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# An updated review on pharmacological studies of *Rumex nepalensis*

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**Abstract**
Medicinal plants are necessary part of human society since the civilization started. Medicinal plants are the boon of nature to treat a number of ailments of human beings. Plants contain bioactive molecules and thus can provide lead structures for the development of alternative medicines to available toxic commercial drugs with better effectively and increased safety. Rumex, a genus of polygonaceae family, is very prevalent worldwide. There are about 200 species of this genus, many of which are beneficial and used as vegetables and for their medicinal properties. Root, seed, leaf, fresh plant juice, aerial parts etc. are the parts generally used. *Rumex nepalensis* Spreng. (Polygonaceae) commonly known as Nepal Dock has wide-spectrum therapeutic potencies and is extensively used for centuries in traditional medicine systems. The leaves of this plant are edible and a rich source of natural antioxidants. They act as a possible food supplement and are largely used in pharmaceutical industry. Extracts and metabolites from this plant exhibit many pharmacological activities. Due to its remarkable biological activities, it has the potential to act as a rich source of drug against life threatening diseases. However, more studies are needed to scientifically validate the traditional uses of this plant, beside isolating and identifying their active principles and characterizing the mechanisms of action. We present herein a decisive account of its botany, ecology, traditional uses, phytoconstituents profile and major pharmacological activities reported in recent years and therefore will provide a source of information on this plant for further studies.

**Keywords:** Medicinal plants, polygonaceae, *Rumex nepalensis*

## Introduction
The evolution of mankind has happened along with their surrounding herbs and medicinal plants from ancient period of time. Approximately 270,000 plant species have been discovered by human, while there is a possible of existence of close to 400,000 species in mother earth [1]. No synthetic substitute is currently available for about 121 major plant based drug molecules, comprising 45 from tropical and 76 from subtropical areas. A recent study by World Health Organization claimed 80% dependency of world population on ethno medicines in some extent [2]. Medicinal plants are nature's gift for answering a limitless range of fatal diseases among human beings, therefore medicinal plants are getting more consideration currently than ever, especially in the line of medicine and pharmacology. The bioactive phytochemical constituents of the plant are being explored worldwide for their broad-spectrum medicinal potencies. Medicinal plants are explored as a source to isolate pure active principles or in the form of phyto complex, where there is a synergistic combination of active ingredients and other substances like enzymes, resins, essential oils, tannins to facilitate their actions. The health-promoting properties of medicinal plants are usually derived from the interaction of all the substances naturally present in the phyto complex. However, the emphasis on the use of total herbs as medicines and food supplements is gradually replacing the techniques to isolate the biologically active novel compounds and molecules as leading drug molecules [3]. The *Rumex* species, belonging in the Polygonaceae family, comprise about 200 species widely distributed around the World. The name *Rumex* originated from the Latin word for dart, alluding to the shape of the leaves [4]. There have been numerous ethno botanical and ethno pharmacological literature reports dealing with the occurrence and traditional uses of *Rumex* species [5-7]. *Rumex Nepalensis* Spreng. (*R. Nepalensis*) is a perennial, ascending herb [8], commonly known by the name Nepal dock and vernacular names are in English-Sheep sorrel, Nepal duck, Hindi-Jangli palak, Amlya, Amlora, Bhilmora, Malori, Sanskrit-Amlavetasa, Kashmiri-Aliphiri, Bengali-Pahari palang, Pakistani-Shalkhay, Hoola, Nepali-Halhale sag, Ban haldi, Halya, Halye, Uttarakhandi- Kathura, Tamil-Sukkankeerai, Manipuri-Torongkhongchak [3].

