taxonomy

Kingdom: Plantae, Phylum: Streptophyta, Class: Equisetopsida, Subclass: Magnoliidae, Order: Boraginales, Family: Boraginaceae, Genus: Cordia, Species: *Cordia macleodii* (Griff.) Hook.f. & Thomson.

The generic name *Cordia* L. commemorates Enricius Cordus (1443-1543) and his son Valerius Cordus (1515-1544), the German botanists[6]. The species name *macleodii* was given by William

Table 1 — Vernacular names in different languages

S. No.	Language	Vernacular name
1	Sanskrit	Dadhimanth, Sitapatra
2	Hindi	Dahiman, Dahipalash, Dadhipalash, Dahipalas, Gadhapalash, Dhengan, Gonni, Kuhman, Bohad, Daiwas, Dahichir
3	Marathi	Bhoti, Dhaiwan, Daivas, Dhaim
4	Tamil	Palandekku
5	Telgu	Botuku, Peddabotuku, Iriki
6	Kannad	Bilichlle, Doddachelle
7	Oriya	Bhoto, Bohurolo, Baurlo, Sambarsinga, Shikari, Panki
8	Bengali	Sitapatra

*Correspondent author
Email: sikarwarrls@gmail.com

Griffith in 1843 in honour of Mr D. Macleod, Principal Assistant to the Commissioner of Jubbulpore (Jabalpur), who sent the specimen to him of this plant from (Jubbulpore) Jabalpur[7].

It was originally described by Griffith (1843) as *Hemigymnia macleodii* Griff., based on a plant specimen sent to him by his friend D. Macleod from Jubbulpore (Jabalpur, Madhya Pradesh), where it was growing abundantly[8].

C. macleodii (Griff.) Hook.f. & Thomson J. Linn. Bot. Soc. 2: 128. 1858. C.B. Clarke Hook.f. Fl. Brit. India 4: 139.1883. *Hemigymnia macleodii* Griff. Calc. J. Nat. Hist. 3: 363. 1843. *Lithocardium macleodii* (Griff.) Kuntze Revis Ge. Pl. 2:977. 1891. *Gerascanthus macleodii* (Griff.) Borhidi in Acta Bot. Hung. 34: 405. 1988.

It is a medium-sized deciduous tree with white hairy branches. Leaves alternate, broadly ovate, or orbicular, 8-18 x 7-17 cm, obtuse at apex, cordate or rounded at base, impressed rugose above, densely grey or tawny woolly tomentose beneath; petiole stout 3-5 cm long, tomentose. Flowers white, fragrant, polygamous, in terminal and axillary, dense, tomentose, paniculate cymes. Calyx 6 lobed, lobes as long as or longer than the tube, in fruits accrescent; Corolla funnel-shaped; stamens 4-8, usually hairy at base. Drupe ovoid, yellowish, non-edible, supported by copular tomentose ribbed calyx[9] (Fig. 1). Flowering & Fruiting: April to June.

Distribution

The native range of this species is Uttarakhand, and it extends to North and Central India. It is a tree that grows primarily in a seasonally dry tropical biome[10].

Fig. 1 — *Cordia macleodii* (Griff.) Hook.f. & Thomson in Natural Habitat with flowers and Fruits.

C. macleodii is widely distributed in the moist and dry deciduous forests of Bihar, Chhattisgarh, Jharkhand, Gujarat, Karnataka, Kerala, Maharashtra, Madhya Pradesh, Odisha, Rajasthan, Tamil Nadu,Uttarakhand, and West Bengal[11].

Ethnobotanical uses

An ethnobotanical study of the plant was carried out by different workers among the various tribal communities of different states of India. In Madhya Pradesh, the Kol, Gond, Mawasi, and Baiga tribes use leaves to cure mouth sores, stem bark decoction for blood purification, cure leucorrhea, stomachache, and heart diseases; roasted seed paste with clarified butter, sugar and one glass cow's milk as an aphrodisiac; one-tea spoon bark powder with sugar candy with one glass cow's milk given in leucorrhea, bark paste is applied on the wound of cattle and buffaloes, bark decoction to cure jaundice, the bark is chewed to reduce high blood pressure, a necklace of beads of rosary is made from the wood and worn to cure leukoderma. The tribal people believe that if a stick of plant is kept in hand, it cures skin diseases, reduces blood pressure, and keeps snakes away; if the cattle rub their body with the tree, the wound of cattle is quickly healed. They also believe it is a deity's tree; therefore, they do not use its wood to make doorframes, ploughs, etc. Touching wood with feet is taboo in tribal communities. However, local folk communities prefer the wood of 'Dahiman' for making yokes, axe handles, furniture, carts, turnery, etc. They specially make beds from the Dahiman to ward off the snakes. The axe handle is made from the wood to cure palm sores. A churner is made from the wood. It is believed that the churner of 'Dahiman' increases the quantity of butter[12-15]. In Jharkhand, the Birhore tribe uses fresh leaves on the forehead to treat high fever, and powdered fruit is used to cure dysentery[16]. The Souria Paharias of Santhal Pargana utilise leaves for the colouring of the mouth and for the treatment of fever[17]. In Bargad district of Odisha, the macerated leaves of the plant have been used by the tribal people for checking bleeding from cut and wound injuries. They use the leaves for packaging meat to carry home and found that the blood had coagulated from the minced meat[18]. Its fruits are eaten by tribal communities of Odisha[19]. The Korku tribe of Amravati district, Maharashtra, applied leaf paste on their heads to cure headaches and seeds used for insanity[20]. Tribal people of Raigarh district use bark

for the treatment of jaundice[21], and Akola district uses root bark to cure piles[22]. In Andhra Pradesh, tribal communities of Eastern Ghat utilise stem bark decoction for the treatment of jaundice, fruits eaten, and cots made from wood[23,24]. The Baiga tribe of Chhattisgarh use the plant to treat diseases such as flu, fever, asthma, cough, malaria, wound healing, blood purification and other health problems[25], and other tribes utilise stem for making furniture and agriculture implements[26].

