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REVIEW

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Ethnopharmacology and therapeutic potentials of *Oxalis corniculata*: an in-depth study

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Abstract

Background For centuries, plants have been used in the folk medicine of various cultures for their healing properties. It is amazing how nature has provided us with such powerful remedies. *Oxalis corniculata* (*O. corniculata*) has always been used traditionally for its medicinal attributes. In Asia, this herbaceous plant is used for treating many gastrointestinal disorders, such as diarrhea and dysentery. In African folk medicine, on the other hand, this herb is used for respiratory diseases, skin diseases, and fever.

Main body Scientific research has revealed numerous pharmacological potentials of this plant, including antitumor, antimicrobial, antioxidant, anti-inflammatory, and hepatoprotective properties. In addition, studies have indicated that the extract of this plant protects against oxidative stress, inflammation, and various diseases, including cancer and diabetes. Phytochemical analysis of *O. corniculata* revealed various relevant compounds, including phenolic acids, flavonoids, and alkaloids, which are responsible for its therapeutic properties.

Conclusion The various constituents of this plant have significant ethnomedicinal potential. The plant is a possible source of extracts and chemical compounds with pharmacological activity. In the future, *O. corniculata* could have an effective role in the development of modern drugs. The objective of this review is to summarize the current knowledge on the medicinal potential of *O. corniculata*, including its bioactive compounds, mechanisms of action, and therapeutic applications.

Keywords *Oxalis corniculata*, Traditional uses, Phytoconstituents, Pharmacological activities, Phytochemistry, Creeping wood sorrel

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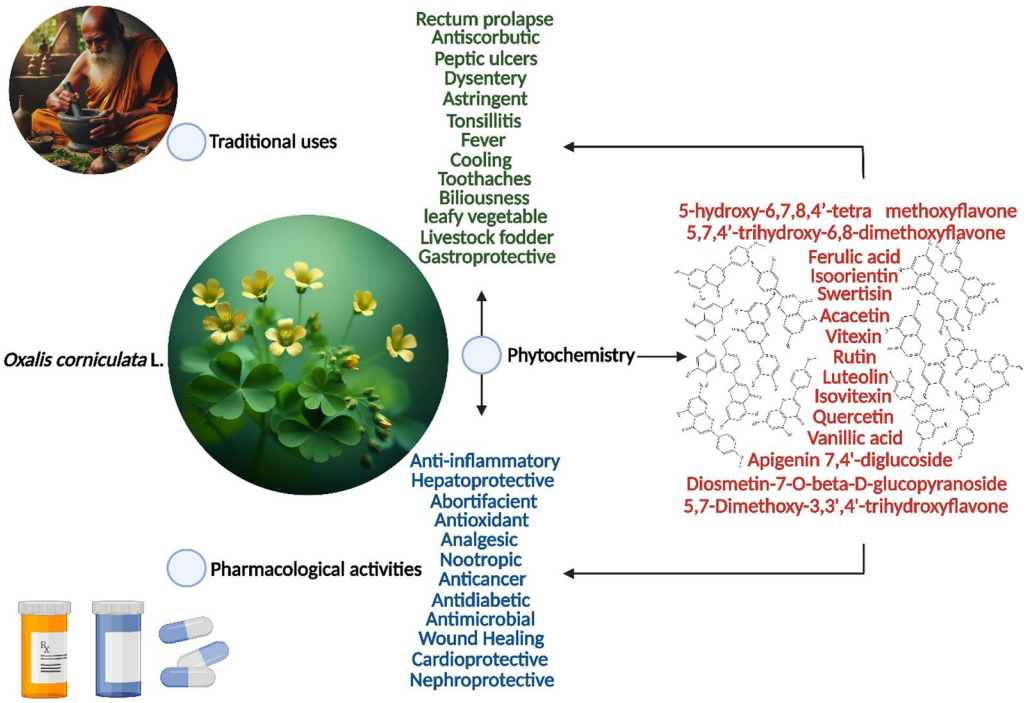
Graphical abstract



1 Background

Oxalis corniculata (*O. corniculata*) is an herbaceous perennial plant that belongs to the Oxalidaceae family [1] and is known for its clover-like leaves and yellow flowers [2]. Taxonomic studies have placed *O. corniculata* in the section Corniculatae of the genus Oxalis. This section includes several other species, and taxonomic revisions have been conducted to better understand the morphological delimitation and relationships within this section [3]. It is a cosmopolitan species which is extensively spread in tropical and temperate areas [4, 5]. In some areas, such as Japan, it is considered a non-native species, as it is thought to have been colonized there in prehistoric times [6]. Its exact origin is still uncertain [7]. The plant is often found in habitats such as roadsides and cultivated fields. Concerning its ecological interactions, the butterfly lays its eggs on the leaves of *O. corniculata*, as these serve as a host for its larvae [8]. The use of this plant has been described in several researches owing to its medicinal possessions and biological activities [9]. It is known to have antioxidant activities and antiradical potential due to its secondary metabolites [10]. The flavonoids found in *O. corniculata* have been researched for their potential health benefits. These compounds have antioxidant properties, can scavenge free radicals, and may aid in the prevention of coronary heart disease [11]. In addition, studies have investigated the antibacterial effect of the plant, particularly against Staphylococcus aureus biofilms, due to the presence of different bioactive constituents such as alkaloids, phenols, and flavonoids [12, 13]. These properties make this plant valuable in the arenas of medicine and pharmacy.

2 Main text

2.1 Methods

This review on *O. corniculata* was compiled using literature from six databases: SciFinder, PubChem, ScienceDirect, Scopus, PubMed, Google Scholar, and Web of Science. The articles included in the review were published in English before August 2023 and focused on the various phytochemicals isolated from distinct parts of *O. corniculata*, the pharmacological activities of the extracts, and their therapeutic uses. The keywords used to retrieve related studies were in vitro systems, virtual screening and animal studies, *O. corniculata*, creeping wood sorrel, ethnopharmacology, phytochemical constituents, traditional medicine, pharmacological properties, and phytochemistry.

2.2 Botany

This review on *O. corniculata* was compiled using literature from six databases: SciFinder, PubChem, ScienceDirect, Scopus, PubMed, Google Scholar, and Web of Science. The articles included in the review were published in English before August 2023. This plant is characterized by a slender stem covered with rounded, tipped hairs [14]. The plant's flower is the smallest compared to other Oxalis species [15]. The species also exhibits an intraspecific polymorphism in leaf color that changes in response to urban heat stress [16]. This is a C3 plant and does not require sodium for its physiological functions [17]. It is considered a weed because it can colonize various environments, including greenhouses [18]. Its distribution in habitats such as roadsides and cultivated fields is further evidence of its weedy character [4]. In addition, its occurrence in various habitats, including fallow land, home gardens, lawns, and public gardens, emphasizes its adaptability to different environmental conditions [19]. The ecological importance of *O. corniculata* also extends to its influence on understorey vegetation in high biodiversity hotspots, where it has been identified as a species capable of expanding into new habitats under the joint effects of environment and awning alterations [20]. The plant is known for its allelopathic effect, hindering the development and progress of various floras [21, 22]. The species is also known for its long flowering period from February to November and its rapid seedling growth compared to other herbaceous species [23].

2.2.1 Synonyms [24, 25]

Sanskrit:	Amlapatrika, Amlalonika, Ambashta, Pūtigandha, Amlika, Amlotaja, Chukrita, Carngeri, Changeri, Cangeri, Chukrika, Shuklika
English:	Indian Sorrel
Gujarati:	Kanjo, Chirbil, Chirmil
Hindi:	Seh, Seh-Patti, Seh-Patti, Tinpatiya; Amili, Khatri-Buti Amrul, Amrulsak, Anboti, Khatari, Khataria, Anboti; Bhilmori, Chalmori; Chuka Tripati, Chukatripati, Cukatripati, Khataro
Kannada:	Putaanipurule, Huli Soppu, Huli Huliche, Hulichikka, Hulihunice, Pullam-Purachi-Sappu, Pullampurachi, Pullampuruchi, Changeri Gida, Majjige Soppu, Majjige Palya, Moorele Huli, Neergoli, Pulibanthunise, Teltuppi, Uppuppina Gida, Huli-Huniche, Pullampurachisappu
Malayalam:	Puliyaral, Pullampurachi, Puliyarila, Poliyarala, Puliyarala
Marathi:	Umbuti, Ambata Chukaa, Bhinsarpati, Aambotee, Ambuti
Oriya:	Duranja, Karanj, Putikaranj
Punjabi:	Papri, Chirbid
Tamil:	Avilo Pattai, Amanitam, Atiyamilaparani, Cenkontai, Cenkottaiccivappi, Civappi5, Kecariyarakkirai, Paliakiri, Kayankaliyatanayaki, Perunkotikkirai, Piliccakkirai, Puli-K-Kirai, Puli-Yarai, Puliakire, Pulicciruki rai, Puliiyarai, Pulikkirai, Pulittacirukirai, Puliyaarai, Atacani, Puliyarai, Puliyarani, Amalakam, Ambal, Kaniyatanayaki, Kentika, Puliyancirukirai, Puliyankirai
Telugu:	Anboti Kura, Anbotikura, Ambotikura, Amboti-Kura, Pulichinta, Pulichintaaku, Pulichintaku, Puli-Chintaku, Pulicintaku, Pullachanchali, Tapazi, Nemalinara
Urdu:	Papri, Khatt-I-Buti

2.2.2 Scientific classification [26]

Kingdom:	Plantae
Division:	Magnoliophyta
Class:	Magnoliopsida
Order:	Oxalidales
Family:	Oxalidaceae
Genus:	Oxalis
Species:	*O. corniculata* (Figs. 1, 2).