Though *R. Nepalensis* is an agricultural weed but this wild plant is not really unwanted in the arena of traditional herbal medicines [9-11]. Several studies have confirmed striking medicinal benefits of this plant. The juvenile leaves of this plant are cooked as vegetables which gives an acidic-lemon flavor to dishes [12]. The young shoot is also locally eaten as a cooked vegetable [13]. This plant is also used as a colouring agent (dye) [14]. Green colour from the leaves of plants is often used in sweet preparations [15]. Phytochemical screening shows that the *R. Nepalensis* contains various constituents *viz*., sterols, amino acids, quercetin, alkaloid, phenolic components, flavonoids, triterpenoids, stilbene glycosides, tannic acid, saponins, resveratrol, anthraquinone glycosides, anthraquinone, vitamin C, some cardiac glycoside, naphthalene's and many more [8,12,16]. The foundations of modern drugs are based on these natural compounds. In North Western Himalaya, *R. Nepalensis* is a high value medicinal herb due to its high anthraquinone content [17]. *R. Nepalensis* has shown purgative, antioxidant, antifungal, antibacterial, antihistaminic, anticholinergic, antibradykinin ant prostaglandin, antipyretic, anti-inflammatory, antialgal, insecticidal [8, 18-20], analgesic and CNS depressant properties. The plant is also reported to possess skeletal muscle relaxant activity [21]. The present review provides a survey of the current state of knowledge of the Ethnopharmacology, Phytochemistry, pharmacological activities, toxicity and safety of *R. Nepalensis*, as well as their traditional uses which have been supported by pharmacological investigations in order to identify their relevance as food and potential therapeutic applications and to show further directions of research.

**Dissemination of *Rumex nepalensis***

*R. Nepalensis* grows in parts of China, Afghanistan, India, Indonesia, Japan, Myanmar Nigeria, Nepal, Pakistan, Tajikistan, Vietnam, South-west Asia, Turkey, Bhutan and South Africa. It grows abundantly in many parts of India. It is widely distributed throughout Himalayas from Bhutan to Kashmir. It is a fairly common plant of higher altitudes and grows between 900-4000 m on moist as well as dry slopes, under shades, and even in plains [8], Western Ghats, Nilgiri, Pulney hills, Nainital hills and Palni hills at altitudes between 1200-4 300 m. R. nepalensis shows flowering from April to May; fruiting from June to July [21-23]. A plant of the warm temperate to tropical zones, usually at higher elevations in the tropics. Succeeds in most soils but prefers a deep fertile moderately heavy soil that is humus-rich, moisture-retentive but well drained and a position in full-sun or part shade [24].

**Morphological Description**

Herbs are perennial with long tap roots, erect stems (50- 100 cm tall) which are branched, glabrous, grooved, green or pale brown in color. Basal leaves: petiole 4-10 cm; leaf blade broadly ovate, 10-15 × 4-8 cm, both surfaces glabrous or abaxially minutely papillate along veins, base cordate, margin entire, apex acute; cauline leaves shortly petiolate, ovate-lanceolate; ocrea fugacious, membranous, inflorescence paniculate. Flowers bisexual. Pedicel articulates below middle. Outer tepals elliptic, ca. 1.5 mm; inner tepals enlarged in fruit; valves broadly ovate, 5-6 mm, valves all or 1 or 2 with tubercles, base truncate, each margin with 7 or 8 teeth, apex acute; teeth 1.5-3 mm, apex hooked or straight. Achenes brown, shiny, ovoid, sharply trigonous, ca. 3 mm, base truncate, apex acute [25]. Part of this plant which is used in its propagation is seed. Vashistha *et al*. [26] studied the phenological observations of this plant and found that the growth initiation occurs in May, senescence occurs in October, wherein flowering (reddish) occurs in between June and July flower, and fruiting takes place from August to September[27].

**Anatomical studies**

**Leaf**

In leaves epidermis is single layered. Irregular epidermal cells with undulating walls are restricted to abaxial surface. Thick and pitted walls have been noted only along with the presence of crystalliferous cells in epidermis [28]. The cells are spherical. Mesophyll is elongated. Collenchyma and sclerenchyma is absent. Endodermis is single layered. Pericycle is oval and single layered. Xylem is oval and phloem is spherical, whereas pith is absent [29].

**Stomata**

Stomata are distributed on both leaf surfaces [28]. Stomata in the upper epidermis of this plant are paracytic and anisocytic, and in the lower epidermis are anisocytic. The percentage of the open and close stomata in the upper epidermis of R. nepalensis is 42 and 58, and that of the lower epidermis is 30 and 70 [30].

**Trichomes**

Glandular trichomes could be considered facultative salt glands and they may be part of apparatus of dispersion of extreme radiation. Non glandular trichomes are totally absent, while glandular trichomes are peltate and 1-4 celled centrally [28].

**Roots**

Epidermis in roots is single layered. Polygonal shape parenchyma is compactly packed. Collenchyma and sclerenchyma is absent. Endodermis is single layered. The cells of endodermis are elongated. Pericycle is single layered having spherical shape. Xylem is oval shaped, phloem and pith is spherical. Stone cells are absent [29].