Materials and Methods

The authors have collected all published literature available on *C. macleodii* from various sources such as NIScPR Online Periodicals Repository, Google scholar, ResearchGate, Scopus, Springer data bases etc., and libraries of different institutions of India including CSIR-NBRI, CSIR-CIMAP- Lucknow and Botanical Survey of India, Central Regional Centre, Prayagraj etc.

Pharmacognostic investigations of stem, bark and leaf

It contains various bioactive compounds with significant pharmaceutical uses. According to available literature[27-59], HPTLC, GC/MS, FTIR, and UV-Vis scientific techniques have been applied to isolate many secondary metabolites like alkaloids, tannins, glycosides, flavonoids from the leaves, bark, stem, and flowers of the plant. These bioactive compounds have immense potential against various diseases and are thus an important candidate in drug industries for developing new medicines. Study was carried out on pharmacognostical characters of the stem bark which includes its macroscopic and microscopic characters and preliminary phytochemistry including TLC and HPTLC. Bark shows microscopic characters like cork, cortex, medullary rays, sclerenchyma fibres, phloem, cambium, and crystals. The phytochemical tests show the presence of alkaloids, glycosides, and tannins, and the HPTLC profile shows the presence of 9 spots and 8 spots at 254 and 366 nm, respectively[27].

The total phenolic content and concentration of flavonoids of two different extracts, from the ethanolic extract of *C. macleodii* were determined using spectrophotometric methods. The total phenolic content ranged from 0.65+0.05 and 1.65+0.12 mg/g of dry weight of leaves and bark extract, expressed as gallic acid equivalents. The total flavonoid concentrations varied from 0.985+0.09 and 1.89+0.11 mg/g in bark and leaves extract, expressed as quercetin equivalents. Ethanolic extract of bark and leaves of *C. macleodii* showed the highest phenolic and flavonoid concentrations, respectively[28,29], and with the help of UV-visible and FTIR spectra of Chloroformic extract of leaf confirms the presence of β-carotene, showing potentiality as a dye sensitised solar cell[30].

Computational experiment on phytocompound of the Cordia-1(4 5)-1formy 1-4- dihydroxy-3oxo 3-4 dihydro-2H-pyran-1-ium) has shown efficient docking score and effective binding affinities. Based on this finding, it is suggested that Cordia-1 bioactive molecule can be used for further drug development process. This study will be addressed to further drug processing analysis[31].

Phytochemical investigations

The phytochemical constituents present in any plant are key factors for determining its therapeutic potency. These phytoconstituents are responsible for the various pharmacological activities of plants. The screening of literature based on phytochemical constituents of *C. macleodii* reveals the presence of various constituent groups such as terpenoids, glycosides, tannins, flavonoids, steroids, phenols, alkaloids, resins, amino acids, and carbohydrates[32,33]. The chemical constituents isolated from different parts (wood, bark, leaves, and flowers) are described in Table 2.

Physico-chemical studies of bark revealed that it contains total ash, acid insoluble ash, hexane soluble extractive, alcohol soluble extractive, water soluble extractive, sugar, starch, and tannins. The hexane and chloroform bark extract mainly contains triterpenoids, acetone, methanol, and aqueous bark extract contains reducing sugar, and aqueous bark extract also contains saponins, tannins, glycosides, and alkaloids[34]. Beside acetone, ethyl alcohol, petroleum ether and water extract also contain carbohydrate, flavonoid, and resin. Moreover, the physicochemical analysis of powdered stem bark using HPTLC reveals foreign matters, loss on drying, alcohol soluble extractive, water soluble extractive, total ash and acid in soluble ash in 2.18, 8.40, 7.01, 24.93, 17.07, and 5.86% respectively. Whereas Leaf physicochemical parameters average value of loss on drying at 105°C 5.22%, water-soluble extractive value 12.56%, alcohol soluble extractive value 4.17%, total ash value

Table 2 — List of identified phytochemical constituents and pharmacological activities from various parts of *C. macleodii*

Plant part	Phytochemicals	Pharmacological Activities	References
Leaf	Glycosides, Alkaloids, Flavonoids, Tannin, Fats, Fixed Oils, Terpenoids, Steroids, Phenolics Compound, and Resin	Antihypertensive activity	44,18
		Wound healing activity	45,46
		Antimicrobial activities	33,3 5,47,49,50,51
		Antifungal activity, Antibacterial activity	52
		Antibiofilm activity	52
		Analgesic activity	52
		Acute toxicity activity	53
		Anti-inflammatory activity	53,55
		Hepatoprotective activity	
		Antioxidant activity	
Bark	Flavonoids, Phenolic saponins, Tannins, Glycosides, Alkaloids	Antibacterial activity	48, 49
		Antifungal activity	49
		Hepatoprotective activity	54
		Antivenom activity	56,57,58
		Antioxidant activity	
Stem	Flavonoids, Phenolics, Synthesis of silver nano particles	Antimicrobial activity	39
		Antibacterial activity	47
		Antifungal activity	