Fig. 1 *Oxalis corniculata* leaves, stem and root

Fig. 2 *Oxalis corniculata* flowers and flower buds

2.3 Traditional uses

O. corniculata is used in folk medicine to alleviate various ailments [27]. In India, this plant is considered astringent, antiscorbutic, cooling, and helpful in the treatment of rectal prolapse, dysentery, fever, and biliousness [28]. In rural parts of Pakistan, Jammu & Kashmir, *O. corniculata* is one of the most commonly mentioned species used for the treatment of diabetes [29]. The herb is also recognized in folk medicine schemes viz. Siddha, Unani, and Ayurveda [30]. The plant is widely distributed and has been recorded as a common weed in various regions, including Southeast Asia, Tanzania, Egypt, and India [4, 7, 31, 32]. The plant is native to inhabitants of Southeast Asia and is commonly utilized as a remedy in this region [7]. The plant has acclimatized in Japan and other regions of the world [4]. Its versatility and broad spectrum of biological activity make it a valuable medicinal plant [33]. Traditionally, it is also used for the treatment of complications like diarrhea, ulcers in the stomach, toothache, and tonsillitis [13, 28, 34, 35]. In Tanzania, extracts of the plant are used traditionally for medicines [13]. The plant is also commonly used as medicine in Southeast Asia, indicating a long association with the society in the region [7]. Ethnobotanical studies in the Balasore district of Odisha, India, have shown that this plant is consumed as a leafy vegetable by the local communities and reportedly has ethnomedicinal uses against gastrointestinal ailments, especially gastrointestinal disorders and diarrhea [32]. This herb is also used as livestock feed [36]. The plant has been found to have gastroprotective effects, with significant antisecretory and antiulcer properties, supporting its traditional use as a remedy for peptic ulcers [35]. The traditional use and bioactivity of this plant suggest its potential as a source of dietary supplements and pharmaceuticals [10].

2.4 Pharmacological activities of *Oxalis corniculata*

The leaf and whole plant of *O. corniculata* have been studied for their pharmacological properties. An overview of these activities is presented in Table 1.

2.4.1 Antimicrobial activity

Recent research has revealed that different organic solvents can extract other phytochemicals from plants [71], each with varying antimicrobial activity [72]. The Ethanol and Methanol fractions of *O. corniculata* have shown notable effectiveness in combating *Staphylococcus aureus* [48] and its biofilm formation ability [12], along with some clinical isolates of *Vibrio cholerae* [49] *Staphylococci species*, *Salmonella typhi* [50] and some Multi-Drug Resistant (MDR) strains of *Citrobacter koseri*, *Salmonella typhi*, and *Klebsiella pneumoniae* [51]. *n*-butanol and *n*-hexane soluble fractions also had significant antimicrobial activity for bacterial strains *Shigella dysenteriae*, *Bacillus subtilis, Salmonella typhi*, and strains of fungus, *Fusarium solani*, *Aspergillus flavus,* and *Aspergillus flexneri* [52]. Apart from organic extracts, water extract was also effective against *Candida albicans* [13]. The cream made out of oil in a water-based emulsion and a 20% fresh leaf extract was also effective against bacterial strains of *Escherichia coli* and *Staphylococcus aureus* [53].

2.4.2 Anticancer activity

Several studies have investigated the anticancer potential of *O. corniculata*. One study suggested that the ethanolic extract may cause apoptosis in the MCF7, a breast cancer cell line, by inducing oxidative stress and can exhibit significant anticancer and antitumor activity in Swiss albino mice [41, 42]. The hydroalcoholic extract and ethyl acetate fraction have demonstrated the ability to inhibit the growth of the Hep-G2 cancer cell line; further molecular docking study with phytoconstituents of *O. corniculata* demonstrated that among different compounds, apigenin possesses strong binding energy of − 7.90 kcal/mol compared to the standard drug doxorubicin, which possesses − 7.63 kcal/mol against the epidermal growth factor receptor tyrosine kinase [27]. Another in silico study identified isovitexin as a potential Human Papillomavirus (HPV-18) inhibitor that could help treat cervical cancer [73]. Furthermore, a study in Uganda reported different plants with anticancer activity used locally in Uganda. *O. corniculata* was among the plant species identified for its potential anticancer properties [74]. The exact mechanisms of the anticancer activity of *O. corniculata* have yet to be fully understood. However, it has been suggested that bioactive constituents, such as quassinoids and flavonoids, may contribute to its anticancer effects [75, 76]. Overall, the available studies suggest that *O. corniculata*

Table 1 Pharmacological activities of *Oxalis corniculata* extracts

Sr. no.	Pharmacological activity	Extract	Doses checked	Experimental methods/models	References
1	Abortifacient	Petroleum ether and ethanol	100 to 200 mg/kg b.w	Tween—80, treated abortion model in pregnant rats	[37]
2	Analgesic	Ethanol	80, 200.4, and 400.8 mg/kg b.w.	Acetic acid-induced acute peritonitis model in mice	[38]
		Ethanol	200 to 400 mg/kg b.w.	Acetic acid-induced writhing model in mice	[39]
3	Anthelmintic	Petroleum ether, ethyl acetate, and methanol	100, 200, and 400 mg/mL	Adult earthworm, *Eisenia foetida*, observed for time of paralysis and death	[40]
4	Anticancer	Ethanol	31.25 to 2000 g/mL	MTT assay	[41]
		Ethanol	100 to 400 mg/kg b.w.	Ehrlich ascites carcinoma mice model	[42]
		Ethanol and Water (70:30)	10 to 50 µg/mL	MTT assay	[27]
5	Antidiabetic	Ethanol	200 to 400 mg/kg b.w.	Streptozotocin-induced diabetic model in rats	[43]
		Water	100 mg/mL	Streptozotocin-induced diabetic model in rats	[14]
6	Antidiarrhea	Water and Methanol	160, 320, and 640 mg/kg b.w.	Castor oil-induced diarrhea model in rats	[44]
		Methanol	20 mg/kg b.w.	Anticolonization assay in suckling mice model	[45]
7	Anti-inflammatory	Ethanol	200 to 400 mg/kg b.w.	Acetic acid induce colitis model in rats	[46]
		Petroleum ether, Chloroform, Ethyl acetate, and Methanol	100 mg/kg b.w.	Carrageenan-induced paw edema model in rats	[47]
		Ethanol	80, 200.4, and 400.8 mg/kg b.w.	Acetic acid-induced acute peritonitis model in mice	[38]
8	Antimicrobial	Methanol	15, 20, 30, and 40%	Agar well diffusion assay	[48]
		Ethanol	1 to 0.25%	Biofilm eradication assay	[12]
		Methanol	100 µg/mL	Agar well diffusion assay	[49]
		Ethanol, methanol, and chloroform	512 to 2 µg/mL	Agar disk diffusion assay	[50]
		Methanol	50 mg/mL	Agar well diffusion assay	[51]
		n-Hexane, ethyl acetate, *n*-butanol, and chloroform	2 mg/mL	Agar well diffusion assay	[52]
		Water	20 mg/mL	Agar well diffusion assay	[13]
		Oil, water	2 mg/mL	Agar well diffusion assay	[53]
9	Antioxidant	Methanol, dichloromethane, ethyl acetate, water, and *n*-butanol	0 to 80 µg/mL	Reducing power assay	[54]
		Methanol, *n*-butanol, dichloromethane, ethyl acetate, and water	250 to 500 mg/kg b.w.	CCl4-induced hepatotoxic model in male rats	
		Methanol	125 to 500 mg/kg b.w.	Carrageenan-induced rat paw edema model	[55]
		Methanol	0.2 to 15 mg/mL	Diphenyl-1-picrylhydrazyl (DPPH) Assay	[56]
		Methanol, acetone, and ethanol	1000 to 9000 µg	Nitric oxide radical scavenging assay	[57]
		Water	0 to 800 µg/mL	H2O2-induced oxidative damage model in HEK 293 cells	[58]
			0 to 8 mg/mL	Thermal stress model in *C. elegans*	
		Methanol	100 to 200 mg/kg b.w.	CCl4-induced hepatotoxic model in male rats	[59]

Table 1 (continued)