**Stem**

Epidermis in stem of R. nepalensis is single layered and shape is oval. Collenchyma is present which is spherical in shape. Sclerenchyma is absent. Single layered endosperm is present. The cells are oval. Pericycle is single layered and spherical in shape. Xylem is oval shaped, phloem and pith is spherical. Mean length and width of the cell in R. nepalensis is 52.1 μm and 16.9 μm, respectively. Stone cell is absent in stem [29].

**Petiole**

Epidermis is single layered. The cells are oval in shape. Parenchyma is compactly packed. It is spherical. Collenchyma is present and is spherical in shape. Mean length and width of the cell 50.1 μm and 23.9 μm. Sclerenchyma is absent. Endodermis is single layered. The cells are oval in shape. Pericycle is single layered and spherical. Xylem is oval in shape. Phloem is spherical. Pith is spherical in shape in R. Nepalensis [29].

**Pollen**

Pollen grains usually tricolpate and tetracolpate, circular in shape. The size of pollen grain (polar axis × equatorial diameter) reported is (24×22) μm. The pollen is radially

symmetrical and isopolar. Under scanning electron microscope, tectum can be seen as perforate punctate in *R. Nepalensis* [31].

**Plant Development and Flexibility**

*R. Nepalensis* is herb that grows in fertile areas that is rich in nitrogen. The plant is palatable to cattle and is high in fibre and nutrition [32]. Reports revealed that enzymatic activities of this plant related to carbon metabolism such as aspartate aminotransferase (EC 2.6.1.1), ribulose-1,5-bisphosphate carboxylase / oxygenase (EC 4.1.1.39), phosphoenolpyruvate carboxylase (EC 4.1.1.31) and glutamine synthetase (EC 6.3.1.2) increased with altitude *viz*. 1 300, 2 250, and 3 250 m. The elevated oxygenase activity of ribulose-1,5-bisphosphate carboxylase/ oxygenase in *R. Nepalensis* supports its role in protection against photo oxidative damage. These enzymatic alterations also provide adaptive advantage to plant in order to conserve carbon and nitrogen at high elevation [33]. When R. nepalensis is exposed to CO2 to assess its effect on their growth, it is found that elevated CO2 (EC) has been reported to enhance vegetative growth and biomass accumulation through enhanced photosynthetic activity in annual C3 plants. Therefore, elevated CO2 significantly stimulates the growth and biomass through increased plant height, leaf number and area [34].

**Uses in Traditional Medicine**

*R. Nepalensis* has served as the basis of traditional medicine systems in India, Nigeria, China and Indonesia. *R. Nepalensis* is used for various therapeutic purposes and is well known in Indian traditional medicine. Plant of *R. Nepalensis* is consumed fried in olive oil or sautéed with butter or lard or are used as filling for pie [35]. The leaves of this plant are diuretic, astringent and demulcent. It also soothes the irritation caused by Urtica dioica L. [36]. This plant is used for treatment of scurvy as it is rich in vitamin C [37] and also for treatment of rheumatism [21]. Infusion of leaves is purgative [38], the juice of the leaves is applied externally to relieve headache and also used for its astringent qualities [39]. Its leaf extract has antiseptic properties and is used to stop bleeding. It is also used against allergy caused by leaves of *Acacia nilotica* (L.) Willd ex Delile [40] and also for the treatment of syphilic and colic ulcers [8]. Leaf extract is applied to cure skin sores. Aqueous extract is used as wash for reducing body pain. Leaf powder mixed with butter is used to treat scabies [41, 42]. Infusion of leave is used in dysmenorrhoea and stomach ache [43, 44]. Crushed leaf extract is applied externally on cuts, boils, blisters and wounds as an anti-allergic [42, 45, 46]. This plant is also used to treat skin infections in Jimma [47]. *R. Nepalensis* acts as a favourite source of fodder for cows, horses and sheep [9, 48]. Leaves are crushed and solution is made and used as pesticide to kill pests. Also leaves are crushed and paste is made with milk, churned curd, or with the urine of cow, and applied on the area around the snake bite on the body [46]. The fresh young leaves of *R. Nepalensis* are rubbed over the affected areas after injury from stinging nettles [49]. Root juice of *R. Nepalensis* is orally given on empty stomach as an effective cure for jaundice [50, 51]. The roots of plant are traditionally used for the treatment of pain, inflammation [52], bleeding, constipation and tinea in Chinese folk medicine [8]. The pounded root is given to animals in case of diarrhoea [43] and dysentery [41, 42]. The root of *R. Nepalensis* is also used as an astringent [36], purgative [19, 53]. A decoction is applied to dislocated bones and to reduce body pain. A paste of the root is applied to swollen gums, pimples and ringworm [39, 52, 54] and applied externally to relieve headache [8, 55, 56]. Methanolic root extract is applied in joint pain, paralysis and significantly possesses hypotensive effect and also shows property of muscle relaxant and tranquilizer activity [57]. Traditional medicine practitioners of Bale used R. nepalensis to treat diarrhoea, blackleg and swelling. In Ethiopia this plant is used to treat colic in livestock and as an antidote for poisoning as well as a laxative [58]. The roots of the plant have been used in folklore medicine to relieve mental tension and disturbance [49]. Root is crushed and the juice is applied on the scalp to prevent hair loss [46]. Half spoon of the grounded floral parts and root extract is used to cure joint pain. It also cures body ache. Roots grounded powder is applied on burned body part to avoid infection and for immediate healing [59]. The roots of plant are also used in traditional Chinese medicine for the treatment of emostasis [60]. Crushed fresh root and leaf with water is taken orally to treat tonsillitis [61]. In South Africa strong decoction of leaf in tablespoon doses 3 times daily to treat bilharziasis [62].