13.68%, acid insoluble ash value 3.12%, respectively[35]. Unsaponifiable fraction of petrol-ether bark extract using GC/MS analysis and IR and UV characterisation yielded three compounds: Stigmasterol, Campesterol and Cholest-5-EN -3OL (3 Beta)-Carbonylchlorinated in addition with p-hydroxyphenyl acetic acid and β-sitosterol. UV spectrum studies of bark fraction show the presence of flavonoids. Besides, two other flavonoids apigenin and kaempferol were isolated from methanolic bark extract[36]. Meanwhile, the UV spectrum analysis of a pure fraction of leaf shows the presence of phenolics and ethanolic leaf extract yielded gallic acid (3, 4-dihydroxy-5-methoxybenzoic acid)[37]. The granular activated charcoal prepared from the bark at pH 11.5, 330-minute contact time, 6 mg/L initial metal concentration, 1.4 g adsorbent dose, and 650°C temperature has the potentiality in adsorbing toxic element manganese from wastewater[38]. The study of the stem on the UV-Vis spectrophotometry of silver nitrate colloidal solution of stem extracts with maximum absorption spectrum at 424 and 437.4 nm confirms the presence of silver nanoparticles[39].

Physicochemical studies on leaves suggest that the drug moisture minimises the drying of leaves, inorganic materials in total ash content, acid insoluble ash, along with extractive values that are water and alcohol-soluble[40]. The qualitative analysis of powered, methanolic, petroleum ether and water extract of the leaf shows the presence of glycosides, alkaloids, flavonoids, tannin, fats and fixed oils, terpenoids, steroids, phenolics compound, andresin[41,42].

Pharmacological activities

The pharmacological activities of *C. macleodii* has been studied since many years. The plant has been shown to possess antimicrobial, antioxidant, anti-inflammatory, analgesic, hepatoprotective, and antivenom activities. The plant parts mainly stem, bark, and leave in form of extracts, powder, and decoction either internal or external applicability, shows wider pharmacological activities[32,33,43].

Antihypertensive activity

Hypertension is a serious medicalcondition andcan increase the risk of heart, brain, kidney, and other diseases in hypertension conditions the blood vessels have persistently raised pressure. The leaf samples of Cordia were analysed for antihypertensive activity against the Supagandha (*Rauvolfia serpentina*) powderby selecting 20 patients randomly. The patients were divided into two groups. Where one group was treated with Supagandha (*Rauvolfia serpentina*) powder (3 g twice daily with water for one month) and another with Dadhimanth (*Cordia macleodii*) leaf powder (3-6 g twice daily with water for one month). As a result, Dadhimanth leaf powder showed more effectiveness and benefit from antihypertensive activity compared to Supangandha powder for both diastolic and systolic hypertension[44].

Wound healing activity

Leaves of the Panki (*C. macleodii*) plant heal up wound in acute and chronic stage. An ointment prepared from the leaves has been presented by an allopathic doctor (co-author). Several patients with cut injuries/wounds have been cured in his medical practice. The authors concluded that some antibiotic properties associated with the plant species prevent pus formation in a chronic/active wound, which is supported by previous findings[18].

Clinical evaluation of Shikari (*C. macleodii*) ghrita on vranaropana (wound healing) property reported as a wound healing drug, by the tribal people of Odisha and Madhya Pradesh. An attempt has been made to evaluate the wound-healing properties of the ghrita (cow's ghee) based formulation of its leaf scientifically through an exploratory, open, and controlled clinical study. Twenty patients with classical signs and symptoms of shuddhavrana (fresh wound) were selected irrespective of their age, sex, and religion. They were randomly allotted into two groups; one group was managed with *C. macleodii* ghrita and the control group was treated with Povidone Iodine as a local application for a duration of 21 days. The effect of drug on sign and symptoms was assessed at 7th, 14th and 21st days. Significant changes were observed in discharge, tenderness, wound margin and wound size in *C. macleodii* ghrita treated group while in Povidone Iodine treated group showed highly significant result[45].

The plant leaves exhibit low degree of wound healing capacity. The external application of 100 g dose of plant leaf powder shows wound healing in wistar rats after 29 days with 88% healing capacity. Moreover, the incision wound shows nearly 318 g/100 g body weight tensile strength along with neo- vascularisation in the dead space wounds, presenting weak recovery in tested animalmodel[46].

Antimicrobial activities

Antimicrobial activity of leaves of *C. macleodii* was evaluated against clinically important bacteria, yeast and fungal strains using agar disc diffusion method. The mixture of plant leaf and its ghrita base in different concentrations shows antibacterial activity against gram-negative- *Pseudomonas aeruginosa* and *Escherichia coli*, and gram-positive- *Streptococcus pyogenes* and *Streptococcus aureus* bacteria[33] and water and n-hexane extract of leaf exhibited effective action against gram-positive bacteria *Bacillus subtilis* and fungi *Aspergillus niger* after 12 h[35]. The silver nanoparticles synthesised from plant stem extract showed high degree of antibacterial activity against *S. aureus*, *Citrobacter* sp. and *Klebsiella* sp. With 15.1 mm, 14.0 mm and 11.9 mm zone of inhibition, respectively[47].

Study on ethanolic extract of bark at 100 mg/mL demonstrated significant antibacterial activity against *Comamonas testosteroni* and *Pseudomonas plecoglossicida* with 7 and 9 mm zone of inhibition. Petroleum ether extract of bark exhibited significant inhibition of two gram-positive bacteria *Streptococcus pyogenes* and *Staphylococcus aureus*, and two gram-negative bacteria *P. aeruginosa* and *E. coli*[48].