Sr. no.	Pharmacological activity	Extract	Doses checked	Experimental methods/ models	References
		Water	250 mg/kg b.w.	Isoproterenol-induced oxidative stress model in male rats	[60]
		Methanol	100 to 200 mg/kg b.w.	CCl4-induced hepatotoxic model in male rats	[61]
10	Anti-pyretic	Ethanol	200 to 400 mg/kg b.w.	Brewer's yeast-induced pyrexia model in rats	[39]
11	Antiulcer	Methanol	125 to 500 mg/kg b.w.	Pylorus ligation-induced gastric ulceration in rats	[35]
12	Anxiolytic	Ethanol	100 to 300 mg/kg b.w.	Open-field test, elevated plus-maze test, and anti-fighting effects on mice	[62]
		Ethanol	200 to 400 mg/kg b.w.	Elevated plus maze, open field test, light–dark exploration test, and hole board test on mice	[63]
		Water	10 to 50 mg/mL	Angiotensin converting enzyme (ACE) inhibition assay	[64]
		Methanol	100 to 200 mg/kg b.w.	Forced swimming and tail suspension test on mice	[65]
13	Cardioprotective	Water	250 mg/kg b.w.	Isoproterenol (ISO) induced myocardial infarction model in rats	[60]
14	Hepatoprotective	Water	500 mg/kg b.w.	CCl4-induced hepatotoxic model in female rats	[66]
		Water and Ethanol	200 to 400 mg/kg b.w.	Thioacetamide-induced hepatotoxic model in rats	[67]
15	Nephroprotective	Water	0.5 to 2%	Struvite kidney stones, grown in a gel medium by in vitro single diffusion gel growth technique	[68]
16	Nootropic	Ethanol	250 to 500 mg/kg b.w.	1-methyl-4-phenyl-1, 2, 3, 6-tetrahydropyridine (MPTP) induced behavior alteration model in mice	[69]
17	Wound healing	Petroleum ether and ethanol	300 to 500 mg/kg b.w.	Excision, incision, and dead space wound model in rats	[70]

b.w. body weight

exhibits potential anticancer activity, possibly through its antioxidant properties and induction of apoptosis. The phytochemical composition and biological activities of *O. corniculata* make it a promising candidate for further investigation and development of novel anticancer agents [5]. However, additional research is warranted to elucidate the underlying mechanisms and potential therapeutic applications of *O. corniculata* in cancer treatment.

2.4.3 Antioxidant activity

Free radicals can cause damage to the body, but antioxidants offer protection against this by reducing oxidative stress [10]. The antioxidant activity of *O. corniculata* has been studied from different parts of this plant., including leaves, whole plants, and extracts obtained using other solvents [56]. *O. corniculata* has been found to contain various phytochemicals that possess antioxidant activity, such as glycosides, phytosterols, tannins, flavonoids, and polyphenols [77, 78]. These compounds have been shown to scavenge free radicals and reduce oxidative stress [79–82]. Several studies have supported the antioxidant activity of *O. corniculata*. In one study, the extract from methanol and their sub-fractions of different solvents demonstrated strong antioxidant capabilities when compared to ascorbic acid used as the reference standard [56, 83]. The plant's methanolic extract showed significant in vivo antioxidant activity in rat paw edema and cotton pellet-induced granuloma formation [55]. In another study, oxidative stress induced by carbon tetrachloride (CCl_4) in rats was significantly attenuated by treatment with methanolic extract, as evidenced by a decrease in the levels of liver enzymes [59]. Apart from methanol, ethyl acetate and ethanol fractions also showed the highest antioxidant activity [56, 57]. The acidic polysaccharide,

the primary active ingredient in aqueous extract, significantly reduced oxidative damage in the HEK-293 cell line and *Caenorhabditis elegans* [58]. Moreover, *O. corniculata* has been traditionally used for various medicinal purposes. According to a study by Rahman et al. (2019), local inhabitants in Pakistan use *O. corniculata* to treat Vitamin C deficiency and bad mouth smell [84].

2.4.4 Wound healing activity

The petroleum ether and alcohol extracts of *O. corniculata*, when administered to rats in different models of experimental wounds, showed potential wound-healing activity, as evidenced by their ability to promote granulation tissue formation, collagen synthesis, and wound closure. However, it is essential to note that these findings are based on animal models, and further research is needed to validate these results in human subjects [70].

2.4.5 Antidiarrheal activity

In a study of diarrhea induced by the administration of castor oil in rats, the water extract displayed greater efficacy than the methanolic extract at all doses [44]. In the evaluation of anti-colonization properties, an infant mouse model was exposed to an intragastric challenge with *S. flexneri* 2a and *S. dysenteriae* 1. Methanolic extract showed higher efficacy against *S. dysenteriae* 1 as compared to *S. flexneri* 2a. Examination of the methanolic extract of the leaf by High-performance Liquid Chromatography (HPLC) revealed the presence of various flavonoids and phenolic acids, such as rutin, p-hydroxybenzoic acid, ferulic acid, which are responsible for the antidiarrheal activity [45].

2.4.6 Anti-inflammatory activity

An experimentally induced in vivo inflammatory bowel disease model showed significant anti-inflammatory activity when treated with ethanolic extract of *O. corniculata* leaves in rats [46]. In another animal model, ethanolic extract demonstrated anti-inflammatory and analgesic effects in mice with acute peritonitis induced by acetic acid [38]. Apart from ethanolic extract, β-sitosterol isolated using petroleum ether extraction demonstrated dose-dependent anti-inflammatory activity, reducing paw edema in the rat model of carrageenan-induced hind paw edema [47].

2.4.7 Nootropic activity

The ethanolic extract showed potential neuroprotective effects and improved cognitive and motor performance in the 1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine (MPTP) induced mouse model of Parkinson's disease. The potential improvement in memory performance by ethanolic extract might possibly be ascribed due to the occurrence of flavonoids, coumarins, tocopherols, and phenolic acids [69].

2.4.8 Hepatoprotective activity

The liver of rats treated with aqueous leaf extract significantly reduced CCl_4-induced increases in serum levels of bilirubin, AST, ALT, and ALP. It only showed less damage than the livers of rats treated with CCl4 [66]. Another study with ethanolic extract showed a membrane-stabilizing effect, which helped protect the liver cells from damage caused by thioacetamide (TAA) in rats [67]. In an in silico study, active compounds of *O. corniculata* and 30 potential targets, like TP53, AKT1, ALB, and IL6, were employed in network pharmacology and constructed a "drug-active ingredient-target-disease" network. The study identified several biological processes and signaling pathways potentially involved in the antihepatic effects [85].

2.4.9 Analgesic activity

The ethanol-derived extract had a remarkable effect on reducing acetic acid-induced twitching in mice, indicating potential analgesic properties compared to the control group [39]. In addition, ethanol extract showed a significant decrease in body torsions and a noticeable reduction in abdominal capillary permeability in mice with acute peritonitis induced by acetic acid [38]. β-Sitosterol, an isolated phytochemical compound from the petroleum ether extract of *O. corniculata*, exhibits significant analgesic properties in acetic acid-induced twitching in mice. Analgesic properties of β-sitosterol might be because of its capability to either hinder pain perception at nerve terminals or to regulate pain-inducing mediators [47].

2.4.10 Anthelmintic activity

In vitro studies have shown that *O. corniculata* has potential anthelmintic activity. All three extracts (petroleum ether, methanol, and ethyl acetate) showed significant anthelmintic activity at 400 mg/mL, with the most potent methanol extract. The methanolic extract caused paralysis and death of earthworms in 11.33 and 41.33 min, respectively [40].

2.4.11 Antidiabetic activity

Treatment with ethanolic and aqueous extract showed a rectification in the final body weight and level of blood glucose in streptozotocin (STZ) induced hyperglycemia in rats compared to the untreated control group of diabetics [14, 43].

2.4.12 Abortifacient activity

The petroleum ether extract of the whole plant showed more activity than the ethanol extract regarding anti-implantation and abortifacient effects. A 100 mg/kg body weight dose of the extract from petroleum ether in all six rats resulted in complete pregnancy inhibition [37].

2.4.13 Anti-ulcer activity

Administration of the methanolic extract in an indomethacin-induced ulcer model in rats at doses of 125, 250, and 500 mg/kg b. w. decreased ulcer score, ulcer index, and number of ulcers in a dose-dependent manner. The presence of flavonoids in the methanolic extract could be the reason for its anti-ulcer effect [35].

2.4.14 Nephroprotective activity

An aqueous extract effectively suppresses the growth of struvite stones grown in a gel medium using the in vitro single diffusion gel growth assay, leading to the stones' dissolution [68].

2.4.15 Anxiolytic activity

The ethanolic extract showed an anxiolytic effect, as evidenced by improved locomotor activity in the open field test, improved entries into the open arms of the elevated plus-maze test, and decreased fighting episodes [62]. Another study indicated a reduction in anxiety-like behavior in the ethanolic extract-treated groups. Treatments increased the time spent in the open arm of the elevated plus maze and decreased the number of head dips in the hole board test compared to the control group [63]. The methanolic extract also showed neuroprotective activity in mice models of depression in the tail suspension test and the swimming test; methanolic extract-treated groups showed a substantial decline in immobility time compared to the control group [65]. Since 1970, angiotensin-converting enzymes (ACE) have been targeted for hypertension control [86]. The aqueous extract was found to have dose-dependent ACE inhibitory activity in vitro more effectively than the standard ACE inhibitor, captopril, at all doses tested ranging from 10 to 50 mg/mL [64].

