Pharmacology and phytochemistry of the Nitraria genus (Review)

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Abstract. Plants from the Nitraria genus, members of the Zygophyllaceae family, grow naturally in Europe, Africa, Australia and the central Asian desert. Previous pharmacological research has provided evidence that members of the *Nitraria* genus have numerous beneficial effects. In the present review, the pharmacological and phytochemical studies of *Nitraria* were presented and assessed. The review was written using information published between 1968 and 2013 from a number of reliable sources, including ScienceDirect, Springer, PubMed, EMBASE and CNKI. Numerous compounds, such as alkaloids and flavonoids have been isolated from the plants of this genus in the past, and multiple members of these constituents have been demonstrated to exert antitumor or anti-oxidative activities. The extracts of plants of the Nitraria genus possess antitumor, antiproliferative, anti-oxidative, antifatigue, anti-mutagenic, antimicrobial, hypotensive, hepatoprotective, lipid-lowering and hypoglycemic effects. However, the possible active components in the fraction and the molecular mechanisms require further investigation prior to their use in clinical practice.

Contents

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1. Introduction

The Nitraria genus, a member of the family Zygophyllaceae, is one of the dominant species in the Mediterranean and central Asian deserts. The English name Nitre-bush is from the Latin word *saltpetre*, referring to the fact that it can thrive in saline soil. It serves an key ecological role due to its superior tolerance to severe drought and high salinity. Nitraria are shrubs 25-200-cm tall, with spiny branches at the apex and simple serrated leaves. The flowers are yellowish-gray or white, 2-4 cm pubescent, with five petals and five sepals, while the fruit is a fleshy drupe. The Nitraria genus consists of 13 species across the world, which are mainly distributed in Asia, Europe, Africa and Australia (Table I).

A growing body of evidence now demonstrates that Nitraria extract has numerous biomedical properties, including antifatigue, antitumor, anti-oxidative and antimutagenic activities. In addition, the fruit of *Nitraria sibirica* is extensively used to treat hypertension, menstrual disorders and gastroenteritis in folklore medicines of Northwest China (1,2). The leaves of *Nitraria retusa* also serve as supplement tea and are used as a poultice in Africa (3,4).

To provide further support and evidence for the clinical use of this genus, a systematic review of the modern phytochemical and pharmacological properties of Nitraria was performed. The available information on the pharmacology and phytochemistry of the Nitraria genus was collected via libraries and electronic searches using PubMed (http://www.ncbi.nim.nih.gov/pubmed), ScienceDirect (http://sciencedirect.com), Springer (http://springer.com), EMBASE (http://elsevier.com/online-tools/embase) and CNKI (http://www.cnki.net).

2. Phytochemical studies

Currently, the following six species of the Nitraria genus have been observed for their phytochemical properties: *N. komarovii, N. schoberi, N. sibirica, N. tangutorum, N. retusa* and *N. billardieri*. These investigations suggested that members of the Nitraria genus contain numerous components categorized as alkaloids, flavonoids and phenolic acid, of which alkaloids and flavonoids are the most abundant constituents. An overview of ingredients contained in the Nitraria genus is presented in Table II.

Numerous studies (5-36) have been conducted to explore the alkaloids contained in the members of the Nitraria

Table I. Species of the Nitraria genus and the geographical distribution.

No.	Species	Geographical distribution
1	*N. schoberi*	China, Europe
2	*N. sibirica*	China, Siberia
3	*N. senegalensis*	Africa
4	*N. billardieri*	Austraria
5	*N. retusa*	Mediterranean coast
6	*N. sphaerocarpa*	Northwest China
7	*N. roborowskii*	Northwest China, Russia
8	*N. komarovii*	Europe caspian coast
9	*N. tangutorum*	Northwest China
10	*N. praevisa*	Northwest China
11	*N. pamirica*	China
12	*N. sinensis*	China
13	*N. tridentate*	Africa

genus. Nearly all known alkaloids (Table II, nos. 1-36) identified in plants of the Nitraria genus were initially isolated in these studies. These studies also observed that the content of alkaloids in the leaves is higher than the content in the roots, stems and seeds of *Nitraria komarovii* and *Nitraria sibirica* (37-38). There are also various types of alkaloids that have been isolated and purified in other studies. In the crude MeOH extracts of *N. rhoberi*, nazlinin was purified by Üstunes *et al* (39). In a proceeding study, tangutorine was isolated from the leaves of *N. tangutorum* (40). Three novel alkaloids, 3-epinitrarine, 1-epinitraramine and nitrarine (41) were identified in *N. billardieri*, which is a species that is mainly distributed in Australia. Phytochemical studies of the aerial sections of *N. retusa* reported the novel alkaloids 5,7-dihydroxy-3-deoxy vasicine and 7-hydroxy-3-deoxy-1-vasiciene (42) (Fig. 1). Nitraria was also reported by Saleh *et al* (43) to contain the flavonoids rutin, kaempferol and isorhamnetin. The flavonoids isolated in other studies are listed in Table II, nos. 67-87 (44-48) (Fig. 2).