The antifungal activity of the extracts on three common pathogenic fungi – *A. niger, A. flavus* and *Candida albicans*. The testing was done by the agar plate method. Zones of inhibition of extracts were compared with that of different standard like Ampicillin, Ciprofloxacin, Norfloxacin and Chloramphenicol for antibacterial activity and Nystatin and Griseofulvin for antifungal activity. The extracts showed antibacterial and antifungal activities comparable with that of standard against the organisms tested. The results showed that the inhibition of bacterial growth was more pronounced in *E. coli* and *S. aureus* as compared to the other tested organisms. The extract showed the antifungal activity against *C. albicans* and *A. niger*. They have also investigated the antibacterial and antifungal potential of bark of *C. macleodii*. They have assessed antibacterial potential of methanolic extracts of the bark against two Gram negative bacteria – *E. coli*, and *P. aeruginosa* and two Gram positive bacteria – *Staphylococcus pyogenes* and *S. aureus*[49].

The antibacterial activity of its leaves, along with its ghrita base preparation against medically important human pathogenic bacteria (two gram positive- *S. aureus, S. pyogenes*, two gram negative- *E. coli,* and *P. aeruginosa*) and fungal strains- *A. niger,* and *C. albicans*, at different concentrations (5, 25, 50, 100, 250 µg/mL), using agar disc diffusion method. The zone of inhibition of these samples was compared withthat of different standards (Ampicillin, Ciprofloxacin, Norfloxacin and Chloramphenicol for antibacterial activity and Nystatin and Griseofulvin for antifungal activity). Only ghrita showed more effective result, at different concentration, in comparison to leave water extract and ghrita base formulation[50].

Preliminary analysis of methanolic extract of *C. macleodii* leaf revealed the existence of various flavonoids including tiliroside. *In vitro* antimicrobial assay of methanolic extract and bioactive compound (Tiliroside) showed antibacterial and antibiofilm activity against the MDR pathogen. The MIC value of methanolic leaf extract and tiliroside was found to be 5 per cent and 50 mM respectively. Methanolic extract of *C. macleodii* leaf, as well as tiliroside at sub-MIC value, significantly mitigated the biofilm formation. *In silico* molecular docking analysis of tiliroside against the targeted protein was also determined to predict the possible binding site. Transcriptomic analysis determined the significance of tiliroside in the reduced expression of certain genes (bssS and metE), which are involved in biofilm formation in *Klebsiella pneumoniae*. Overall, the methanolic extract of *C. macleodii* leaf with varying degree of antimicrobial potency might be used as potent alternative to conventional antibiotics to combat MDR mediated infections[51].

Analgesic activity and acute toxicity

The extracts of *C. macleodii* leaves were evaluated for analgesic activity using hot plate test in mice at different time intervals in hot plate analgesiometer study. The extracts were found to have significant analgesic activity as compared to the reference standard Pentazocine. The alcoholic extract of *C. macleodii* bark was used for the acute toxicity and study was carried out at 2 g/kg oral dose. For that the albino Nulliparous and non-pregnant female were used and observed continuously for 24 h for behavioral, neurological, and autonomic profiles. The result shows that the oral administration of the *C. macleodii* did not produce toxic effect up to 2 g/kg in oral dose[52].

Anti-inflammatory activity

The extracts of *C. macleodii* leaves were also evaluated for anti-inflammatory activity by carrageenan induced rat paw oedema method. *C. macleodii* extracts inhibited carrageenan induced oedema when compared with the control group. At 0.5 h, the mean increase in paw volume in the group treated with *C. macleodii* extract was 0.252±0.012 which at 5 h got significantly reduced to 0.102±0.004. The ethanolic extracts demonstrated significant anti-inflammatory activity[52].

Hepatoprotective activity

Ethanolic extract of *C. macleodii* leaves was evaluated for hepatoprotective activity by carbon tetrachloride (CCl_4) induced liver damage model in rats. CCl_4 produced a significant increase in levels of serum glutamate pyruvate transaminase (GPT), serum glutamate oxaloacetate transaminase (GOT), Alkaline Phosphatase (ALP) and total bilirubin. Pretreatment of the rats with ethanolic extract of *C. macleodii* (100, 200 and 400 mg/kg po) inhibited the increase in levels of GPT, GOT, ALP and total bilirubin and the inhibition was comparable with Silymarin (100 mg/kg po). The study revealed that *C. macleodii* leaves have significant radical scavenging and hepatoprotective activities[53].

The hepatoprotective activity of aqueous and ethanolic extract of bark in ethanol and CCl4 induced hepatotoxicity in male Wistar rats was evaluated. In both the cases, the extract reduced level of Serum glutamic Pyruvate transaminase (SGPT) enzyme activity in liver. Further, the extract exhibited a significant reduction in the level of mitochondrial enzyme serum Glutamic Oxaloacetic Transaminase (SGOT) and Alkaline phosphatase (ALP), an enzyme obtained from hepatic parenchyma, along with maintaining liver weight[54].

Antioxidant activity

Antioxidant activity of the ethanolic extract of leaves of *C. macleodii* was evaluated by four established *in vitro* methods viz. 1, 1-diphenyl-2-picryl hydroxyl (DPPH) radical scavenging method, nitric oxide (NO) radical scavenging method, iron chelation method and reducing power method. The extract demonstrated a significantdose-dependent antioxidant activity comparable to that of ascorbic acid. They have reportedleaf ethanolic extract at 800 g/mL dose exhibit maximum inhibition of DPPH and nitric oxide radicals 81.20 and 72.70%, respectively. Further, ethanolic extract in the same dose was found effective in inhibiting reducing power and iron chelation with absorbance mean of 1.53 and 0.433, respectively in animal models[53]. Similarly, the ligand cordia-1, an important phytochemical of the plant, binds with antioxidant enzymes Catalase (CAT), Superoxide dismutase (SOD) and Glutathione peroxidase (GPx) showing scavenging action and has a wider impact on antioxidant activities[55].