2.4.16 Anti-pyretic activity

The efficacy of the extracts in reducing fever was tested by inducing pyrexia in rats using Brewer's yeast. The administration of a 200 mg/kg body weight dose of ethanolic extract resulted in a significant reduction in pyrexia from 1 to 4 h compared to the initial measurement (0 h) in the same group of animals [39].

2.4.17 Cardioprotective activity

In a study, the potential protective effect of an aqueous extract was investigated in isoproterenol-induced myocardial infarction in rats. Histopathological analysis of cardiac tissue after pretreatment with the aqueous extract showed normal myocardial fibers with mild inflammatory changes in comparison with isoproterenol-treated rats [60].

2.5 Phytochemistry

We have collected information on several phytoconstituents extracted from *O. corniculata* and provided comprehensive information on their pharmacological activities, chemical structures, IUPAC names, and corresponding references in Table 2. "ChemDraw JS 19.0" was used to create the chemical structures of the phytochemicals found in *O. corniculata*. https://chemdrawdirect.perkinelmer.cloud/js. PubChem database was used to retrieve the International Union of Pure and Applied Chemistry (IUPAC) chemical names.

2.6 Toxicology of *O. corniculata*

An acute oral toxicity test was conducted in male and female mice with the methanol extract of *O. corniculata* in accordance with Organisation for Economic Co-operation and Development (OECD) guideline 425. No signs of toxicity, mortality, and behavioral changes were observed following administration of 2000 mg/kg b. w. The extract was, therefore, reported safe up to 2000 mg/kg b. w. [35, 65]. OECD guidelines 423 and 425 were followed to test the acute toxicity of the ethanolic extract, and the animals survived at 2000 mg/kg body weight, demonstrating the safety of the extract up to this dose [43, 46, 63].

3 Conclusion

Oxalis corniculata is a promising plant for future research as it combines traditional ethnomedicinal knowledge with modern scientific findings. The traditional use of the is supported by scientific evidence of its pharmacological activities. Organic solvent-based extraction techniques are widely used and well-documented in the literature for extracting bioactive compounds from medicinal plants. The diverse range of solvent polarities available enhances the selectivity and efficiency of compound separation, enabling the extraction of a wide variety of compounds such as saponins, phenolic compounds, flavonoids, and alkaloids from plants. *O. corniculata* methanol extract was found to have significant potency over ethanol, water, and the other solvents listed in Table 1 in a range of pharmacological activities, suggesting that they are

Table 2 Phytoconstituents of *Oxalis corniculata*

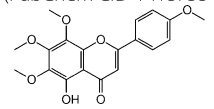
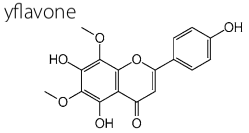
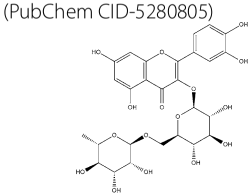
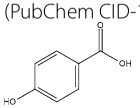
Sr. no.	Purified compounds	Parts of plant	Model used for the study (in vivo or in vitro)	Doses checked	Pharmacological activity	Conclusion	References
1	5-hydroxy-6,7,8,4′-tetra methoxy flavone (PubChem CID-14137334)  5-hydroxy-6,7,8,4'-tetra methoxy flavone	Whole plant	In vitro	–	Antimicrobial	The compound was active against the tested strains	[52]
2	5,7,4′-trihydroxy-6,8-dimethoxyflavone  5,7,4'-TRIHYDROXY-6,8-DIMETHOXYFLAVONE	Whole plant	In vitro	–	Antimicrobial	The compound was active against the tested strains	[52]
3	Rutin (PubChem CID-5280805)  2-(3,4-dihydroxyphenyl)-5,7-dihydroxy-3-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-[[(2R,3R,4R,5R,6S)-3,4,5-trihydroxy-6-methyloxan-2-yl]oxymethyl]oxan-2-yl]oxychromen-4-one	Leaf	In vitro	0.05 and 0.2 mg/mL	Antioxidant	In vitro studies have shown that Rutin possesses a concentration-dependent ability to combat a variety of antioxidant systems, indicating robust antioxidant properties	[49, 87]
4	p-hydroxybenzoic acid (PubChem CID-135)  4-hydroxybenzoic acid	Leaf	In vitro	10^{-4} M	Estrogenic activity	The expression of an estrogen responsive reporter gene (ERE-CAT) that is stably integrated was enhanced by p-hydroxybenzoic acid at a concentration of 5×10^{-4} M in MCF7 cells after 24 h and 7 days	[49, 88]

Table 2 (continued)

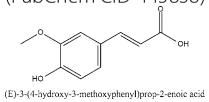
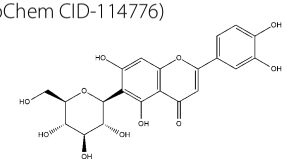
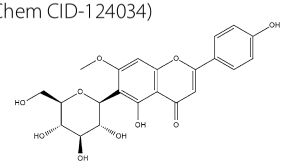
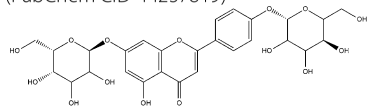
Sr. no.	Purified compounds	Parts of plant	Model used for the study (in vivo or in vitro)	Doses checked	Pharmacological activity	Conclusion	References
5	Ferulic acid (PubChem CID-445858)  (E)-3-(4-hydroxy-3-methoxyphenyl)prop-2-enoic acid	Leaf	In vitro	5 mM	Antioxidant	Ferulic acid (5 mM) inhibited 70.9% of lipid peroxidation in rat brain homogenates in vitro	[49, 89]
6	Isoorientin (PubChem CID-114776)  2-(3,4-dihydroxyphenyl)-5,7-dihydroxy-6-[(2S,3R,4R,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]chromen-4-one	Whole plant	In vivo	10 and 20 mg/kg b.w	Anti-inflammatory	It has been observed that Isoorientin possesses anti-inflammatory properties in both LPS-induced RAW cells and carrageenan-induced inflammatory model systems	[90, 91]
7	Swertisin (PubChem CID-124034)  5-hydroxy-2-(4-hydroxyphenyl)-7-methoxy-6-[(2S,3R,4R,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]chromen-4-one	Whole plant	In vivo	2.5 mg/kg b.w.	Antidiabetic	When the pancreas of diabetic mice was treated with Swertisin, it was able to regain its function	[90, 92, 93]
8	Apigenin 7,4′-diglucoside (PubChem CID-44257819)  5-hydroxy-7-[(2S,3S,6S)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxy-2-[4-[(2S,5S)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxyphenyl]chromen-4-one	Whole plant	Pharmacological activity not reported in the literature	[90]			

Table 2 (continued)

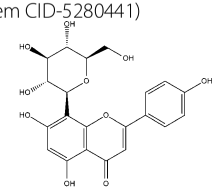
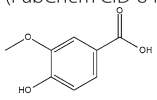
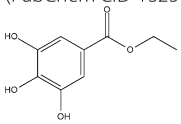
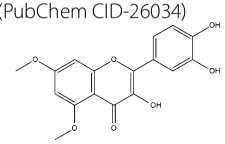
Sr. no.	Purified compounds	Parts of plant	Model used for the study (in vivo or in vitro)	Doses checked	Pharmacological activity	Conclusion	References
9	Vitexin (PubChem CID-5280441)  5,7-dihydroxy-2-(4-hydroxyphenyl)-8-[(2S,3R,4R,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]chromen-4-one	Whole plant	In vitro	10, 25, and 50 µM	Anticancer	The induction of apoptosis by Vitexin is believed to play a role in suppressing drug resistance in the colon cancer cell line, HCT-116DR	[90, 94]
10	Vanillic acid (PubChem CID-8468)  4-hydroxy-3-methoxybenzoic acid	Whole plant	In vivo	10 to 40 mg/kg b.w.	Cardioprotective	Treatment with Vanillic acid significantly increased systolic blood pressure and partially restored heart rate to normal levels compared to the doxorubicin group	[90, 95]
11	Ethyl gallate (PubChem CID-13250)  ethyl 3,4,5-trihydroxybenzoate	Whole plant	In vitro	0, 0.625, 1.25, 2.5, 5, 10, 20, 40 and 80 µg/mL	Anticancer	Ethyl gallate reduces breast cancer cell growth and spread by affecting the PI3K/Akt pathway and inhibiting the activity of molecules like NF-κB p-65, Bcl-2/Bax, MMP-2, and MMP-9	[90, 96]
12	5,7-Dimethoxy-3,3′,4′-trihydroxyflavone (PubChem CID-26034)  2-(3,4-dihydroxyphenyl)-3-hydroxy-5,7-dimethoxychromen-4-one	Whole plant	Pharmacological activity not reported in the literature	[90]			

Table 2 (continued)