**Phytochemical constituents**

*R. Nepalensis* has been reported to contain phytochemicals like phenols, flavonoids, anthraquinones, naphthalenes, saponins, cardiac glycosides, stilbene glycosides, triterpenoids, anthraquinone glycosides, tannic acid and sterols, tannins, steroids, reducing sugar, saponin and sitosterols. Investigation of the *n*-butanolic extract of the roots of *R. nepalensis* yielded two *seco* anthraquinone glucosides, nepalensides A and B and the seco nor derivative aloesin. The *seco*-anthraquinones are probably formed by the decomposition and oxidation of the anthraquinones chrysophanein and pulmatin [60]. Emodin, Chrysophanol, physcion, citreoresin, endocrocin, emodin-8-*O*-*β*-D-Glucopyranoside, chrysophanol – 8 – *O* – *β* D Glucopyranoside, chrysophanol -8-*O*-*β*-D-(6'-*O*acetyl) glucopyranoside and emodin-8-*O*-*β*-D-(6'-*O*-acetyl) glucopyranoside, were isolated from the roots of *R. Nepalensis* [63]. From the roots of *R. nepalensis*, aloesin, rumexoside, orientaloside and torachrysone were isolated by [60]. Later, Gautam *et al*. reported nepodin and its glucoside from the plant [64]. Liang *et al*. identified nepodin-8-*O*-β-Dglucopyranoside, torachrysone, torachrysone-8-*O*-β-D-glucopyranoside and two naphthalene acylglucosides, rumexneposides A and B and Epicatechin and epicatechin-3-*O*-gallate were then detected in the roots of the plant [60]. An investigation of the EtOAc fraction of *R. nepalensis* roots and the ethanolic extract of *R. hastatus* roots also resulted in the isolation of resveratrol [65], From the roots of *R. nepalensis*, (3,5-dimethoxy-4-hydroxyphenol)-1-*O*-β-D-(6-*O*-galloyl) glucose, orcinol-glucoside, a lignan derivative, lyoniresinol 3α-*O*-β-D-glucopyranoside was isolated [60]. It is reported that anthraquinones have several pharmacological properties like antifungal, anti-inflammatory, antioxidant and anticancer, whereas naphthalene derivatives possess anti-inflammatory and antioxidant activities [3].

**Pharmacological properties**

Researchers reported the different pharmacological activities of R. nepalensis, which are discussed in the following sections.

**Antioxidant activities**

Several studies showed the antioxidant activity of *R. nepalensis*. Water, ethyl acetate, ethanol, methanol, acetone extracts of this plant has been shown to have antioxidant

