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A critical review on Nepal Dock (*Rumex nepalensis*): A tropical herb with immense medicinal importance

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ABSTRACT

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 exhibits pharmacological activities including anti-inflammatory, antioxidant, antibacterial, antifungal, antiviral, insecticidal, purgative, analgesic, antipyretic, anti-algal, central nervous system depressant, genotoxic, wound healing and skeletal muscle relaxant activity. 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 critical account of its botany, ecology, traditional uses, phytoconstituent profile and major pharmacological activities reported in recent years and therefore will provide a source of information on this plant for further studies.

1. Introduction

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 phytocomplex, 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 phytocomplex. 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.

The genus *Rumex* consists of about 250 species of herbs[1]. *Rumex nepalensis* Spreng. (*R. nepalensis*) belongs to family Polygonaceae

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and is a perennial, ascending herb[2], commonly known by the name 'Nepal dock', and vernacular names are given in Table 1. Though *R. nepalensis* is an agricultural weed but this "wild plant" is not really "unwanted" in the arena of traditional herbal medicines[12,19,20]. 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[21]. The young shoot is also locally eaten as a cooked vegetable[22]. This plant is also used as a colouring agent (dye)[23]. Green colour from the leaves of plants is often used in sweet preparations[16].

Table 1

Vernacular names of *R. nepalensis*.

Language	Vernacular name	Reference
English	Sheep sorrel, Nepal duck	[3,4]
Hindi	Amlya, Jangli palak, Amlora, Bhilmora, Malori	[5,6]
Pangwali	Ubbal	[7]
Bengali	Pahari palang	[8]
Sanskrit	Amlavetasa	[3]
Pakistani	Shalkhay, Hoola	[9,10]
Nepali	Halhale sag, Ban haldi, Halya, Halye	[3,4,11]
Kashmiri	Aliphiri	[12]
Ethiopian	Girshu, Gorengoch, Bacharu, Timbilki, Lut	[13-15]
Uttarakhandi	Kathura	[16]
Bhangali	Albar	[17]
Manipuri	Torongkhongchak	[18]
Tamil	Sukkankeerai	[18]

Phytochemical screening shows that the *R. nepalensis* (jangli palak) contains various constituents *viz.*, triterpenoids, stilbene glycosides, tannic acid, saponins, resveratrol, sterols, amino acids, quercetin, alkaloid, phenolic components, flavonoids, anthraquinone glycosides, anthraquinones[2], vitamin C[21], some cardiac glycoside, naphthalenes, and many more[24]. 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 [25]. *R. nepalensis* has shown purgative, antioxidant, antifungal, antibacterial[5], antihistaminic, anticholinergic, antibradykinin antiprostaglandin[26], antipyretic, antiinflammatory, antialgal, insecticidal[2,6], analgesic and CNS depressant properties. The plant is also reported to possess skeletal muscle relaxant activity[27].

We are presenting this review with an aim to critically assess the available literature for its phytochemical profiles, its traditional medicinal usages, validation of these claims as well as other potent properties and uses of this highly medicinal herb, to provide the scientific community a source of information on this plant and future perspectives.

2. Classification and distribution of *Rumex nepalensis*

The genus *Rumex* is ubiquitous in habit thus distributing worldwide and belonging to family Polygonaceae [1]. *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[28]. 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 900-4 000 m on moist as well as dry slopes, under shades, and even in plains[2], Western Ghats, Nilgiri, Pulney hills, Nainital hills and Palni hills at altitudes between 1 200-4 300 m[27, 29]. *R. nepalensis* shows flowering from April to May; fruiting from June to July[28].

3. Botanical description

R. nepalensis is an erect plant 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 cm long and 4-8 cm wide), both the surfaces of leaf are glabrous or abaxially minutely papillate along veins, base cordate, margin entire, apex acute; cauline leaves shortly petiolate, ovate-lanceolate; ocrea fugacious, membranous, inflorescence paniculate with bisexual pedicellate flowers. 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[1,28]. Part of this plant which is used in its propagation is seed. Vashistha *et al*.[30] 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[30,31].