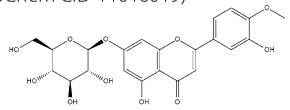
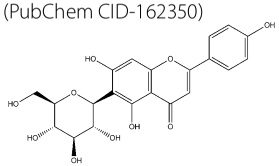
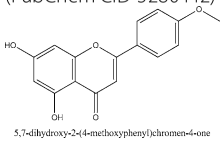
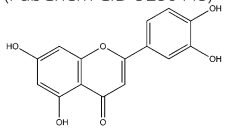
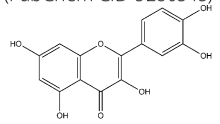
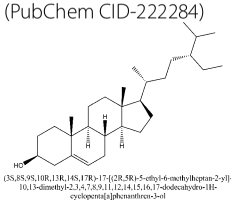
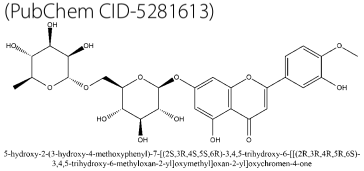
Sr. no.	Purified compounds	Parts of plant	Model used for the study (in vivo or in vitro)	Doses checked	Pharmacological activity	Conclusion	References
13	Diosmetin-7-O-beta-D-glucopyranoside (PubChem CID-11016019)  5-hydroxy-2-(3-hydroxy-4-methoxyphenyl)-7-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]oxychromen-4-one	Whole plant	Pharmacological activity not reported in the literature	[90]			
14	Isovitexin (PubChem CID-162350)  5,7-dihydroxy-2-(4-hydroxyphenyl)-6-[(2S,3R,4R,5S,6R)-3,4,5-trihydroxy-6-(hydroxymethyl)oxan-2-yl]chromen-4-one	Leaf	In vivo	5 to 20 mg/kg b.w.	Anticancer	Isovitexin treatment triggered ER stress in liver cancer cells, resulting in apoptosis and autophagy	[93, 97]
15	Acacetin (PubChem CID-5280442)  5,7-dihydroxy-2-(4-methoxyphenyl)chromen-4-one	Leaf	In vivo	50 mg/kg b.w.	Antitumor	The growth of gastric cancer xenograft tumors was inhibited by Acacetin, which reduced EGFR phosphorylation	[98–100]
16	Luteolin (Corniculatin A) (PubChem CID-5280445)  2-(3,4-dihydroxyphenyl)-5,7-dihydroxychromen-4-one	Whole plant	In vitro	2.5 to 20 µM	Antioxidant	Luteolin can reduce the phosphorylation of P38 MAPK and the activation of NF-κB induced by H_2O_2 through a signaling pathway dependent on ROS	[101, 102]

Table 2 (continued)

Sr. no.	Purified compounds	Parts of plant	Model used for the study (in vivo or in vitro)	Doses checked	Pharmacological activity	Conclusion	References
17	Quercetin (PubChem CID-5280343)  2-(3,4-dihydroxyphenyl)-3,5,7-trihydroxychromen-4-one	Whole plant	In vivo	2 to 300 mg/kg b.w	Antihypertensive	Chronic administration of quercetin has been demonstrated to reduce blood pressure in rodents with hypertension in a dose-dependent manner	[90, 103]
18	β-sitosterol (PubChem CID-222284)  (3S,8S,9S,10R,13R,14S,17R)-17-[(2R,5R)-5-ethyl-6-methylheptan-2-yl]-10,13-dimethyl-2,3,4,7,8,9,11,12,14,15,16,17-dodecahydro-1H-cyclopenta[a]phenanthren-3-ol	Leaf	In vivo	10, 15, and 20 mg/kg b.w	Antidiabetic	The regeneration of beta cells was observed in diabetic rats treated with beta-sitosterol, according to histological findings	[47, 104]
19	Diosmin (PubChem CID-5281613)  5-hydroxy-2-(3-hydroxy-4-methoxyphenyl)-7-[(2S,3R,4S,5S,6R)-3,4,5-trihydroxy-6-[[(2R,3R,4R,5R,6S)-3,4,5-trihydroxy-6-methyloxan-2-yl]oxymethyl]oxan-2-yl]oxychromen-4-one	Whole plant	In vivo	50 mg/kg b.w.	Nephroprotective	No significant histological changes were observed in the group treated with diosmin alone	[105, 106]

b.w. body weight

potential candidates for additional investigations in the field of pharmaceutical research and drug discovery.

There is considerable potential for future research into the pharmacological activities of this plant, particularly for the elucidation of its mechanisms of action. This medicinal plant has the potential to become an important source of herbal medicines for the pharmaceutical industry. Future studies should aim to elucidate the mechanisms of action of key phytochemicals, conduct rigorous clinical trials to confirm traditional claims, explore potential synergistic effects of compounds, and develop standardized formulations for therapeutic use. As research on *O. corniculata* continues, it is essential to use multidisciplinary approaches and promote collaborative projects to fully harness the medicinal properties of this plant for modern healthcare. By combining expertise from different scientific disciplines and fostering partnerships between research institutions and industry, we can maximize the therapeutic potential of *O. corniculata* and ensure its safe and effective integration into modern medicine.

Abbreviations

µg	Microgram
mL	Milliliter
mg	Milligrams
b.w.	Body weight
MDR	Multi-drug resistant
HPV-18	Human Papillomavirus-18
CCl4	Carbon tetrachloride
MPTP	1-Methyl-4-phenyl-1,2,3,6-tetrahydropyridine
AST	Aspartate aminotransferase
ALT	Alanine aminotransferase
ALP	Alkaline phosphatase
TAA	Thioacetamide
TP53	Tumor protein p53
AKT1	AKT serine/threonine kinase 1
ALB	Serum albumin protein
IL6	Interleukin 6
STZ	Streptozotocin
ACE	Angiotensin converting enzymes
IUPAC	International Union of Pure and Applied Chemistry
CID	Compound ID number
mM	Millimole
LPS	Lipopolysaccharide
µM	Micromole
PI3K	Phosphoinositide 3-kinases
NF-κB	Nuclear factor kappa-light-chain-enhancer of activated B cells
Bcl-2	B-cell lymphoma 2
MMP-2/9	Matrix metalloproteinases-2/9
ER	Endoplasmic reticulum
MAPK	Mitogen-activated protein kinase
ROS	Reactive oxygen species
OECD	Organisation for Economic Co-operation and Development
HPLC	High performance liquid chromatography

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Author contributions
RB was responsible for data curation, writing the original draft, and methodology. PP was responsible for reviewing, editing, and data curation. PB was responsible for data curation and methodology. NK was responsible for editing the manuscript, conceptualization, reviewing, writing, and data curation.

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No competing interests.

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References

1. Shamso EM, Draz A, Hosni HA, Hussein SR (2022) Taxonomic revision of genus Oxalis L. (Oxalidaceae) in the flora of Egypt. Taeckholmia 41:56–69. https://doi.org/10.21608/TAEC.2022.118726.1036
2. Miller TW, Libbey CR, Maupin BG (2013) Evaluation of organic amendments and flaming for weed control in matted-row strawberry. HortScience 48:304–310. https://doi.org/10.21273/HORTSCI.48.3.304
3. Nuernberg-Silva A, Phytotaxa PF (2021) Taxonomic revision and morphological delimitation of Oxalis sect. Ripariae (Oxalidaceae). Phytotaxa 529:125–159
4. Hoshino Y, Hoshino M, Yoshioka K, Washio T, Nakamura M, Maki M, Dohzono I (2022) The effects of inbreeding depression and pollinator visitation on the maintenance of herkogamy in Oxalis corniculata, a species derived from a heterostylous ancestor. Plant Species Biol 37:349–360. https://doi.org/10.1111/1442-1984.12387
5. Mekap SK, Mishra SK, Panda PK, Panda SS, Sarangi DK (2022) A systematic review on Oxalis corniculata Linn. a crop field weed with promising pharmacological activities. Asian J Pharm Clin Res 15:4–8. https://doi.org/10.22159/AJPCR.2022.V15I8.45017
6. Ren L, Guan K, Tan M, Yang J, Wang G (2023) Description of four new species, two new records, and mitochondrial COI gene of eriophyoid mites from Nanning, China (Acari: Eriophyoidea). Syst Appl Acarol (SAA) 28:1195–1223. https://doi.org/10.11158/SAA.28.7.2
7. Groom QJ, Van Der Straeten J, Hoste I (2019) The origin of Oxalis corniculata L. PeerJ. https://doi.org/10.7717/PEERJ.6384
8. Kunte K, S.S.P.R. (Chief E. Butterflies of India, v. 4.18. Indian Foundation for Butterflies. https://www.ifoundbutterflies.org/pseudozizeeria-maha. Accessed 14 Dec 2023
9. Van der Straeten J, Groom Q (2018) A bibliography of the medicinal uses of Oxalis corniculata. Zenodo. https://doi.org/10.5281/ZENODO.1254000
10. Tibuhwa DD (2017) Antioxidant potentialities and antiradical activities of Oxalis corniculata Linn from Tanzania. J Appl Biosci 116:11590–11600. https://doi.org/10.4314/JAB.V116I1.7
11. Kumar S, Pandey AK (2013) Chemistry and biological activities of flavonoids: an overview. Sci World J 2013:16. https://doi.org/10.1155/2013/162750