Wang *et al* (49) determined fatty acids in *N. tangutorum* seed by supercritical carbon dioxide extraction and high-performance liquid chromatography/atmospheric pressure chemical ionization/mass spectrometry. Using gas chromatograph-mass spectrometry, numerous volatile substances were detected in the extract of the stem, leaves and fruits of *N. tangutorum* and *N. sibirica* (50-52). Additionally, Wu *et al* (53) isolated phenolic acid from the water extraction of *N. tangutorum*.

3. Pharmacological effects

Antifatigue activity. The antifatigue activity of polysaccharides from the fruits of N. *tangutorum* was assessed in mice using the forced swim test (FST). The results demonstrated that the FST-induced reductions in glucose, superoxide dismutase (SOD) and glutathione peroxidase (GPx), and the increases in creatine phosphokinase, lactic dehydrogenase, blood urea nitrogen, triglyceride (TG) and malondialdehyde (MDA) levels, were inhibited by the polysaccharides from *N. tangutorum*. Additionally, at the same dosage, the extract of *N. tangutorum* is more potent than *Hippophae rhamnoides* and *Lycium ruthenicum*, which are traditionally used as medicinal foods with antifatigue and antioxidant potential in Tibet (54). Fruit extracts of *N. tangutorum* markedly prolonged the swimming time, climbing time and survival time in low temperature of mice compared with the control group in a study by Suo *et al* (55). The seed oil of *N. tangutorum*, when extracted by supercritical CO_2, displayed similar effects as the fruit, and upregulated the contents of serum urea-nitrogen and hepatic glycogen, but downregulated the serum lactic acid contents, consequently improving the swimming and climbing time. This result has been repeated in other studies (56,57).

Antitumor activity. Boubaker *et al* investigated the apoptotic potential of *N. retusa* ethyl acetate (EA) extract and isorhamnetin 3-*O*-rutinoside (I3-*O*-R) isolated from the ethyl acetate extract, in K562 human chronic myelogenous erythroleukemia cells. After 48 h incubation with *N. retusa* extract and I3-*O*-R, K562 cell viability was significantly suppressed by inducing apoptosis, and the caspase 3 and caspase 8 activity was increased (58). The extract and the component inhibited the genotoxicity induced by hydroxyl radicals in K562 cells (59). Another similar study indicated that EA extract of *N. retusa* and I3-*O*-R have a strong antiproliferative effect on TK6 human lymphoblastoid cells, possibly due to their involvement in the apoptotic pathway (60).

The hexane (Hex), chloroform (Chl) and methanol (MeOH) extracts of *N. retusa* were utilized to test their antiproliferative effects on K562 cells. The Hex and Chl extracts were demonstrated to induce stronger antiproliferative effects than the MeOH extracts, by ameliorating the DNA fragmentation, poly ADPribose polymerase cleavage, and caspase 3 and caspase 8 activity (61). In another study, 3H-thymidine incorporation-induced proliferation of the HT29 human colon cancer cells was reduced in a dose-dependent manner following treatment with tangutorine, a β-carboline alkaloid from the leaves of *N. tangutorum*. Tangutorine may induce p21 suppression of all cyclins and their associated kinases, such as the topoisomerase II, and thus inhibit normal DNA replication and mitosis (62). The activities of fractions/extracts of *N. retusa* were compared with their flavanoid contents, which consisted of the following four major flavonoids: Isorhamnetin; isorhamnetin-3-*O*-glucoside (I3-*O*-G); I3-*O*-R; and isorhamnetin-3-*O*-robinobioside (I3-*O*-Rb). They inhibited the proliferation of Caco-2 cells *in vitro* (63).

The total flavones from the *N. tangutorum* fruits repress proliferation of the SGC-7901 human gastric adenocarcinoma cell line and A-704 human kidney adenocarcinoma cell line by regulating the levels of Ca^{2+}, K^{+} and P^{3+} in the cell (64-65). The *in vivo* experiment demonstrated that flavones, in addition to the aqueous extract of *N. tangutorum*, combined with 5-fluorouracil, induced a significantly increased inhibitory rate in the Hep human throat cancer cell line and U14 human cervical cancer cell line by regulating the weight of immune organs, the formation value of serolysin and phagocytic index (66-67). Additionally, the lipids of *N. tangutorum* were cytotoxic against the MGC-803 human gastric carcinoma cell line (68).