properties. *In vitro* assays such as 2,2'-azinobis (3-ethylbenzothiazoline-6-sulphonic acid (ABTS), 2,2-diphenyl-1-picrylhydrazyl (DPPH), superoxide, hydroxyl and nitric oxide radical scavenging were employed to evaluate free radical scavenging and antioxidant potential of methanol, water and acetone extracts [66]. The components of ethanolic, chloroform and ethyl acetate extracts are inhibitors of DPPH radical [67], and also are reported to scavenge the NO radical, inhibite the lipid-peroxidation and also chelate the metal ions [68]. Bhattacharya *et al*. [69] evaluated antioxidant potentials of *in vitro* propagated plants of R. nepalensis, with highest activities in plants obtained through indirect shoot organogenesis. The antioxidant effects (DPPH and ABTS) of the chloroform and ethyl acetate extracts of *R. nepalensis* root were evaluated. Both fractions contained phenolic compounds, but their level was higher in the ethyl acetate extract (27.71%) than in the chloroform extract (8.20%). Trolox (IC50 = 15.7 µM in the case of DPPH, and 16.2 µM in the case of ABTS) and ascorbic acid (IC50 = 22.4 µM in the case of DPPH, and 25.5 µM in the case of ABTS) were used as positive controls. These extracts contained anthraquinones and naphthalenes too. The higher radical scavenging activity could be due to the phenolic content (in the case of the ethyl acetate extract) and the presence of nepodin (in the case of the chloroform extract) [64].

**Antitumour activity**

A cytotoxic assay of emodin, chrysophanol, physcion, citreoresin, emodin-8-*O*-*β*-D-glucopyranoside, aloesin nepalensides A and B, rumexneposides A and B and (3,5-dimethoxy-4-hydroxyphenol)-1-*O*-β-D-(6-O-galloyl)-glucose ect, isolated from *R. nepalensis* and *R. hastatus* was performed against A549, H522 (lung cancer), MCF-7, MCF-10A and SKBR3 cancer cell lines by using the MTT method, with cisplatin as positive control. Compounds exhibited marked activities [64]. A recent study on cytotoxicity of methanolic root extracts of R. nepalensis against Artemia salina has been reported. It was reported that 1 000 µg/mL concentration of methanolic root extracts showed significant cytotoxic activity against Artemia salina and the phytotoxicity activity against Lemna minor[56].

**Anti-inflammatory activities**

We can associate inflammation with several acute and chronic diseases which have been a matter of concern for mankind. The ethanolic root extract of R. nepalensis showed activity against carrageenan induced rat paw edema, comparative to the standard anti-inflammatory drug diclofenac [69]. Anti-inflammatory activity of chloroform and ethyl acetate root extracts against ear edema was evaluated in a 12-O-tetradecanoylphorbol-13-acetate (TPA)-induced acute inflammation mouse model and found significant reduction in ear edema [65]. HPLC analysis of root revealed the presence of nepodin and chrysophanol [71] which showed significant cyclooxygenase inhibitory activity. Aqueous and alcoholic leaf extract was reported to reduce size of the wheal produced by bradykinin, histamine, carbachol and acetylcholine, which indicate that this plant has antibradykinin, antihistaminic and anticholinergic activity [6].

**Antimicrobial activity**

**Antibacterial activities**

In an investigation, methanolic leaf extract of R. nepalensis showed potential activity against pathogenic bacterial strains such as Escherichia coli, Bacillus subtilis, Pseudomonas aeruginosa and Bacillus cereus [18]. Antibacterial activities of methanolic root extracts of this plant against Pseudomonas aeruginosa, Salmonella typhi, Enterobacter aerogenes, Citrobacter freundii were studied by Hussain *et al*. Highest activity was observed against E. coli and Staphylococcus aureus [71]. The leaves stem and root extracts were also investigated for their activity against Proteus vulgaris, Salmonella sp. (MTCC), Rhodococci sp., Bacillus stearothermophilus [39], Streptococcus mutans [42], Streptococcus pyogenes [47] and S. aureus [67]. Ghosh *et al*. reported antibacterial property of methanol extract against Bacillus subtilis, S. aureus, Vibrio cholerae, E. coli and Shigella dysenteriae. Aloe-emodin is reported to possess antibacterial activity [72]. The compounds isolated from *R. nepalensis* were investigated against *Mycobacterium tuberculosis* exhibited potent inhibitory activity. Isoniazid was used as positive control. Moreover, torachrysone displayed significant inhibitory activity against the *p*-aminobenzoic acid pathway [63].

**Antiviral activity**

Methanol root extract of R. nepalensis exhibited inhibitory action against RNA polymerase of hepatitis C virus. Extracts inhibited HCV-RdRp by 77.9% at a concentration of 50 µg/ml, and extract contained a high percentage of tannin [73]. Leaves showed anti-HIV activity [74]. Extract obtained from the leaves of *R. bequaertii* (syn. *Rumex nepalensis* Spreng.) (SI > 11; EC50 = 17.7 µg/mL; CC50 > 200.0; 89% protection against HIV-induced cytopathic effect) [75].