12. Hamzah H, Siregar KAAK, Nurwijayanto A, Wahyuningrum R, Sari S (2021) Effectiveness of Oxalis corniculata L. ethanol extract against mono-species of biofilm Staphylococcus aureus. Borneo J Pharm 4:184–191. https://doi.org/10.33084/BJOPV4I3.2418
13. Tibuhwa DD (2016) Oxalis corniculata L. in Tanzania: traditional use, cytotoxicity and antimicrobial activities. J Appl Biosci 105:10055–10063. https://doi.org/10.4314/jab.v105i1.2
14. Al-Qalhati IRS, Waly MI, Al-Subhi L, Al-Attabi Mostafa Z, Waly I (2021) Anti-diabetic potential properties of two edible Omani wild plants (Pteropyrum scoparium and Oxalis corniculata). J Agric Mar Sci [JAMS] 26:56–63. https://doi.org/10.53541/JAMS.VOL26ISS2PP56-63
15. Pathak SK, Kumar J (2018) Studies on morphological and quantitative characters of different species of Oxalis growing in Ranchi, Jharkhand. J Nat Prod Resour 04:160–161. https://doi.org/10.30799/JNPR.055.18040102
16. Fukano Y, Yamori W, Misu H, Sato MP, Shirasawa K, Tachiki Y, Uchida K (2023) From green to red: urban heat stress drives leaf color evolution. Sci Adv 9:eabq3542. https://doi.org/10.1126/SCIADV.ABQ3542/SUPPL_FILE/SCIADV.ABQ3542_TABLES_S1_TO_S4.ZIP
17. Sakauchi K, Taira W, Toki M, Tsuhako M, Umetsu K, Otaki JM (2021) Nutrient imbalance of the host plant for larvae of the pale grass blue butterfly may mediate the field effect of low-dose radiation exposure in fukushima: dose-dependent changes in the sodium content. Insects 12:149. https://doi.org/10.3390/INSECTS12020149
18. Benvenuti S (2007) Weed seed movement and dispersal strategies in the agricultural environment. Weed Biol Manag 7:141–157. https://doi.org/10.1111/J.1445-6664.2007.00249.X
19. El-Ghani MA, Bornkamm R, El-Sawaf N, Turky H (2015) Heterogeneity of soil and vegetation in the urban habitats of new industrial cities in the desert landscape of Egypt. Not Sci Biol 7:26–36. https://doi.org/10.15835/NSB719433
20. Naqinezhad A, De Lombaerde E, Gholizadeh H, Wasof S, Perring MP, Meeussen C, De Frenne P, Verheyen K (2022) The combined effects of climate and canopy cover changes on understorey plants of the Hyrcanian forest biodiversity hotspot in Northern Iran. Glob Change Biol 28:1103–1118. https://doi.org/10.1111/GCB.15946
21. Li J, Zhao T, Chen L, Chen H, Luo D, Chen C, Miao Y, Liu D (2022) Artemisia argyi allelopathy: a generalist compromises hormone balance, element absorption, and photosynthesis of receptor plants. BMC Plant Biol 22:1–17. https://doi.org/10.1186/S12870-022-03757-9/FIGURES/7
22. Li J, Chen L, Chen Q, Miao Y, Peng Z, Huang B, Guo L, Liu D, Du H (2021) Allelopathic effect of Artemisia argyi on the germination and growth of various weeds. Sci Rep 11:1–15. https://doi.org/10.1038/s41598-021-83752-6
23. Hayasaka D, Akasaka M, Miyauchi D, Box EO, Uchida T (2012) Qualitative variation in roadside weed vegetation along an urban-rural road gradient. Flora Morphol Distrib Funct Ecol Plants 207:126–132. https://doi.org/10.1016/J.FLORA.2011.11.005
24. Ministry of Ayush Government of India (2001) The ayurvedic pharmacopoeia of India part-I volume-III; Delhi
25. FRLHT Indian Medicinal Plants Database. http://www.medicinalplants.in/searchpage/showdetails/xplant_id/0ef91fd7704967eb83c9addd59ecd7ed. Accessed 15 Nov 2022
26. Badwaik H, Singh K, Thakur D, Giri K, Tripathi DK (2011) The botany, chemistry, pharmacological and therapeutic application of Oxalis corniculata Linn—a review. Int J Phytomed 3:1–08
27. Gudasi S, Gharge S, Koli R, Patil K (2023) Antioxidant properties and cytotoxic effects of Oxalis corniculata on human hepatocarcinoma (Hep-G2) cell line: an in vitro and in silico evaluation. Future J Pharm Sci 9:1–13. https://doi.org/10.1186/S43094-023-00476-2
28. Sarma G, Das S (2017) Hypoglycaemic action of ethanolic extract of leaves of Oxalis corniculata L. on normal and alloxan-induced diabetic albino rats. J Evid Based Med Healthc 4:4755–4761. https://doi.org/10.18410/JEBMH/2017/949
29. Begum S, Hussain S, Mehmood A, Ahmad KS, Hamid A (2018) Harnessing the potential of medicinal plants used for the treatment of diabetes in rural areas of Azad Jammu and Kashmir, Pakistan. Appl Ecol Environ Res 16:6549–6566. https://doi.org/10.15666/AEER/1605_65496566
30. Silalahi M (2022) Utilization of Oxalis corniculata Linn as a traditional medicine and its bioactivity. Magna Sci Adv Res Rev 5:027–033. https://doi.org/10.30574/MSARR.2022.5.2.0052
31. Bonna I, Afroz M, Sultana S, Alam S (2017) Comparative karyotype and RAPD analysis of four Oxalis L. species. Cytologia 82:527–533. https://doi.org/10.1508/cytologia.82.527
32. Noor N, Satapathy KB (2023) Leafy vegetable diversity and their ethnomedicinal uses against gastrointestinal disorders in the Balasore district of Odisha, India. J Appl Biol Biotechnol 11:259–267. https://doi.org/10.7324/JABB.2023.69250
33. Singh K, Gambhir L (2017) Antimicrobial effects of leaf extracts from Oxalis corymbosa against pathogenic bacterial and fungal isolates. WJPR 6:1267–1278. https://doi.org/10.20959/wjpr20177-8830
34. Manna D, Dutta PK, Achari B, Lohia A (2010) A novel galacto-glycerolipid from Oxalis corniculata kills entamoeba histolytica and giardia lamblia. Antimicrob Agents Chemother 54:4825–4832. https://doi.org/10.1128/AAC.00546-10/SUPPL_FILE/SUPPLEMENTARY_TABLE_1.PDF
35. Sakat SS, Tupe P, Juvekar A (2012) Gastroprotective effect of Oxalis corniculata (whole plant) on experimentally induced gastric ulceration in wistar rats. Indian J Pharm Sci 74:48–53. https://doi.org/10.4103/0250-474X.102543
36. Popay I (2022) Oxalis corniculata (creeping Woodsorrel). CABI compendium. https://doi.org/10.1079/CABICOMPENDIUM.38154
37. Sharangouda K, Patil SB (2007) Antiimplantation and abortifacient activities of Oxalis corniculata in albino rats. Niger J Nat Prod Med 11:58–60. https://doi.org/10.4314/NJNPM.V11I1.11883
38. Mei-Xian G, Yan-Shuang W, Gui-Rong S, Lei S (2014) Anti-inflammatory and analgesic effects of Oxalis corniculata L. on acute peritonitis in mice. J Dali Univ 13:6
39. Venkateswaran V, Shanmuga Sudaram R, Sambathkumar R (2017) Evaluation of analgesic and antipyretic activity of ethanol extract of Oxalis corniculata Linn. Int J Chem Pharm Sci 8:30–34
40. Dighe SB, Kuchekar BS, Wankhede SB (2012) Pharmacological evaluation of Oxalis corniculata Linn for anthelmintic activity. Res J Pharmacol Pharmacodyn 4:1–4
41. Gholipour AR, Jafari L, Ramezanpour M, Evazalipour M, Chavoshi M, Yousefbeyk F, Moghaddam SJK, Kooshali MHY, Ramezanpour N, Daei P et al (2022) Apoptosis effects of Oxalis corniculata L. extract on human MCF-7 breast cancer cell line. Galen Med J 11:e2484–e2484. https://doi.org/10.31661/GMJ.V11I.2484
42. Kathiriya A, Das K, Kumar E, Mathai K (2010) Evaluation of antitumor and antioxidant activity of Oxalis corniculata Linn. against ehrlich ascites carcinoma on mice. Iran J Cancer Prev 3:157–165
43. Dutta A, Lahkar M, Handique C (2017) Evaluation of antidiabetic activity of Oxalis corniculata in streptozotocin induced diabetic rats. Int J Basic Clin Pharmacol 5:2178–2183. https://doi.org/10.18203/2319-2003.IJBCP20163258
44. Watcho P, Nkouathio E, Nguelefack TB, Wansi SL, Kamanyi A (2005) Antidiarrhoeal activity of aqueous and methanolic extracts of Oxalis corniculata klotzsch in rats. Cameroon J Exp Biol 1:46–49. https://doi.org/10.4314/CAJEB.V1I1.37933
45. Mukherjee S, Koley H, Barman S, Mitra S, Datta S, Ghosh S, Paul D, Dhar P (2013) Oxalis corniculata (Oxalidaceae) leaf extract exerts in vitro antimicrobial and in vivo anticolonizing activities against Shigella dysenteriae 1 (NT4907) and Shigella flexneri 2a (2457T) in induced diarrhea in suckling mice. J Med Food 16:801–809. https://doi.org/10.1089/jmf.2012.2710
46. Dutta A, Handique C, Lahkar M (2015) Evaluation of anti-inflammatory activity of Oxalis corniculata in experimentally induced inflammatory bowel disease in rats. Int J Basic Clin Pharmacol 4:744–748. https://doi.org/10.18203/2319-2003.IJBCP20150383
47. Dighe SB, Kuchekar BS, Wankhede SB, Santosh M, Dighe Head B (2016) Analgesic and anti-inflammatory activity of β-sitosterol isolated from leaves of Oxalis corniculata. Int J Pharmacol Res 6:109–113. https://doi.org/10.7439/ijpr
48. Misrahanum M, Almunawwarah SD, Helwati H, Maysarah H, Sadli S (2021) Antimicrobial activity Jangjingki (Oxalis corniculata L.) against the growth of Staphylococcus aureus, Escherichia coli, and Candida albicans. J Pharm Sci 4:1–11. https://doi.org/10.36490/journal-jps.com.v4i1.58