Table II. Compounds isolated from the Nitraria genus.

A, Alkaloid compounds

No.	Compound	Species	Part of plant	Reference
1	Nitraricine	*N. komarovii*	Epigeal	5
2	Nitrarizine	*N. komarovii*	Epigeal	5
3	Isokomarovine	*N. komarovii*	Epigeal	6
4	Komarovidinine	*N. komarovii*	Epigeal	6
5	Komarovinine	*N. komarovii*	Epigeal	7
6	Peganine N-oxide	*N. komarovii*	Epigeal	8
7	Nallylschoberine	*N. komarovii*	Epigeal	8
8	Dehydronitramidine	*N. komarovii*	Epigeal	8
9	Komavicine	*N. komarovii*i	Epigeal	9
10	Deoxypeganine	*N. komarovii*	Epigeal	10
11	Nitraramine	*N. schoberi*/*N. komarovii*	Epigeal	11
12	Komarovine	*N. komarovii*	Epigeal	12
13	Komarovidine	*N. komarovii*	Epigeal	12
14	Komaroine	*N. komarovii*	Epigeal	13
15	Nitraraine	*N. schoberi*	Epigeal	14
16	Nitrabirine	*N. sibirica*	Epigeal	14
17	Nitramine	*N. sibirica*	Epigeal	15
18	Isonitramine	*N. sibirica*	Epigeal	16
19	Sibirine	*N. sibirica*	Epigeal	17
20	Vasicinone N-oxide	*N. komarovii*	Epigeal	18
21	Deoxyvasicinone N-oxide	*N. komarovii*	Epigeal	18
22	Dihydronitraraine	*N. komarovii*	Epigeal	19
23	Deoxyvasicinone	*N. komarovii*	Epigeal	20
24	Vasicinone	*N. komarovii*	Epigeal	20
25	Peganine	*N. komarovii*	Epigeal	20
26	Deoxypeganine	*N. komarovii*	Epigeal	20
27	Dehydroschoberine	*N. komarovii*	Epigeal	20
28	Nitraroxine	*N. komarovii*	Epigeal	20
29	Tryptamine	*N. komarovii*	Epigeal	20
30	Schoberine	*N. komarovii*	Epigeal	20
31	Schoberidine	*N. komarovii*	Epigeal	21
32	Nitrarine	*N. schoberi*	Epigeal	22
33	Tetramethylenetetrahydro-β-carboline N-oxide	*N. komarovii*	Epigeal	23
34	Sibirinine	*N. sibirica*	Epigeal	24
35	Dihydroschoberine	*N. sibirica*	Aerial	25
36	Nitrabirine N-oxide	*N. sibirica*	Aerial	25
37	O-acetylnitraraine	*N. schoberi*	Aerial	26
38	N-methylnitrarine	*N. schoberi*	Aerial	27
39	Komavine	*N. komarovii*	Aerial	28
40	Acetylkomavine	*N. komarovii*	Aerial	28
41	N-allylnitrarine	*N. komarovii*	Aerial	29
42	Komarovidinine N-oxide	*N. komarovii*	Aerial	29
43	Sibiridine	*N. sibirica*/*N. schoberi*	Aerial	30
44	Nitraramidine	*N. sibirica*	Aerial	31
45	Nitraraidine	*N. sibirica*	Aerial	31
46	Komarin	*N. komarovii*	Aerial	32
47	Peganol N-oxide	*N. komarovii*	Aerial	32
48	N-allylisonitrarine	*N. schoberi*	Aerial	33
49	Nitraridine	*N. komarovii*	Aerial	34

Table II. Continued.

No.	Compound	Species	Part of plant	Reference
50	Dihydronitraridine	*N. komarovii*	Aerial	34
51	Tetrahydronitraridine	*N. Komarovii*	Aerial	34
52	Schobericine	*N. Schoberi*	Aerial	35
53	Komaroidine	*N. Komarovii*/*N. Schoberi*	Aerial	35
54	Acetylkomaroidine	*N. Komarovii*/*N. Schoberi*	Aerial	35
55	Tetrahydronitramarine	*N. Komarovii*.	Epigeal	36
56	Tetrahydrokomarovinine	*N. Komarovii*	Epigeal	36
57	Dihydroisokomarovine	*N. Komarovii*	Epigeal	36
58	Tetrahydroisokomarovine	*N. Komarovii*	Epigeal	36
59	Nazlinin	*N. Schoberi*	Epigeal	39
60	Tangutorine	*N. Tangutorum*	Leaves	40
61	Nitrarine	*N. Billardieri*	Aerial	41
62	1-Epinitraramine	*N. Billardieri*	Aerial	41
63	3-Epinitrarine	*N. Billardieri*	Aerial	41
64	5,7-Dihydroxy-3-deoxy-vasicine	*N. Retusa*	Aerial	42
65	7-Hydroxy-3-deoxy-1-vasiciene	*N. Retusa*	Aerial	42
66	Allantoin	*N. Tangutorum*	Seed	48