The successful extraction of leaf and bark powder with methanol and water was tested for the quantitative determination of total phenolics, total

flavonoids, and various *in vitro* antioxidant activities. Phytochemical screening of crude plant extracts revealed the presence of sterols, alkaloid, flavonoid, phenolic, reducing sugar, glycosides, tannins and saponins. All extracts showed significant total phenolic and flavonoid contents as well as radical scavenging and iron-chelating activities. Among all, methanol leaf extract was observed to have higher antioxidant activity than other extracts. The methanol extracts showed greater antioxidant activity by DPPH scavenging the free radical with IC50 values of 7.63±0.38 µg gm-1 along with scavenged free radical in a concentration depended manner, which is compared to the standard ascorbic acid[56].

Antioxidant activity has also been assessed by *in vitro* method for phytochemical fraction of plant, viz. methanolic and butanol extracts of *C. macleodii* bark. The extracts were evaluated for their phenolic content and antioxidant activity. Phenolic content was measured using Folin-ciocalte reagent & was calculated as Gallic acid equivalents. Antiradical activity of both extracts was measured by 1, 1, diphenyl-2, picrylhydrazyl (DPPH) assay and was compared to ascorbic acid and Ferric reducing power (FRAP) of the extract was also evaluated by Oyaizu *et al.* In the present study three *in vitro* models were used to evaluate antioxidant activity. The first two methods were for direct measurement of radical scavenging activity & remaining one method evaluated the reducing power. The present study revealed the *Cordia macleodii* bark has significant radical scavenging activity[57].

Antivenom activity

The ethanolic extract of *Cordia macleodii* bark significantly inhibited the *Naja*venom induced lethality, hemorrhagic lesion, necrotising lesion, oedema in rats. The extract also antagonised the cardiotoxic and neurotoxic effect of venom in isolated frog heart and rectus abdominus muscle of frog. The result shows that at the dose of 400 and 800 mg/kg ethanolic extract of *C. macleodii* bark significantly inhibited the Naja venom induced lethality, hemorrhagic lesion, necrotising lesion, and oedema in rats. The protective effect of extract of *C. macleodii* against Naja venom poisoning may be due to precipitation of active venom constituents[58].

Antidepressant activity

It is studied that two different doses of extract (100 and 500 mg/kg) *of C. macleodii* were used to investigate the antidepressant effect of this plant in rats. Injection of control did not exhibit significant effect on immobility time and swimming time in the forced swimming test compared to pre injection status. Therefore, all experimental groups were compared with saline as the control group. The administration of fluoxetine (15 mg/kg) as a positive control, in rats significantly decreased immobility time respectively compared to the control group. While extract (100 and 500 mg/kg) significantly decreased immobility time 99.0±1.73, 63.6±5.84, 49.3±3.17 respectively. *C. macleodii* extract and standard drug (fluoxetine 15 mg/kg) induced significant diminution of immobility time in tail suspension test (Control, 164.33±8.37, *C. macleodii* 100 mg/kg and 500 mg/kg 155.6±4.6, 89.6±7.8 and fluoxetine 15 mg/kg, 96.6±6.3, compared with the control. The results obtained were shown in table. The open field test provides simultaneous measure of locomotion, exploration, and anxiety. They concluded on their findings that the doses of *C. macleodii* extract (100 and 500 mg/kg) showed significant antidepressant activity[59].

Threat status and conservation

C. macleodii, an endangered plant species native to India, faces several significant threats that have led to its decline. These threats are primarily anthropogenic encompassing habitat destruction and over-exploitation. Large-scale logging and clearing of forests for agriculture and urbanisation have drastically reduced its habitat. The plant is harvested for its wood and medicinal properties, leading to over-exploitation. Various workers have carried out a detailed study on the threat status as per as per IUCN Red List Criteria 2000 -Version 3.1[60] and reported critically endangered (CR) from Vindhyan region[61] Central India[62] and Chhattisgarh[63], and Endangered (EN) from West Bengal[7] Odisha[64,65], Madhya Pradesh[66], Chhattisgarh[67] Maharashtra[2] and Rajasthan[68].

An effort has been made by first author to propagate *C. macleodii* in herbal garden of Arogyadham, Deendayal Research Institute, Chitrakoot and forest nursery of Forest Research and Extension Circle, Rewa with Dr. P.C. Dubey then Chief Conservator of Forest. The authors have tried to propagate through cuttings method and it was observed that it thrives better without producing roots in polybags for one to two months only and there after die. An effort has also been made to propagate it

through seeds. Fruits have been collected from various localities with the help of forest staff and tribal people and raised the nurseries. The germination percentage was very high but not exactly calculated. Seedlings were distributed to the different forest departments, institutions, and universities for conservation in their respective gardens.

Conservation measures proposed

Cordia macleodii, is facing threats due to habitat loss and degradation. Conservation measures for this species should focus on protecting its natural habitat, promoting sustainable use of forest resources, and raising awareness about its ecological importance. Here are some proposed conservation measures:

- Collect and store seeds of *C. macleodii* in seed banks to preserve its genetic diversity and provide material for future reforestation efforts.
- Cultivate *C. macleodii* in botanic gardens and arboreta to serve as a genetic reservoir and an educational resource for conservation awareness.
- Raise awareness among local communities, stakeholders, and the public about the importance of conserving *C. macleodii* and its habitat.
- Develop guidelines for the sustainable harvesting of this plant, including rotational harvesting and limits on the amount of biomass removed.
- Engage local communities in sustainable forest management practices to reduce over-exploitation and promote the conservation of *C. macleodii*.
- Implement reforestation and afforestation programs in degraded areas to restore the natural habitat and increase the available habitat for the species.
- Implement educational programs in schools and community centers to promote the value of biodiversity and the need to protect native plant species.