49. Mukherjee S, Pal S, Chakraborty R, Koley H, Dhar P (2018) Biochemical assessment of extract from Oxalis corniculata L.: its role in food preservation, antimicrobial and antioxidative paradigms using in situ and in vitro models
50. Rahman M, Khan M (2010) Anti-bacterial evaluation and minimum inhibitory concentration analysis of Oxalis corniculata and Ocimum santum against bacterial pathogens. Biotechnology. https://doi.org/10.3923/biotech.2010.533.536
51. Manandhar S, Luitel S, Dahal RK (2019) In vitro antimicrobial activity of some medicinal plants against human pathogenic bacteria. J Trop Med. https://doi.org/10.1155/2019/1895340
52. Rehman A, Rehman A, Ahmad I (2015) Antibacterial, antifungal, and insecticidal potentials of Oxalis corniculata and its isolated compounds. Int J Anal Chem. https://doi.org/10.1155/2015/842468
53. Johnson BL, Arakareddy B, Sam KK (2020) Formulation of an anti-bacterial cream from plant Oxalis corniculata and its evaluation. Int J Curr Pharm Res. https://doi.org/10.22159/IJCPR.2020V12I5.39763
54. Badrul Alam M, Sarowar Hossain M, Chowdhury NS, Ehsanul Haque Mazumder M, Ekramul Haque M, Islam A (2011) In vitro and in vivo antioxidant and toxicity evaluation of different fractions of Oxalis corniculata Linn. J Pharmacol Toxicol 6:337–348. https://doi.org/10.3923/JPT.2011.337.348
55. Juvekar A, Sakat S, Wankhede S, Juvekar M, Gambhire M (2009) Evaluation of antioxidant and anti-inflammatory activity of methanol extract of Oxalis corniculata. Planta Med 75:PJ78. https://doi.org/10.1055/S-0029-1234983
56. Ahmed D, Zara S, Baig H (2013) In vitro analysis of antioxidant activities of Oxalis corniculata Linn. fractions in various solvents. Afr J Tradit Complement Altern Med 10:158–165. https://doi.org/10.4314/AJTCAM.V10I1.21
57. Borah A, Yadav R (2012) Evaluation of antioxidant activity of different solvent extracts of Oxalis Corniculata L. J Pharm Res 5:91–93
58. Gao T, Hu W, Zhang Z, Tang Z, Chen Y, Zhang Z, Yuan S, Chen T, Huang Y, Feng S et al (2022) An acidic polysaccharide from Oxalis corniculata L. and the preliminary study on its antioxidant activity. J Food Biochem 46:e14235. https://doi.org/10.1111/JFBC.14235
59. Khan MR, Marium A, Shabbir M, Saeed N, Bokhari J (2012) Antioxidant and hepatoprotective effects of Oxalis corniculata against carbon tetrachloride (CCl4) induced injuries in rat. Afr J Pharm Pharmacol 6:2255–2267. https://doi.org/10.5897/AJPP11.370
60. Abhilash PA, Nisha P, Prathapan A, Nampoothiri SV, Lijo Cherian O, Sunitha TK, Raghu KG (2011) Cardioprotective effects of aqueous extract of Oxalis corniculata in experimental myocardial infarction. Exp Toxicol Pathol 63:535–540. https://doi.org/10.1016/J.ETP.2010.04.004
61. Khan MR, Zehra H (2013) Amelioration of CCl4-induced nephrotoxicity by Oxalis corniculata in rat. Exp Toxicol Pathol 65:327–334. https://doi.org/10.1016/J.ETP.2011.11.007
62. Gupta G, Kazmi I, Afzal M, Rahman M, Anwar F (2012) Anxiolytic effect of Oxalis corniculata (Oxalidaceae) in mice. Asian Pac J Trop Dis 2:S837–S840. https://doi.org/10.1016/S2222-1808(12)60275-8
63. Sampath ST, Lahkar M, Kumars P, Sampath S (2011) Anxiolytic effect of ethanolic extract of Oxalis corniculata L. in mice. Int J Pharm Biol Sci 2:281–290
64. Moyeenudin HM, Vijayalakshmi S (2019) The antihypertensive effect from aqueous extract of Oxalis corniculata by in vitro antihypertensive activity assay. Res J Pharm Technol 12:2981–2986. https://doi.org/10.5958/0974-360X.2019.00504.3
65. Das M, Gohain K (2018) Study of neuroprotective activity of methanolic extract of Oxalis corniculata Linn on animal models of depression. Int J Eng Sci Res Technol 7:396–405. https://doi.org/10.5281/zenodo.1297373
66. Jadhav AG, Anil JG, Mrutyunjay PB, Sachin NB, Vidya Sagar G (2010) Hepatoprotective activity of Oxalis corniculata leaves against carbon tetrachloride induced hepatotoxicity in female albino wistar rats. Res J Pharmacogn Phytochem 2:136–139
67. Das K, Kathiriya AK, Kumar EP, Benson MK, Einstein JW (2012) Evaluation of hepatoprotective activity of aqueous and ethanolic extract of Oxalis corniculata against intoxication of thioacetamide induced rats. Rev Bras 22:412–417. https://doi.org/10.1590/S0102-695X2011005000189
68. Das P, Kumar K, Nambiraj A, Awasthi R, Dua K, Malipeddi H (2018) Antibacterial and in vitro growth inhibition study of struvite urinary stones using Oxalis corniculata Linn. leaf extract and its biofabricated silver nanoparticles. Recent Pat Drug Deliv Formul 12:170–178. https://doi.org/10.2174/1872211312666180723160624
69. Aruna K, Rajeswari PDR, Sankar SR (2017) The effect of Oxalis corniculata extract against the behavioral changes induced by 1-methyl-4-phenyl-1, 2, 3, 6-tetrahydropyridine (MPTP) in mice. J Appl Pharm Sci 7:148–153. https://doi.org/10.7324/JAPS.2017.70324
70. Taranalli AD, Tipare SV, Kumar S, Torgal SS (2004) Wound healing activity of Oxalis corniculata whole plant extract in rats. Indian J Pharm Sci 66:444
71. van Ngo T, Scarlett CJ, Bowyer MC, Ngo PD, van Vuong Q (2017) Impact of different extraction solvents on bioactive compounds and antioxidant capacity from the root of Salacia chinensis L. J Food Qual. https://doi.org/10.1155/2017/9305047
72. Silvestre M, Gonzalez-Pastor R, Carrera-Pacheco SE, Zúñiga-Miranda J, Rodríguez-Pólit C, Mayorga-Ramos A, Guamán LP, Barba-Ostria C (2023) Current landscape of methods to evaluate antimicrobial activity of natural extracts. Molecules 28:1068. https://doi.org/10.3390/MOLECULES28031068
73. Salaria D, Rolta R, Mehta J, Awofisayo O, Fadare OA, Kaur B, Kumar B, da Costa RA, Chandel SR, Kaushik N et al (2022) Phytoconstituents of traditional Himalayan herbs as potential inhibitors of human papillomavirus (HPV-18) for cervical cancer treatment: an in silico approach. PLoS ONE 17:e0265420. https://doi.org/10.1371/JOURNAL.PONE.0265420
74. Omara T, Kiprop AK, Ramkat RC, Cherutoi J, Kagoya S, Moraa Nyangena D, Azeze Tebo T, Nteziyaremye P, Nyambura Karanja L, Jepchirchir A et al (2020) Medicinal plants used in traditional management of cancer in Uganda: a review of ethnobotanical surveys, phytochemistry, and anticancer studies. Evid Based Complement Altern Med. https://doi.org/10.1155/2020/3529081
75. Ambu G, Chaudhary RP, Mariotti M, Cornara L (2020) Traditional uses of medicinal plants by ethnic people in the Kavrepalanchok District, Central Nepal. Plants 9:759. https://doi.org/10.3390/PLANTS9060759
76. Norfarizan-Hanoon NA, Nurraihana H, Hasmah A, Wan Rosli WI (2017) Phytochemical and antioxidant potential of four traditional Malaysian medicinal plants. J Trop Resour Sustain Sci (JTRSS) 5:9–14. https://doi.org/10.47253/JTRSS.V5I1.648
77. Saracila M, Panaite TD, Untea AE, Varzaru I (2022) Effect of dietary supplementation of some antioxidant combinations on nutrient digestibility in heat-stressed broilers. Archiva Zootechnica 25:116–129. https://doi.org/10.2478/AZIBNA-2022-0008
78. Handique JG, Boruah MP, Kalita D (2012) Antioxidant activities and total phenolic and flavonoid contents in three indigenous medicinal vegetables of north-east India. Nat Prod Commun 7:1021–1023
79. Hossain S, Islam J, Ahmed F, Hossain A, Abdul M, Siddiki K, Moazzem Hossen SM (2015) Free radical scavenging activity of six medicinal plants of Bangladesh: a potential source of natural antioxidant. J Appl Pharm 7:96–104
80. Pandey K, Pokhrel S (2022) Phytochemical screening and biological activities of Oxalis corniculata leaves of Sindhupalchowk District, Nepal. BIBECHANA 19:27–33. https://doi.org/10.3126/BIBECHANA.V19I1-2.46094
81. Fathima SN, Vasudeva Murthy S (2018) Current pharmacological status of cardioprotective plants against isoproterenol induced myocardial infarction. Asian J Pharm Clin Res 11:17–27. https://doi.org/10.22159/AJPCR.2018.V11I4.24158
82. Gaire BP, Subedi L (2011) Medicinal plant diversity and their pharmacological aspects of Nepal Himalayas. Pharmacogn J 3:6–17. https://doi.org/10.5530/PJ.2011.25.2
83. Hennia A, Miguel MG, Nemmiche S (2018) Antioxidant activity of Myrtus communis L. and Myrtus Nivellei Batt. & Trab. extracts: a brief review. Medicines 5:89. https://doi.org/10.3390/MEDICINES5030089
84. Rahman IU, Afzal A, Iqbal Z, Hart R, Abd Allah EF, Hashem A, Alsayed MF, Ijaz F, Ali N, Shah M et al (2019) Herbal teas and drinks: folk medicine of the Manoor Valley, Lesser Himalaya, Pakistan. Plants 8:581. https://doi.org/10.3390/PLANTS8120581
85. Ding Q, Huang X, Yang X, Zhang M, Qin P, Wu H, Wang X (2021) Study of the mechanism of Oxalis corniculata (L.) in the treatment of hepatitis based on network pharmacology. IOP Conf Ser Earth Environ Sci 714:032021. https://doi.org/10.1088/1755-1315/714/3/032021