B, Flavanoid compounds

No.	Compound	Species	Part of plant	Reference
67	Narcissin	*N. Komarovii*	Leaves	28
68	Rutin	*N. Retusa*	Leaves and stems	43
69	Kaempferol	*N. Retusa*	Leaves and stems	43
70	Isorhamnetin 3-O-4^{rham}-galactosylrobinobioside	*N. Retusa*	Leaves and stems	44
71	Isorhamnetin 3-robinobioside	*N. Retusa*	Leaves and stems	44
72	Isorhamnetin 3-rutinoside	*N. Retusa*	Leaves and stems	44
73	Isorhamnetin 3-galactoside	*N. Retusa*	Leaves and stems	44
74	Isorhamnetin 3-glucoside	*N. Retusa*	Leaves and stems	44
75	Isorhamnetin	*N. Retusa*	Leaves and stems	44
76	Isorhamnetin 3-xylosylrobinobioside	*N. Retusa*	Leaves and stems	44
77	Isorhamnetin-7-*O*-α-L-rhamnoside	*N. Tangutorum*	Seeds	45
78	Isorhamnetin-7-*O*-β-D-glucoside	*N. Tangutorum*	Seeds	45
79	Kaempferol-7-*O*-α-L-rhamnoside	*N. Tangutorum*	Seeds	45
80	Quercetin-7-*O*-α-L-rhamnoside	*N. Tangutorum*	Seeds	45
81	Quercetin	*N. Tangutorum*	Seeds	45
82	3,5-Dimethylether-kaempfrol-7-*O*-β-D-glucoside	*N. Tangutorum*	Leaf	46
83	3-Methylether-kaempferol-7-*O*-β-D-glucoside	*N. Tangutorum*	Leaf	46
84	Isorhamnetin-3-*O*-β-D-glucopyranosyl-(1-2)-α-L-rhamnopyranoside	*N. Tangutorum*	Fruit	47
85	5,7,2'-Trihydroxyflavonol	*N. Tangutorum*	Fruit	47

Table II. Continued.

No.	Compound	Species	Part of plant	Reference
86	Cyaniding 3-[6'-(6-trans-p-coumaroyl-β-D-glucopyranosyl)-β-D-galactopyranoside]	*N. Tangutorum*	Fruit	47
87	Apigenin 5-*O*-(2'-*O*-E-P-coumaroyl)-β-D-glucopyranoside	*N. Tangutorum*	Fruit	47