4. Discussion

4.1. 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[32]. 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[33].

4.2. 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[33].

4.3. 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[33].

4.4. 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*[33].

4.5. Stomata

Stomata are distributed on both leaf surfaces[32]. 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[34].

4.6. 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[32].

4.7. 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*[35].

5. Plant growth and plasticity

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[36]. 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 photooxidative damage. These enzymatic alterations also provide adaptive advantage to plant in order to conserve carbon and nitrogen at high elevation[37]. When *R. nepalensis* is exposed to CO_2 to assess its effect on their growth, it is found that elevated CO_2 (EC) has been reported to enhance vegetative growth and biomass accumulation through enhanced photosynthetic activity in annual C3 plants. Therefore, elevated CO_2 significantly stimulates the growth and biomass through increased plant height, leaf number and area[38].

6. Uses in traditional medicine

For thousands of years, *R. nepalensis* has served as the basis of traditional medicine systems in Nigeria, India, China and Indonesia. *R. nepalensis* is used for various therapeutic purposes and is well known in Indian traditional medicine. The leaves of this plant are diuretic, astringent and demulcent. It also soothes the irritation caused by *Urtica dioica* L.[10]. This plant is used for treatment of scurvy as it is rich in vitamin C[39] and also for treatment of rheumatism[27]. Infusion of leaves is purgative[1], the juice of the leaves is applied externally to relieve headache and also used for its astringent qualities[40]. 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[41] and also for the treatment of syphilic and colic ulcers[2]. 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[15,17]. Infusion of leave is used in dysmenorrhoea and stomach ache[42,43]. Crushed leaf extract is applied externally on cuts, boils, blisters and wounds as an anti-allergic [7,17,44]. This plant is also used to treat skin infections in Jimma[45]. *R. nepalensis* acts as a favourite source of fodder for cows, horses and sheep[12, 46]. Leaf is also used to treat ear infection [13]. 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[7]. The fresh young leaves of *R. nepalensis* are rubbed over the affected areas after injury from stinging nettles[47].

Root juice of *R. nepalensis* is orally given on empty stomach as an effective cure for jaundice [48, 49]. The roots of plant are traditionally used for the treatment of pain, inflammation[4], bleeding, constipation and tinea in Chinese folk medicine [2]. The pounded root is given to animals in case of diarrhoea[42] and dysentery [15,17]. The root of *R. nepalensis* is also used as an astringent[10], purgative[6,8] and is used as a substitute for rhubarb (*Rheum* species[50]. 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 [4,40,51], and applied externally to relieve headache[2,52,53]. Methanolic root extract is applied in joint pain, paralysis and significantly possesses hypotensive effect and also shows property of muscle relaxant and tranquilizer activity[3]. 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[54]. The roots of the plant have been used in folklore medicine to relieve mental tension and disturbance[47]. Root is crushed and the juice is applied on the scalp to prevent hair loss[7]. 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[55]. The roots of plant are also used in traditional Chinese medicine for the treatment of hemostasis[56]. Crushed fresh root and leaf with water is taken orally to treat tonsillitis[57].

7. Phytochemical constituents

R. nepalensis has been reported to contain pytochemicals like phenols, flavonoids, anthraquinones, naphthalenes[2], saponins, cardiac glycosides, stilbene glycosides, triterpenoids, anthraquinone glycosides, tannic acid and sterols[6], tannins[43], steroids, reducing sugar, saponin[58] and sitosterols[3].

Further, two new naphthalene acylglucosides, *R. neposides* A and *R. neposides* B, along with other compounds in chrysophanol (1,8-Dihydroxy-3-methyl-9,10-anthraquinone), chrysophanol-8-*O*-β-D-glucopyranoside, chrysophanol-8-*O*-β-(6'-*O*-acetyl)-glucopyranoside[59], emodin-8-*O*-β-D-glucopyranoside, emodin (6-methyl-1,3,8-trihydroxyanthraquinone), citreorosein, resveratrol, nepodin-8-β-D-glucopyranoside, torachrysone-8-*O*-β-D-glucopyranoside, physcion and torachrysone[6] are reported from this plant[3,6,10,56,58]. 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[58]. The summarized phyto-constituent components are listed in Table 2.