86. Wong MKS (2016) Angiotensin converting enzymes. In: Handbook of hormones: comparative endocrinology for basic and clinical research, pp 263-e29D-4. https://doi.org/10.1016/B978-0-12-801028-0.00254-3
87. Yang J, Guo J, Yuan J (2008) In vitro antioxidant properties of rutin. LWT Food Sci Technol 41:1060–1066. https://doi.org/10.1016/J.LWT.2007.06.010
88. Pugazhendhi D, Pope GS, Darbre PD (2005) Oestrogenic activity of P-hydroxybenzoic acid (common metabolite of paraben esters) and methylparaben in human breast cancer cell lines. J Appl Toxicol 25:301–309. https://doi.org/10.1002/JAT.1066
89. Graf E (1992) Antioxidant potential of ferulic acid. Free Radic Biol Med 13:435–448. https://doi.org/10.1016/0891-5849(92)90184-I
90. Prasad Pandey B, Prakash Pradhan S, Adhikari K (2020) LC-ESI-QTOF-MS for the profiling of the metabolites and in vitro enzymes inhibition activity of Bryophyllum pinnatum and Oxalis corniculata collected from Ramechhap District of Nepal. Chem Biodivers 17:e2000155. https://doi.org/10.1002/CBDV.202000155
91. Anilkumar K, Reddy GV, Azad R, Sastry Yarla N, Dharmapuri G, Srivastava A, Kamal MA, Pallu R (2017) Evaluation of anti-inflammatory properties of isoorientin isolated from tubers of Pueraria tuberosa. Oxid Med Cell Longev. https://doi.org/10.1155/2017/5498054
92. Srivastava A, Dadheech N, Vakani M, Gupta S (2018) Swertisin ameliorates diabetes by triggering pancreatic progenitors for islet neogenesis in streptozotocin treated BALB/c mice. Biomed Pharmacother 100:221–225. https://doi.org/10.1016/J.BIOPHA.2018.01.096
93. Mizokami H, Tomita-Yokotani K, Yoshitama K (2008) Flavonoids in the leaves of Oxalis corniculata and sequestration of the flavonoids in the wing scales of the pale grass blue butterfly, Pseudozizeeria maha. J Plant Res 121:133–136. https://doi.org/10.1007/s10265-007-0132-x
94. Bhardwaj M, Cho HJ, Paul S, Jakhar R, Khan I, Lee SJ, Kim BY, Krishnan M, Khaket TP, Lee HG et al (2018) Vitexin induces apoptosis by suppressing autophagy in multi-drug resistant colorectal cancer cells. Oncotarget 9:3278. https://doi.org/10.18632/ONCOTARGET.22890
95. Baniahmad B, Safaeian L, Vaseghi G, Rabbani M, Mohammadi B (2020) Cardioprotective effect of vanillic acid against doxorubicin-induced cardiotoxicity in rat. Res Pharm Sci 15:87. https://doi.org/10.4103/1735-5362.278718
96. Cui H, Yuan J, Du X, Wang M, Yue L, Liu J (2015) Ethyl gallate suppresses proliferation and invasion in human breast cancer cells via Akt-NF-KB signaling. Oncol Rep 33:1284–1290. https://doi.org/10.3892/OR.2014.3682/HTML
97. Lv SX, Qiao X (2018) Isovitexin (IV) induces apoptosis and autophagy in liver cancer cells through endoplasmic reticulum stress. Biochem Biophys Res Commun 496:1047–1054. https://doi.org/10.1016/J.BBRC.2018.01.111
98. Draz AA, Kawashty SA, Shamso EM, Hosni HA, Hussein SR (2022) Chemical profiling of Oxalis species growing wild in Egypt using HRLC/MS spectrometry. Int J Second Metab 9:426–439. https://doi.org/10.21448/ijsm.1110807
99. Zhang G, Dong J, Lu L, Liu Y, Hu D, Wu Y, Zhao A, Xu H (2023) Acacetin exerts antitumor effects on gastric cancer by targeting EGFR. Front Pharmacol 14:1121643. https://doi.org/10.3389/FPHAR.2023.1121643/BIBTEX
100. Sakauchi K, Taira W, Otaki JM (2022) Metabolomic profiles of the creeping wood sorrel Oxalis corniculata in radioactively contaminated fields in fukushima: dose-dependent changes in key metabolites. Life. https://doi.org/10.3390/life12010115
101. Ibrahim M, Hussain I, Imran M, Hussain N, Hussain A, Mahboob T (2013) Corniculatin A, a new flavonoidal glucoside from Oxalis corniculata. Rev Bras 23:630–634. https://doi.org/10.1590/S0102-695X2013005000059
102. Chen HI, Hu WS, Hung MY, Ou HC, Huang SH, Hsu PT, Day CH, Lin KH, Viswanadha VP, Kuo WW et al (2020) Protective effects of luteolin against oxidative stress and mitochondrial dysfunction in endothelial cells. Nutr Metab Cardiovasc Dis 30:1032–1043. https://doi.org/10.1016/J.NUMECD.2020.02.014
103. Perez-Vizcaino F, Duarte J, Jimenez R, Santos-Buelga C, Osuna A (2009) Antihypertensive effects of the flavonoid quercetin. Pharmacol Rep 61:67–75. https://doi.org/10.1016/S1734-1140(09)70008-8/METRICS
104. Gupta R, Sharma AK, Dobhal MP, Sharma MC, Gupta RS (2011) Antidiabetic and antioxidant potential of β-sitosterol in streptozotocin-induced experimental hyperglycemia. J Diabetes 3:29–37. https://doi.org/10.1111/J.1753-0407.2010.00107.X
105. Kiran KS, Kameshwar VH, Kumar Munakudu-Nagaraju K, Nagalambika P, Kavitha R, Karthick A, GuruKumar D, Swamy SN, Krishna KL, Kumar JR (2023) Diosmin: a Daboia russelii venom PLA2s inhibitor- purified, and characterized from Oxalis corniculata L medicinal plant. J Ethnopharmacol. https://doi.org/10.1016/J.JEP.2023.116977
106. Eraslan G, Sarıca ZS, Bayram LÇ, Tekeli MY, Kanbur M, Karabacak M (2017) The effects of Diosmin on aflatoxin-induced liver and kidney damage. Environ Sci Pollut Res 24:27931–27941. https://doi.org/10.1007/S11356-017-0232-7/METRICS

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