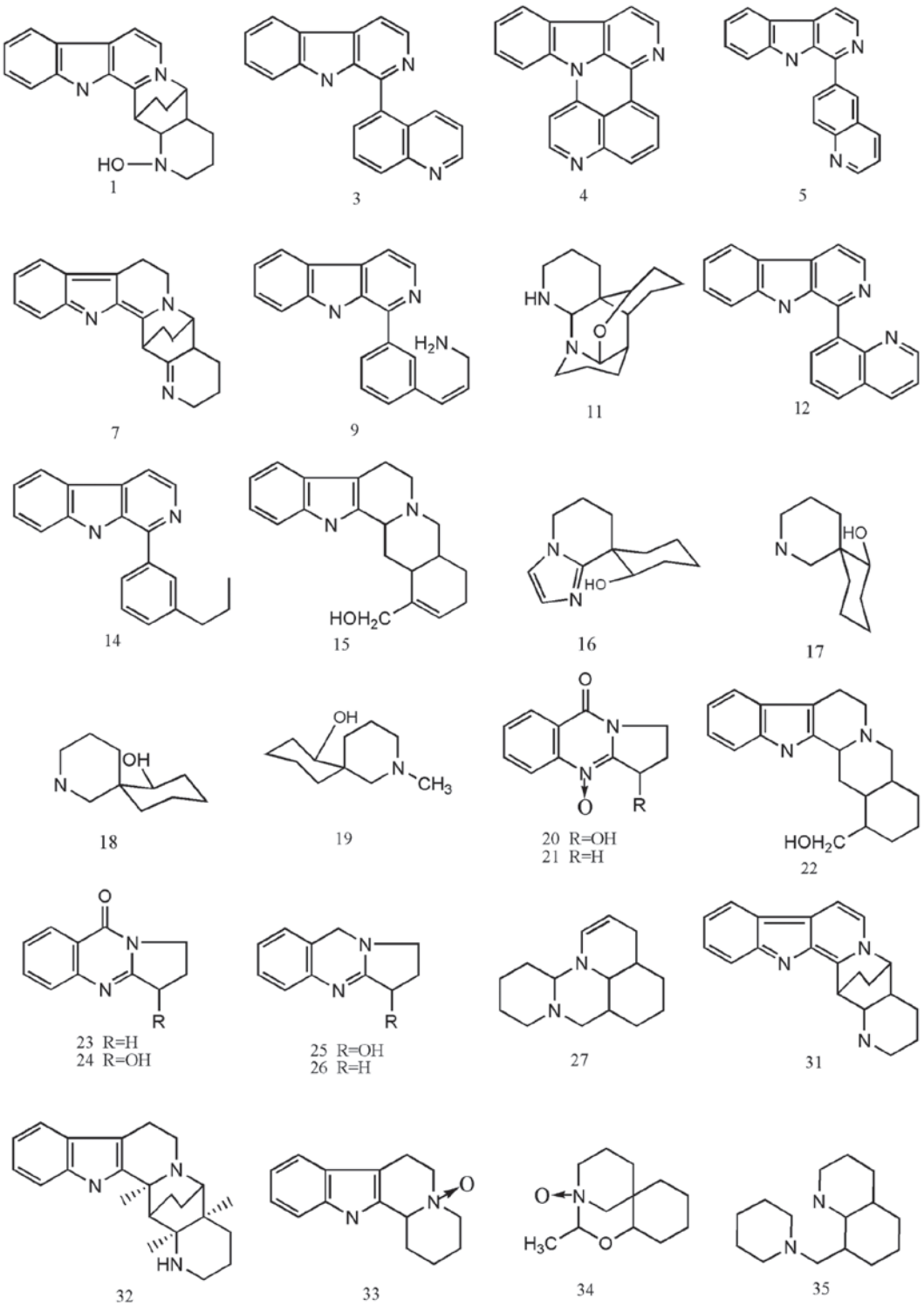


Figure 1. Chemical structures of the main alkaloids from the genus Nitraria.