Table 2

Phytoconstitutent components reported from *R. nepalensis.*

Phytoconstituent compounds	Extraction	Plant part	Technique	Country	Reference
Anthraquinones (1)Emodin glycoside (2)Emodin (3)Chrysophanol glycoside (4)Chrysophanol	Soxhlet extraction with methanol	Roots	HPLC	India	[2]
Nepalenside A Nepalenside B	Ethanol with reflux	Roots	NMR NMR	China	[10]
Chrysophanein Pulmatin	*n*-butanol with reflux	Roots	HPLC	Hungary	[47]
(1)Chrysophanol-8-*O*-β-D glucopyranoside (2)Chrysophanol-8-*O*-β-D(6'- O –acetylglucopyranoside (3)Emodin-8-*O*-β-D -(6-O-acetyl)glucopyranoside	Ethyl acetate with ultra-sonication	Roots	HPLC	China	[47]
(1)Torachrysone (2)Rumexoside (3)Orientaloside (4)Orcinol glucoside (5)Aloesin (6)Lyonorecinol 3-*O*-β-D-glucopyranoside (7) (-)-epicatechin	*n*-Butanol	Roots	IR absorption NMR ESI/MS	China	[56]
(vinyloxy)benzene	Ethyl acetate	Roots	GC-MS	Nepal	[61]
Benzeneacetic acid	Ethyl acetate	Roots	GC-MS	Nepal	[61]
Indole	Ethyl acetate	Roots	GC-MS	Nepal	[61]
*(1-iodo)Tridecane	Ethyl acetate	Roots	GC-MS	Nepal	[61]
p-Terphenyl	Ethyl acetate	Roots	GC-MS	Nepal	[61]
1-Octadecene	Ethyl acetate	Roots	GC-MS	Nepal	[61]
Pentadecanoic acid	Ethyl acetate	Roots	GC-MS	Nepal	[61]
*Bis(2-methylpropyl)ester 1,2-Benzenedicarboxylic acid	Ethyl acetate	Roots	GC-MS	Nepal	[61]
1Z2z-1,2-bis(3,5,5-trimethylcyclohex-2-en-1-ylidene)hydrazine	Ethyl acetate	Roots	GC-MS	Nepal	[61]
7-hydroxy-2,5-dimethyl 4H-1-Benzopyran-4-one	Ethyl acetate	Roots	GC-MS	Nepal	[61]
1-(1-hydroxy-3-methoxynapthalen-2-yl)ethan-1-one	Ethyl acetate	Roots	GC-MS	Nepal	[61]
Cis -Vaccenic acid	Ethyl acetate	Roots	GC-MS	Nepal	[61]
(*E*)-3-Ecosene	Ethyl acetate	Roots	GC-MS	Nepal	[61]
(3-methyl)Anthracene-1,8,9-triol	Ethyl acetate	Roots	GC-MS	Nepal	[61]
1-Tricosene	Ethyl acetate	Roots	GC-MS	Nepal	[61]
*1-Iodo-2-isopropylbenzene	Ethyl acetate	Roots	GC-MS	Nepal	[61]
Glycosides (1)Chrysophanol-8-*O*-β-D-glucopyranoside (2)Neopodin-8-*O*-β-D-glucopyranoside (3)Emodin-8-*O*-β-D-glucopyranoside	By Methanol with reflux method followed by ultracentrifugation	Roots	HPLC	India	[62]
Aglycones (1)Neopodin (2)Chrysophanol (3)Emodin (4)Physcion	By methanol Ultrasonication in presence of the solvent	Roots	HPLC	India	[63]
Neopodin	Ethyl acetate	Roots	NMR	India	[64]

8. Nutritional and elemental compositions

8.1. Elemental analysis

In *R. nepalensis,* elements like O, Si, C and K are reported from all plant organs, whereas, Na in stems and leaves, Mg in petioles and

flowers, Si in stems, Cl in stems, leaves, petioles and flowers, Ca in roots, petioles and flowers, Fe in petioles and Al is found in all plant organs except in roots and flowers[52]. Hameed *et al*.[65] reported 19.1% fats and oils in flowers whereas stem contains 18.69%. Further, authors reported the plant as highly fibrous as fruits 50.83% fibers while flowers contain 48.43% fibers[65].