Conclusion

C. macleodii is an endangered and endemic plant of India and its different parts (leaf, stem bark, seeds) have been utilised by several tribal communities of different states for the treatment of various ailments and diseases such as cut and wound, jaundice, mouth sores, blood pressure, blood purifier, fever, stomachache, leucorrhea, flue, asthma, mouth sores, piles, snake bite, dysentery, headache, insanity, and skin diseases etc. Pharmacological activities such as wound healing, antimicrobial, antifungal, hepato-protective, antihypertensive, antioxidant, antivenom, and antidepressant have been proved by various scientific investigations from ethnobotanical leads. It can be concluded that this plant has potential medicinal value and is recommended for further scientific exploration to find novel bioactive compounds of pharmaceutical importance for novel drug development for the benefit of human society.

Conflict of interest

The authors state that they have no conflict of interest.

References

1 Mabberley D J, *A portable dictionary of plants, their classification and uses*, (Cambridge University Press), 2008.

2 Shinde R D and Neha G, A brief account of the genus *Cordia* (Boraginaceae) in Maharashtra, *Ann Plant Sci*, 2022, **11**(10), 5455-5464.

3 Santapau H and Henry AN, *A Dictionary of Flowering Plants of India*, (Publication and Information Directorate, CSIR, New Delhi), 1973.

4 Hooker J D, *The Flora of British India*, (Reeve & Co. Ltd., London), 1885, **4**, 148-153.

5 Maity D, Notes on the typification of *Hemigymnia macleodii* Griff. (Boraginaceae), *Pleione*, 2020, **14**(2), 337-340.

6 Nayar M P, *Meaning of Indian Flowering Plant Names*, (Bishen Singh Mahendrapal Singh, Dehradun), 1985.

7 Deb D, Li B, Chattopadhyay S K and Ray A, Identification of an endangered tree as a new record of *Cordia macleodii*, with an update of *Cordia* in West Bengal, India, *Webbia*, 2018, **73**(1), 81-88.

8 Griffith W, Remarks on a few plants from Central India, *Calcutta J Nat Hist*, 1843, **3**, 361–367.

9 Mudgal V, Khanna K K and Hajra P K, *Flora of Madhya Pradesh*, (Botanical Survey of India, Calcutta), **2**, 1997.

10 Plants of the world online, https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:114321-1, (Accessed on 20 October, 2023).

11 Sanjappa M and Sringeswara A N, *Flora of Karnataka, A Checklist* (*Gymnosperms & Angiosperms*), (Karnataka Biodiversity Board), 2000, 1-1002.

12 Dubey P C, Sikarwar R L S and Tiwari A P, Ethnobotany of *Cordia macleodii*, *J Trop Med Plants*, 2007, **8**(2), 78-81.

13 Shukla P, Chaturvedi M, Patel R and Saraswat R, *Medicinal Plant: Cordia macleodii*, (Notion Press, New Delhi), 2020.

14 Tiwari A P, Dubey P C, Sikarwar R L S and Khanna K K, Ethnomedicinal plants used by Baiga tribe of Achanakmar-Amarkantak Biosphere Reserve, Central India, *J Trop Med Plants*, 2012, **13**(2), 167-175.

15 Tiwari A P, Dubey P C and Sikarwar R L S, Documentation of ethnobotanical knowledge among the tribes of Achanakmar-Amarkantak Biosphere Reserve, Central India, *Indian J Nat Prod Resour*, 2014, **5**(4), 345-350.

16 Mairh A K, Mishra P K, Kumar J and Mairh A, Traditional botanical wisdom of Birhore tribes of Jharkhand, *Indian J Tradit Know*, 2010, **9**(3), 467-470.

17 Jha P R and Verma S K, Ethnobotany of Sauria Paharias of Santhal Pargana, Bihar:1-Medicinal plants, *Ethnobotany*, 1996, **8**, 31-35.

18 Sen S K, Panda, H S and Behera L M, *Cordia macleodii* (Ehretiaceae)- A wonderful wound healer from Bargarh District, Orissa, *Ethnobotany*, 2005, **17**, 191-192.

19 Sinha R and Lacra V, Wild tribal food plants of Orissa, *Indian J Tradit Know*, 2005, **4**(3), 246-252.

20 Jagtap S D, Deokule S S and Bhosle S V, Some unique ethnomedicinal uses of plants used by Korku tribe of Amravati district of Maharashtra, India, *J Ethnopharmacol*, 2006, **107**(3), 463-469.

21 Kothari M J and Murthy S, Ethnobotany in human welfare of Raigarh district of Maharashtra state, India, In: *Ethnobotany in Human Welfare*, edited by S K Jain, (Deep Publications, New Delhi), 1996, 400-402.

22 Rothe S P, Ethnomedicinal plants from Katepura Wildlife Sanctuary of Akola district, *Indian J Tradit Know*, 2003, **2**(4), 378-382.

23 Rao T K and Henry A N, *The ethnobotany of Eastern Ghats in Andhra Pradesh*, (India, Botanical Survey of India), 1996.