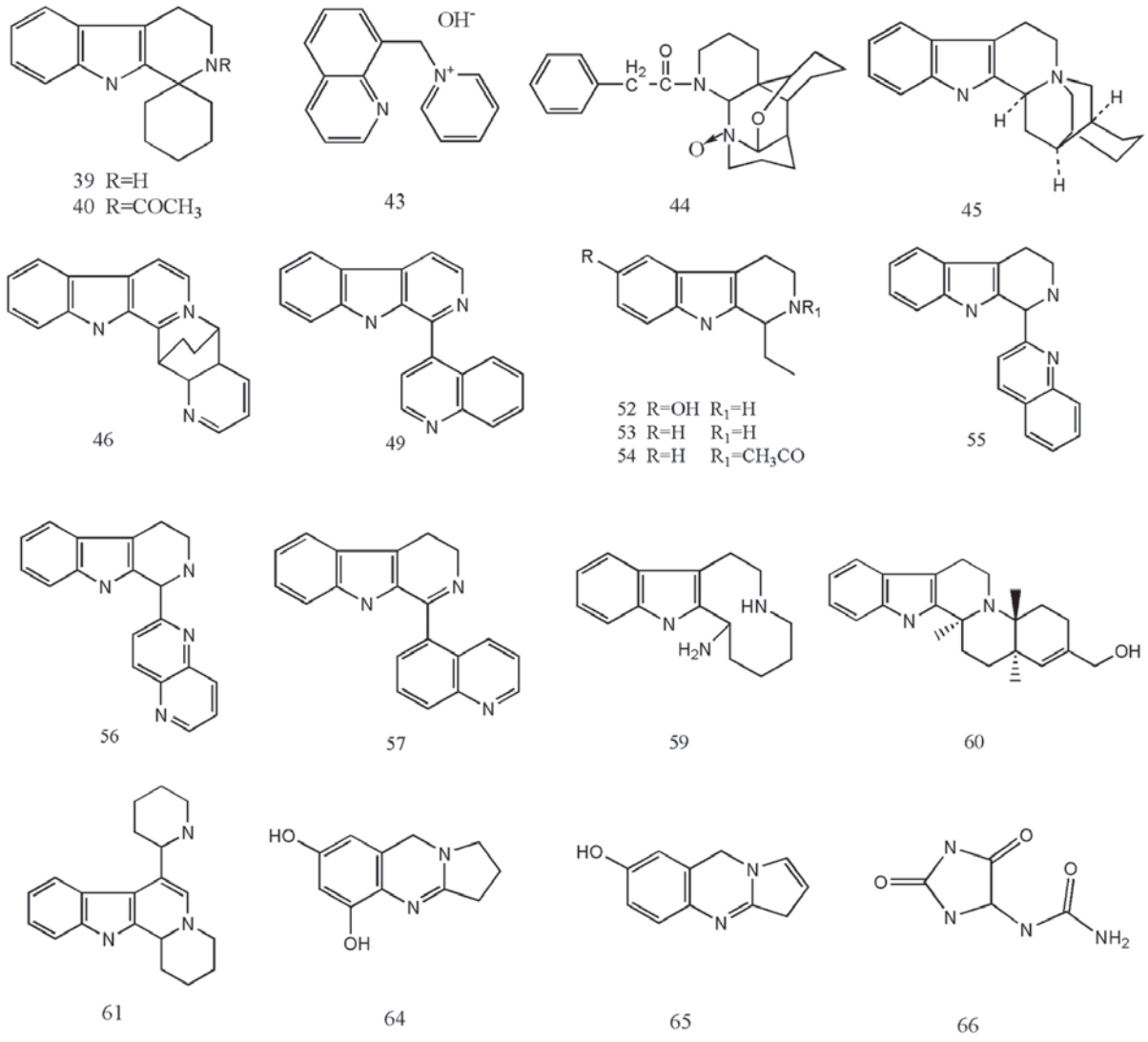
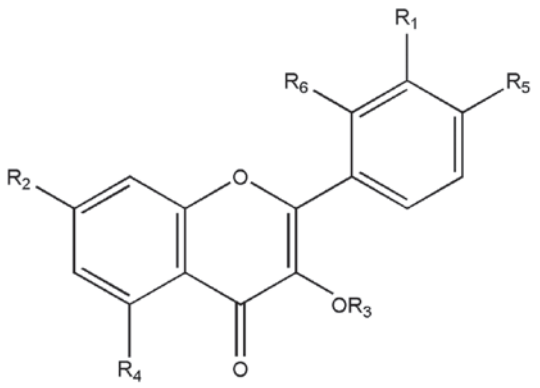


Figure 1 continued. Chemical structure of main alkaloids from the genus *Nitraria*.

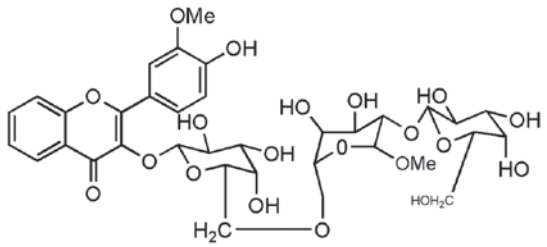
Antioxidant activity. EA extract of *N. retusa* and I3-*O*-R indicated a protective effect against lipid peroxidation induced by H_2O_2. It demonstrated significant antioxidant effects on oxidation induced by 2,2'-azobis (2-amidinopropane) dihydrochloride in K562 cells with 50% inhibitory concentration values (IC50) of 0.225 mg/ml and 0.31 mg/ml (59). Sterols, the main constituents of Hex extract, and sterol and polyphenolic compounds, the main constituents of Chl extract, may participate in the protective effect against lipid peroxidation induced by H_2O_2 in K562 cells (61). Chl extract exhibited the highest ability to protect plasmid DNA against hydroxyl radical-induced DNA damage, and the highest antioxidant capacity, with 0.95 mM trolox equivalent capacity when tested using the ferric reducing/antioxidant method (69). Furthermore, the extract of fruits from *N. tangutorum* displayed a significantly different antioxidant activity when assessed with the 1,1-diphenyl-2-picrylhydrazy (DPPH), 2,2'-Azinobis (3-ethylbenzothiaz-oline-6-sulfonate) (ABTS) and ferric-reducing antioxidant power assays (70).