8.2. Fatty acids profile

R. nepalensis is used as a fodder to feed animals. Khan *et al*.[66] studied the fatty acid content in *R. nepalensis* and also studied the effect of harvest maturity on fatty acid profile. Authors reported that linolenic acid, palmitic acid and linoleic acid are the main fatty acids FAs contributing the major part of the total fatty acid content. The content of palmitic acid, linoleic acid and linolenic acid decreased with maturity[66].

9. Pharmacological properties

Researchers reported the different pharmacological activities of *R. nepalensis*, which are presented in Figure 1 and discussed in the following sections.

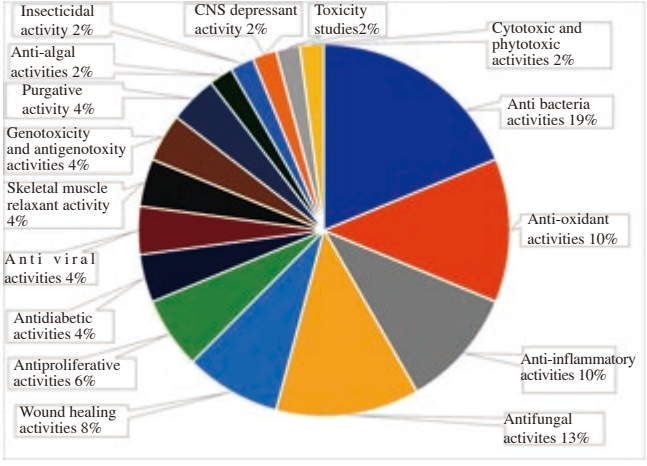

Figure 1. Various pharmacological activities reported from *R. nepalensis*.

9.1. Anti-inflammatory activities

We can associate inflammation with several acute and chronic diseases which have been a matter of concern for mankind. In the western Nepal, *R. nepalensis* is used ethno-medicinally for the relief from pain and several inflammatory conditions. The ethanolic root extract of *R. nepalensis* showed activity against carrageenan induced rat paw edema, comparative to the standard anti-inflammatory drug diclofenac[62]. 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[58] and found significant reduction in ear edema[58]. HPLC analysis of root revealed the presence of nepodin and chrysophanol[63] which showed significant cyclooxygenase inhibitory activity. Thus, the anti-inflammatory effect of root of this plant is assumed to be mediated through cyclooxygenase inhibition by naphthalene and anthraquinone derivative[69]. 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[13].

9.2. 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'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid ($ABTS^{\cdot+}$), 2,2-diphenyl-1-picrylhydrazyl ($DPPH^{\cdot}$), superoxide, hydroxyl and nitric oxide radical scavenging were employed to evaluate free radical scavenging and antioxidant potential of methanol, water and acetone extracts[67]. Plant also showed metal ion chelating capacity. Highly reactive metal-ions like ferrous ions play crucial role in induction of lipid oxidation. Ferrozine assay was used to estimate chelation of ferrous ion by the plant extracts. Ferrozine assay is a colorimetric sensitive, cheap, and reliable method for the quantitation of intracellular iron and for the investigation of iron accumulation in cultured cells. These extracts contain significant amount of flavonoids, phenolics, vitamin C and tannin which showed inhibitory ability against the free radicals, thus aging related diseases will be prevented by these vegetables[67]. The components of ethanolic, chloroform and ethyl acetate extracts are inhibitors of $DPPH^{\cdot}$ radical[61], and also are reported to scavenge the NO radical, inhibite the lipid-peroxidation and also chelate the metal ions[62]. Gautam *et al*.[58] isolated six anthraquinones and two naphthalene derivatives from ethyl acetate extract of *R. nepalensis*, and out of the isolated compounds, emodin (6-methyl-1,3,8-trihydroxyanthraquinone) and nepodin (1-(1,8-dihydroxy-3-methyl-2-naphthyl)-ethanone were identified as a potent cyclooxygenase inhibitors along with significant anti-inflammatory activities in mice. Interestingly, nepodin showed better radical scavenging activities than Trolox and ascorbic acid. This may be because of well-characterized strong antioxidant potentials of naphthalene derivatives[58]. Further, Bhattacharya *et al*.[68] evaluated antioxidant potentials of *in vitro* propagated plants of *R. nepalensis*, with highest activities in plants obtained through indirect shoot organogenesis.