24 Reddy K N, Pattanaik C, Reddy C S, Murthy E N and Raju V S, Plants in traditional handicrafts in northeastern Andhra Pradesh, *Indian J Tradit Know*, 2008, **7**(1), 162-165.

25 Singh A K, Chandra K K and Shukla A K, A detail review of *Cordia macleodii* Hook.f. Thomson- An ethnobotanical plant, *Chhattisgarh J Sci Technol*, 2020, **17**(2), 26-33.

26 Kala C P, Aboriginal uses and management of ethnobotanical species in deciduous forests of Chhattisgarh state in India, *J Ethnobiol Ethnomed*, 2009, **5**, 1-9.

27 Pandey S, Kushwaha S, Singh S, Chaurasia S and Mishra K, Phytochemical and pharmacological investigation of *Cordia Macleodii* Hook., *World J Pharm Life Sci*, 2020, **6**(12), 216-200.

28 Chaubey O N, Upadhyay R, Tripathi N K and Ranjan A, Phytochemical analysis, phenolics and flavonoids contents of *Cordia macleodii* Hook. leaves and bark, *Int J Phytomed*, 2015a, **7**(2), 231-234.

29 Chaubey O N, Upadhyay R, Tripathi NK and Ranjan A, Isolations & characterisation of compounds from *Cordia macleodii* Hook. Bark & Leaves, *J Appl Chem*, 2016, **9**, 83-85.

30 Wanjari A K, Chaudhari U E, Wanjari N W, Barde M P and Kumre N D, Characterisation of chloroform extract of *Cordia macleodii* leaf for possible application in dye sensitised solar cell, *Int J Eng Sci Res Technol*, 2016, **5**, 705-708.

31 Khan M N, MAPK signaling protein molecular target of *Cordia macleodii* phytochemicals for prevention of chronic diseases, *J Engineering*, 2018, **8**(5), 54-60.

32 Chandrakar J and Dixit A K, *Cordia macleodii* Hook f. Thomson- A potential medicinal plant, *Int J Phytomed*, 2017, **9**, 394-398.

33 Ahirwar K, Kumar A, Nag M and Khan J, Phytopharmacology and applications of *Cordia macleodii*: A miraculous plant, *Int J Biol, Pharm Allied Sci*, 2023, **12**(4), 1519-1535.

34 Kumar V, Tiwari S S, Shukla A N, Srivastava S and Rawat A K S, Pharmacognostic and phytochemical evaluation of *Cordia macleodii*, *J Med Aromat Plant Sci*, 2013, **33**(1), 59-63.

35 Kushwaha J, Singh R and Tripathi M K, Pharmacognostic and phytochemical evaluation of *Cordia macleodii* Hook.f. & Thomson, *Eur J Pharm Med Res*, 2015, **2**, 823-831.

36 Nariya P B, Shukla V J, Nariya M B, Bhatt P V, Pandit C M, *et al.*, Isolation and characterisation of phytosterols from *Cordia macleodii* Hook.f. & Thomson bark by chromatographic and spectroscopic method, *Asian J Pharm Clin Res*, 2014, **7**, 86-88.

37 Nayak P and Kalidass C, Ethnobotany, phytochemistry, pharmacognostic and pharmacological aspects of *Cordia macleodii* Hook.f. & Thomson - A review, *J Non-timber For Prod*, 2016, **23**, 67-71.

38 Wanjari A K, Adsorption of manganese (II) by nitric acid treated granular activated charcoal prepared from *Cordia macleodii* tree bark, *Der Pharma Chemica*, 2016, **8**, 87-94.

39 Dhal S, Panda S S, Rout N C and Dhal N K, Biosynthesis of silver nanoparticles using *Cordia macleodii* (Griff.) Hook.f. & Thomason and its antibacterial activity, *World J Pharm Sci*, 2014, **2**, 1051-1057.

40 Bhide B, Pillai A P G, Shukla V J and Acharya R N, Pharmacognostic evaluation of leaves of *Cordia macleodii* Hook. An ethnomedicinally important plant, *Ayu*, 2011, **32**(2), 254-257.

41 Bhide B, Acharya R N, Nariya P, Pillai A P G and Shukla V J, Pharmacognostic evaluation of *Cordia macleodii* Hook. Stem bark, *Pharmacognosy J*, 2012, **4**, 49-53.

42 Gamit R, Patel A G, Shukla V J, Nariya M B and Acharya R N, Phytochemical analysis of successive extracts of the *Cordia macleodii* Hook. Leaves: A Folklore medicinal plant, *J Ayu Herb Med*, 2018, **4**(1), 14-17.

43 Oza M J and Kulkarni Y A, Traditional uses, phytochemistry and pharmacology of the medicinal species of the genus *Cordia* (Boraginaceae), *J Pharm Pharmacol*, 2017, **69**, 755–789.

44 Dikshit M and Jaiswal M L, A study of antihypertensive action of Dadhimanth (*Cordia macleodii*Hook.f. & Thomson), *J Ayurveda*, 2011, **5**(2), 58-65.

45 Sharma A, Acharya R N, Gupta S K, Dudhamal T S and Mohanto V D, Clinical evaluation of shikari (*Cordia macleodii*) Ghrita on Vrana ropana (wound healing) property, *Ayurpharm Int J Ayur Alli Sci*, 2013a, **2**(4), 98 -104.

46 Bhide B, Ashok B K, Acharya R N and Ravishankar B, Antimicrobial and wound healing activities of *Cordia macleodii* Hook.f. & Thomson Leaves, *Indian J Nat Prod Resour*, 2011, **2**, 198-203.