The DPPH scavenging activity, xanthine oxidase inhibition and superoxide scavenging activity of various *N. retusa* extracts and compounds, including isorhamnetin, I3-*O*-G, I3-*O*-R and I3-*O*-Rb, were evaluated to confirm the association between the activities of the fractions and their flavonoid contents. The EA extracts were identified to be most effective at scavenging the DPPH stable free radical, and the $CHCl_3$ extracts exhibited the highest xanthine oxidase inhibition activity; however, only BuOH extract exhibited a scavenging activity toward superoxide radicals. Overall, all the compounds exhibited some level of DPPH and superoxide scavenging and xanthine oxidase inhibition activity, and the aglycone compounds were more active than their glycosylated derivatives (63). Antiradical activities against DPPH, and β-carotene and Fe-reducing power were more efficient in leaf non-polar fractions compared with polar fractions of *N. retusa* (61). Similar studies investigating anti-oxidant properties were also performed by Bouaziz *et al* (71) and demonstrated that the EA fraction and MeOH fraction of *N. retusa* indicated DPPH scavenging activity and reduction of the ABTS radical cation.

Anthocyanins have also been demonstrated to elicit scavenging effects against O_2, OH and DPPH in a dose-dependent manner. Notably, these scavenging capacities were greater than those of vitamin C according to results of *in vitro* anti-oxidative tests (72). Nazlinin isolated from Nitraria and



67 R_1=OH R_2=OH R_3=glu R_4=OH R_5=OH R_6=H
68 R_1=H R_2=OH R_3= glu R_4=OH R_5=OH R_6=H
69 R_1=OCH_3 R_2=OH R_3=bobinobioside R_4=OH R_5=OH R_6=H
71 R_1=OCH_3 R_2=OH R_3=β-D-rutinoside R_4=OH R_5=OH R_6=H
72 R_1=OCH_3 R_2=OH R_3=galactoside R_4=OH R_5=OH R_6=H
73 R_1=OCH_3 R_2=OH R_3=glu R_4=OH R_5=OH R_6=H
74 R_1=OCH_3 R_2=OH R_3=H R_4=OH R_5=OH R_6=H
75 R_1=OCH_3 R_2=OH R_3=xylosylrobinobioside R_4=OH R_5=OH R_6=H
76 R_1=OCH_3 R_2=OH R_3=β-D-rutinoside R_4=OH R_5=OH R_6=H
77 R_1=OCH_3 R_2=O-α-L-rhamnoside R_3=H R_4=OH R_5=OH R_6=H
78 R_1=OCH_3 R_2=O-β-D-glu R_3=H R_4=OH R_5=OH R_6=H
79 R_1=H R_2=O-α-L-rhamnoside R_3=H R_4=OH R_5=OH R_6=H
80 R_1=OH R_2=O-α-L-rhamnoside R_3=H R_4=OH R_5=OH R_6=H
81 R_1=OH R_2=OH R_3=H R_4=OH R_5=OH R_6=H
82 R_1=H R_2=O-β-D-glu R_3=CH_3 R_4=OCH_3 R_5=OH R_6=H
83 R_1=H R_2=O-β-D-glu R_3=CH_3 R_4=OH R_5=OH R_6=H
84 R_1=OCH_3 R_2=OH R_3=rha(2-1)-glu R_4=OH R_5=OH R_6=H
85 R_1=H R_2=OH R_3=H R_4=OH R_5=H R_6=OH



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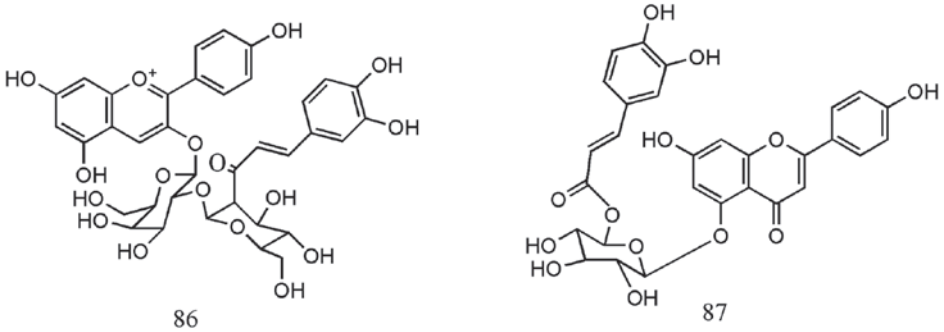

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Figure 2. Chemical structures of flavonoids from the genus Nitraria.

its derivative 1-(4-butylamino)-3,4-dihydro-β-carboline have been indicated to be inhibitors of pig kidney diamine oxidase, while 1-(4-butylamino)-β-carbolin was demonstrated as a substrate (73).