9.3. Antiproliferative activities against cancerous cells

A cytotoxic test of compounds from *R. nepalensis* was conducted against SKBR3, H522, MCF-10A, MCF-7, and A549 cancerous cell lines, chrysophanol-8-*O*-β-D-glucopyranoside: IC_{50}=9.6 μM (MCF-10A); resveratrol: IC_{50}=29.4 μM (MCF-7), 12.3 μM (MCF-10A) and 27.8 μM (A549); orientaloside: IC_{50}=29.0 μM (A549), 38.7 μM (H522), 7.6 μM (MCF-10A) and 19.9 μM (SKBR3); and *rumex neposide* A: IC_{50}=31.0 μM (A549), 22.8 μM (MCF-10A), 15.7 μM (H522), 21.8 μM (MCF-7) and 20.7 μM (SKBR3)][10].

Tauchen *et al*.[15] investigated antiproliferative activity of *R. nepalensis* and significant antiproliferative action against carcinoma cell lines (Hep-G2) was shown by root extract of this plant with IC_{50} of 50.5 μg/mL which is considered as potent. Though the authors did not compare their results with known/standard anticancer agent as positive control, and more such studies to validate the antiproliferative activities of the crude extracts and pure compounds from this plant are necessary. Anthraquinone and naphthalene derivatives isolated from this plant have shown significant antiproliferative properties against various carcinoma cell lines *via in vitro* assays. Emodin exhibits antitumour and antileukaemic properties while physcion has shown cathartic properties[54]. Therefore, this plant seems to serve as prospective material for further development of novel plant-based antiproliferative agents.

9.4. Anti-diabetic activities

Diabetic nephropathy is a kidney disease which is also main problem of diabetes. Main reason in the progression of diabetic nephropathy is the overproduction of extracellular matrix in renal cells and chronic inflammation. Yang *et al*.[69] 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[69].

9.5. Antibacterial activities

R. nepalensis has been extensively used to cure bacterial infections[70]. In an investigation, methanolic leaf extract of *R. nepalensis* showed potential activity against pathogenic bacterial strains such as *Escherichia coli (E. coli), Bacillus subtilis, Pseudomonas aeruginosa* and *Bacillus cereus*[5]. Antibacterial activities of methanolic root extracts of this plant against *Pseudomonas aeruginosa*, *Salmonella typhi*, *Enterobacter aerogenes*, *Citrobacter freundii* were studied by Hussain *et al*.[71]. Highest activity was observed against *E. coli* and *Staphylococcus aureus* (*S. aureus*)[71]. The leaves stem and root extracts were also investigated for their activity against *Proteus vulgaris, Salmonella* sp. (MTCC), *Rhodococci* sp., *Bacillus stearothermophilus*[40], *Streptococcus mutans*[17], *Streptococcus pyogenes*[45] and *S. aureus*[61]. The compounds isolated from *R. nepalensis* is also investigated against *Mycobacterium tuberculosis*; among them, torachrysone, nepodin-8-*O*-β-D-glucopyranoside, chrysophanol-8-*O*-β-D-(6-O-acetyl) glucopyranoside aloesin, torachrysone-8-*O*-β-D-glucopyranoside, (-)-epicatechin-3-*O*-gallate and rumexneposide A exhibited potent inhibitory activity[10]. Ghosh *et al*.[60] 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[60].