**Antifungal activity**

It is reported that the methanolic leaf extract showed potential activity against pathogenic fungi such as Candida albicans [23], Aspergillus niger, Aspergillus flavus [18]. Methanolic root extract showed higher activity against Aspergillus niger and moderate activity against Aspergillus flavus and Alternaria solani [76]. It is also reported that the ethanolic extracts of root of R. nepalensis were significantly active against the fungal pathogens such as, Avicularia versicolor, Fusarium moniliforme, Fusarium semitectum, Fusarium solani, Pythium sp., Rhizopus sp., Sporotrichum sp., Thermomyces sp.[44].

**Antidiabetic activity**

Yang *et al*. showed that anthraquinone derivatives (chrysophanol, emodin, physcion, nepalenside A and nepalenside B) from R. nepalensis could significantly inhibit the secretion of IL-6 at 10 µM concentration. It is investigated that compounds (chrysophanol, emodin, physcion, and nepalenside A) inhibit production of extracellular matrix that could considerably decreases fibronectin and collagen IV production at 10 µM concentration and this concentration is not cytotoxic. This suggests that anthraquinone derivatives are valuable assets to optimize anti-diabetic nephropathy drug [77].

**Psychopharmacological activity**

The methanol extract of *R. nepalensis* was assessed for different psychopharmacological activities in rats and mice. The pharmacological results indicated that the methanol extract of *R. Nepalensis* appears to have an influence on alterations in general behavioural profiles, including alertness, awareness, spontaneous activity, touch, pain and sound responses. The extract significantly potentiated the duration of phenobarbital sodium-induced sleeping time in mice at 200

and 400 mg/kg, suggesting probable tranquillizing and CNS depressant action. Possible effects were examined on other test systems too, e.g. the exploratory behavioural pattern and muscle relaxant activity. Finally, it was concluded that the methanol extract of *R. nepalensis* possessed most of the pharmacological activities characteristic of minor tranquillizers [78].

**Purgative activity**

The methanol extract of *R. nepalensis* root was investigated for its purgative effect in rats. Bisacodyl (3.5 mg/kg) was used as a standard. At oral doses of 100–400 mg/kg, the extract exhibited significant and dose-dependent purgative activity by increasing the intestinal peristalsis and gastrointestinal motility [53].

**Anti-algal activity**

Yi *et al*. screened root extract of R. nepalensis for antialgal activity against the cyanobacterium Microcystis aeruginosa. Coexistence culture system assay reported that remarkable inhibition of the algae with inhibitory rate of 24.4% [57]. This data suggest that this plant has significant anti-algal activity.

**Insecticidal activity**

The methanolic root extracts of R. nepalensis show significant insecticidal activity against Sitophilus oryzae. R. nepalensis methanolic extract also showed high mortality rate against Rhyzopertha Dominica, *Callosobruchus analis* and Trogoderma granarium [71].

**Wound healing activity**

Leaf extract of R. nepalensis was mixed with Vaseline or butter and applied to the wounds. Antibacterial and antipyretic activity of R. nepalensis further justifies its use in traditional medicine to cure wounds [45, 47, 79, 80].

**Conclusion and Future Perspectives**

The aim of this review was to enlighten the valuable application of this unique and valuable plant species. It carries high nutritional and medicinal values for humans and animals. The literature was analyzed to congregate the phytochemical and pharmacological information on R. nepalensis, which reaffirmed that this plant is a good source of phytocomplexes and medicinally important pure compounds for treatment of various diseases. R. nepalensis demonstrated various medicinal, pharmacological and phytoremediation activities which gives immense importance to this herb. However, further clinical trials should be performed to verify efficacy and any side effects or toxicity of purified plant extracts. It is essential to conduct in-depth and comprehensive pharmacological studies at molecular level to investigate unexploited potential of this plant. For these reasons, wide pharmacological and chemical studies, together with human metabolism, might be the focus of future studies. Besides, the isolation of pure compounds with pharmacological activities and deciphering the underlying mechanisms holds significance in contemporary and future research. This plant could also be improved, through the use of conventional breeding techniques and genetic engineering approaches for metal tolerance, or the metabolism of organic chemicals. Therefore, there is huge room for research in these directions.

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