Antimicrobial activity. The EA, ethanol and Chl extracts from the fruits of *N. tangutorum* had antibacterial effects against *Escherichia coli*, *Bacillus subtilis* and *Staphyloccocus aureus*. The EA fraction presented the highest level of antibacterial activity (74,75). In addition, Chl extract from *N. retusa* leaves was more efficient against all human pathogen strains, particularly *Escherichia coli* and *Staphylococcus aureus* (76). The EA and MeOH extracts of *N. retusa* revealed antimicrobial effects against *Pseudomonas aeruginosa* and

Aspergillus niger in vitro (71). The ethanol extracts of *N. retusa* also exhibited cytotoxicity in brine shrimp with LC50 values of 6.2 μg/ml (77).

Antimutagenic activity. The protection of *N. retusa* against mutagenicity induced by methyl methanesulfonate and 2-aminoanthracene in *Salmonella typhimurium* TA102 and TA104 strains was observed. The highest protection was elicited by Chl and MeOH extracts of *N. retusa*, with inhibition percentages of 44.93% at 50 μg/plate in the presence of TA102 strain and 38% at 10 μg/plate in the presence of TA104 strain. Hex and Chl extracts have been demonstrated to reduce the mutagenicity induced by 2-aminoanthracene with 83.4% in TA104 and 65.3% in the TA102 strain (69).

Hypotensive effects. Senejouxa *et al* conducted a study on the vasorelaxant activity and underlying mechanisms of hydroalcoholic extract from the fruits of *N. sibirica* on thoracic aortic rings isolated from Wistar rats. The study revealed that the hydroalcoholic extract was more effective in the induction of vasodilation of phenylephrine- than high KCl-pre-contracted aortic rings with respective E_{max} values of 82.9±2.2 and 34.8±3.6%. The acute intravenous injection of hydroalcoholic extract induced an immediate and transient hypotensive effect in anesthetized spontaneously hypertensive and control rats through an endothelium-dependent pathway involving nitric oxide synthase (NOS) activation, endothelium-derived hyperpolarizing factor production and muscarinic receptor stimulation (78). Flavonoids of different concentrations increased the repair of impaired human umbilical vein endothelial cells induced by high glucose or H_2O_2 by increasing the ratio of NOS, SOD and GPx activity, and NO level (79,80). Notably, the inhibition activity of ethanol extracts from 10 halophytes on angiotensin converting enzyme (ACE) has been investigated extensively. The *Nitraria sibirica* fraction has been demonstrated to significantly inhibit ACE with an IC50 value of 69.36 g/l (81).

Hypoglycemic effects. The fruit of *N. tangutorum* at a dosage of 1.8 g/kg and 3.6 g/kg not only had a therapeutic action in a mouse diabetes model induced by alloxan, but also led to an increase in the glucose-toleration in similar models in rats. It has also been demonstrated to reduce glucose levels in hyperglycemic animal models induced by epinephrine and glucose (82). Shabana *et al* (83) investigated the hypoglycemic activity of 31 desert plants from different Egyptian localities in normal fasting and alloxanised rats, and *Nitraria retusa* had hypoglycemic effects in normal fasting rats.

Lipid lowering effects. An *in vivo* study on the effects of the fruit extracts of *N. tangutorum* on rat and mouse models of hyperlipermia induced by high lipid levels was conducted by Suo *et al*. *N. tangutorum* significantly reduced the serum level of total cholesterol (TC) and TG in a rat hyperlipermia model, and the level of low-density lipoprotein (LDL) in Kunming strain rats. It also increased the ratio of high-density lipoprotein cholesterol (HDL)/TC, HDL/LDL and SOD activity, and reduced the MDA content *in vivo* and *in vitro* (84,85).

Hepatoprotective effects. A study by Zhang *et al* (86) indicated that seed oil of *N. tangutorum* alleviated the increased levels of aspartate aminotransferase, alanine aminotransferase and MDA induced by CCl4, and it also enhanced the level of GPx in liver.

4. Conclusion

The studies summarized above strongly support the theory that the Nitraria genus has favorable therapeutic properties, indicating its potential for clinical use. The present review presents and assesses the previous pharmacological and phytochemical studies published on the Nitraria genus, and may aid the easy identification and further research into properties of members of the Nitraria genus.

Nitraria as a halophyte, is ecologically central in stabilizing wind-blown sand and loess soils and thus reduces erosion. Hence, combined with the pharmacological effects, the rational development and utilization of Nitraria may be beneficial for the local environment and public health.

Numerous alkaloids have been isolated from the Nitraria genus. However, there is currently no research on the pharmacological properties of the alkaloid components, which are the most abundant constituents in nature. Further studies on the antitumor and anti-oxidative activities of these components are required. Furthermore, few molecular mechanisms are known, which may hamper the further clinical application of Nitraria. The possible synergistic action among the bioactive compounds of the plants must be evaluated prior to their use in clinical practice.

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