9.6. Antifungal activities

It is reported that the methanolic leaf extract showed potential activity against pathogenic fungi such as *Candida albicans*[29], *Aspergillus niger*, *Aspergillus flavus*[5]. Methanolic root extract showed higher activity against *Aspergillus niger* and moderate activity against *Aspergillus flavus* and *Alternaria solani*[70]. It is also reported that the ethanolic extracts of root of *R. nepalensis* were significantly active against the fungal pathogens such as *Aspergillus fumigatu, Avicularia versicolor, Fusarium moniliforme, Fusarium semitectum, Fusarium solani*, *Pythium* sp., *Rhizopus* sp., *Sporotrichum* sp., *Thermomyces* sp.[43]. Anthraquinones possessed antifungal activity[63].

9.7. Antiviral activities

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 [72]. Leaves showed anti-HIV activity[73].

9.8. Anti-algal activity

Yi *et al*. 2012 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% [3]. This data suggest that

this plant has significant anti-algal activity.

9.9. 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, Callosbruchus analis* and *Trogoderma granarium*[71].

9.10. 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[7,9,14,45].

9.11. Purgative activities

Reports suggested that the methanol extract of roots of *R. nepalensis* possess a purgative activity by increasing gastro-intestinal motility and intestinal peristalsis. Anthraquinones are reported to possess purgative activity[8]. Giday *et al*.[74] estimated fidelity level values to evaluate the curing potentials of *R. nepalensis* against human ailment (gastrointestinal complaints) which recorded the highest fidelity level values that is 100%[74].

9.12. Skeletal muscle relaxant activities

Methanol extract of roots of *R. nepalensis* showed muscle relaxant activity. By rotarod test, it was reported that the methanolic extract produced remarkable motor discoordination and skeletal muscle relaxant activity in animals[75]. Report suggested that the presence of tannins, steroids, anthraquinone, saponins, and reducing sugars in the plant extract. Thus, the credit for skeletal muscle relaxant properties may goes to these phytochemicals[15].

9.13. Central nervous system (CNS) depressant property

Effects of plant methanolic extract of root were investigated on central nervous system for exploratory behavioural pattern. Noticeable drop of exploratory behavioural pattern was seen in animal treated with extract. Like in case of mice treated with *R. nepalensis* extract exhibited noticeable drop in head dip responses as compared to diazepam[75].

9.14. Toxicity studies

Ghosh *et al*.[75] determined LD_{50} with extract in animal. On the basis of toxicity study, it was found that the methanolic extract (3.2 g/kg) of *R. nepalensis* root was not toxic to animal.

9.15. Cytotoxic and phytotoxic activities

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*[53].

10. Phytoremediation abilities of Rumex nepalensis

R. nepalensis possess ability to accumulate heavy metals. Nazir *et al*.[77] reported Cd accumulation in roots (1.5 mg/kg) and in shoots (1.9 mg/kg). Biological transfer coefficient value for Cd was more than one hence possessed the characteristic of hyperaccumulator[76]. Bahnika and Baruah[77] demonstrated that the plant can grow at contaminated places and they can fascinate the removal of Zn, Cu and Pb. Plant showed considerable accumulation of Pb, Cu and Zn (165.72 mg/kg, 23.38 mg/kg and 55.93 mg/kg respectively)[77]. Ni accumulation by plant growing along drains carrying effluents was also observed along with Ni accumulation in roots, stems and leaves at 417.36 mg/kg, 308.74 mg/kg and 634.47 mg/kg concentrations, respectively. Plant showed feasibility for the phytoextraction of Ni metal. The calculated bioconcentration factor is 8.32 and translocation factor is 1.12[78]. These studies indicate the abilities of this plant to accumulate and tolerate metals, which can be explored for phytoremediation means.

11. 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. Recently, the plant extract was also being used by the researchers to produce nanoparticles, but again more studies are required to use its potential *via* nanotechnologies[79]. 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.

Conflicting interest statement

Authors declare that they have no conflict of ineterst

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