47 Joshi D K, Patel R, Patel N, Patel D and Pandya C, Antimicrobial evaluation of leaf and stem extract of *Cordia macleodii*, *Open Pharm Sci J*, 2014, **1**, 1-3.

48 Chaubey O N, Upadhyay R, Tripathi N K and Ranjan A, Comparative antimicrobial study of *Cordia macleodii* Hook, *J Pharm Biol Sci*, 2015, **10**, 1-3.

49 Nariya P B, Bhalodia N R, Shukla V J and Nariya M B, *In vitro* evaluation of antimicrobial and antifungal activity of *Cordia macleodii* Hook.f & Thomson Bark, *Int J Pharmtech Res*, 2010, **2**(4), 2522-2526.

50 Sharma A, Acharya R N, Shukla V J and Gupta S K, A comparative antimicrobial study on *Cordia macleodii* Hook. Leaf water extract and its ghrita base formulation, *Int J Ayu Med*, 2013, **4**, 9-16.

51 Patel M, Agrawal A and Patel A K, Antimicrobial efficacy of Tiliroside derived from *Cordia macleodii* against *Klebsiella pneumoniae*, *J Adv Biol Biotech*, 2024, **27**(5), 268-276.

52 Qureshi N N, Kuchekar B S, Logade N A and Haleem M A, Analgesic, anti-inflammatory and acute toxicity studies on

Cordia macleodii and *Leucas ciliata* leaves, *Int J Pharm Tech Res*, 2010, **2**, 1311–1315.

53 Qureshi N N, Kuchekar B S, Logade N A and Haleem M A, Antioxidant and hepatoprotective activity of *Cordia macleodii* leaves, *Saudi Pharm J*, 2009, **17**, 299–302.

54 Shukla P, Patel R and Saraswat R, Evaluation of hepatoprotective activity on the leaves of *Cordia macleodii*, *Pramana Res J*, 2019, **9**, 337-347.

55 Khan M N, Qureshi J, Kaushar H and Pusham N, *Silico* analyses of antioxidant related compounds on selected medicinal plant *Cordia macleodii* enzyme-based targets, *Asian J Biotechnol Bioresource Technol*, 2018, **4**(1), 1-9.

56 Chandrakar J, Dubey, Ojha K, Dehariya R and Dixit A K, *In vitro* antioxidant activity, total phenolic contents and phytochemical evaluation from crude extracts of an endangered plant *Cordia macleodii* Hook.f. Thomson, *J Biomed Pharm Res*, 2019, **8**(3), 111-122.

57 Nariya P B, Shukla V J and Acharya R N, Phytochemical screening and *in vitro* evaluation of free radical scavenging activity of *Cordia macleodii* bark. (Hook.f. & Thomson), *Free Radic Antioxidants*, 2012, **2**(3), 36-40.

58 Soni P and Bodakhe S H, Antivenom potential of ethanolic extract of *Cordia macleodii* bark against Naja venom, *Asian Pac J Trop Biomed*, 2014, **4**(1), S449-S454.

59 Singh R, Ahirwar D K, Sahu C K and Kumar P, Antidepressant activity of Dahiman plant (*Cordia macleodii*), *Int J Pharmaceut Res Appl*, 2021, **6**(6), 701-704.

60 International Union for the Conservation of Nature and Natural Resources Red list: categories and criteria (version 3.1). Cambridge (UK): IUCN/SSC Red List Programme, http://www.iucnredlist.org/apps/redlist/static/categories_criteria_3_1#critical, 2001.

61 Dubey P C, Sikarwar R L S, Khanna K K, Saxena R N and Tiwari A P, Identification and conservation priorities of threatened plants of Vindhyan region, *Bharatiya Vaigyanikavam Audhyogik Anusandhan Patrika*, 2008, **16**(1), 16-35.

62 Sikarwar R L S, Tiwari A P and Dubey P C, *Cordia Macleodii* Hook.f. & Thomson (Cordiaceae) - A critically endangered tree species from central India, *Indian Forester*, 2017, **143**(7), 716-717.

63 Ravikumar K, Begam N S, Kumar A N, Kareem A M and Sureshchandra S T, (eds), *Prioritisation of Medicinal Plant Species of Chhattisgarh for Guiding Conservation Action of the State level through Conservation Assessment and Management Prioritization (ACMP) Workshop Using IUCN Red List Categories and Criteria- Version3.1*, (Chhattisgarh State Biodiversity Board Naya Raipur and Foundation for Revilatization of Local Health Traditions, Bangaluru), 2022.

64 Biswal A K and Nair M V, Threatened plants of Orissa, and priority species for conservation, In: *Special Habitats and Threatened Plants of India*, edited by G S Rawat, (ENVIS, Wildlife Institute of India, Dehradun), 2008, 175-186.

65 Ved D K, Kinhal G A, Ravikumar K, Vijayasankar R, Sumathi R, *et al.*, *Conservation Assessment & Management Prioritization for Medicinal Plants of Orissa* (Regional Plant Research Centre, Bhubaneswar and Foundation for Revitalization of Local Health Traditions, Bangalore), 2008.

66 Khanna K K, Dubey P C, Tiwari A P and Sikarwar R L S, Studies on threat status of tree species of Madhya Pradesh, India, *Indian Forester*, 2021, **147**(2), 137-140.

67 Mishra R P and Naik M L, *Floral Diversity of Chhattisgarh* (Chhattisgarh State Biodiversity Board, Naya Raipur, Chhattisgarh), 2021.

68 Singh J and Meena K L, An extended distribution and conservation of *Cordia macleodii* (Griff) Hook.f. & Thomson in Rajasthan, India, *Asian Resource*, 2018, **7**(4), 9-12.