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A Comprehensive Review on Genus *Zygophyllum*

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ABSTRACT

Objectives: This study aimed to make a broad review of the chemical constituents and biological activities of genus *Zygophyllum*. **Methods**: This review covers the peer reviewed articles between 1977 and August, 2018, retrieved from PubMed, Science Direct, Sci-Hub, Springer and Wikipedia **Results:** In traditional medicine, plants of genus *Zygophyllum* have been employed and utilized as anti-rheumatic, anti-gout, antidiabetic, anti-hyperlipidemic, antimicrobial, anti-oxidant, antihypertensive, antiseptic, anti-eczema and antidiarrheal. *Zygophyllum* species have been phytochemically studied leading to the identification of various classes of compounds including triterpenes, flavonoids, saponins, sterols, simple phenolic compounds, and esters. Biological studies on *Zygophyllum* species have also indicated various bioactive potentials including antioxidant, antidiabetic, antimicrobial antitumor and anti-inflammatory effects. The reported medicinal *Zygophyllum* species were selected and summarized on basis of their; geographical distribution, traditional uses, chemical constituents and biological activities. **Conclusion:** It would therefore be important to extensively investigate their phytochemicals and pharmacologically determine their activities for future drug discovery and development.

Keywords: *Biological activities; Chemical constituents; Geographical distribution; Traditional uses; Zygophyllum*

INTRODUCTION

Zygophyllaceae (Caltrop family) is a family of approximately 25 genera and 240 species adapted to semi desert and Mediterranean climates[1]. Species belonging to genus *Zygophyllum* represent a group of succulent plants that are drought resistant and/or salt tolerant, living under severe, dry climatic conditions[2]. Moreover, it is recorded by many authors as one of the important components of the desert vegetation[3]. The abundance of species related to this genus could be attributed to their high tolerance to environmental stresses as well as to their unpalatability[4]. The growth and distribution of *Zygophyllum* species are attributed to their dependence on the chemical nature of the soil of their habitats[5]. The genus *Zygophyllum* consist of 100 species, distributed in desert and steppe habitats from the Mediterranean to central Asia, South Africa and Australia[4]. Most of plants of genus *Zygophyllum* are small perennial herbs with fleshy leaves and flowers, as in cases of Z. *simplex, Z. cocceniem, Z. album, Z. fabago* and *Z. dumosum*[6]. Nine species are widespread in the deserts and salt marshes in Egypt and Sinai Peninsula[5]. They have been utilized in traditional medicine for various ailments, such as treatment of rheumatism, gout, diabetes, asthma, hypertension, dysmenorrhea, as well as fungal infection[7-11]. Biological studies on *Zygophyllum* species have indicated significant antioxidant, antidiabetic, antitumor, antimicrobial and anti-inflammatory activities[12-17]. Such activities were contributed to their phytochemical constituents. Various classes of compounds including triterpenes, flavonoids, saponins, sterols, phenolic, essential oils and esters have been isolated from different *Zygophyllum* species[18-23].

Table 1. Reported *Zygophyllum* species, their distribution and traditional uses

Zygophyllum species	Distribution	Traditional use
Z. aeyptium[18,24]	Egypt, Tunisia, Cyprus	Rheumatism, gout, asthma and hypertension
Z. album[8]	Egypt, Algeria, Tunisia	Diabetes, dermatitis, spasms and dysmenorrheal
*Z. atriplicoides (*Synonym*: Z. eurypterum)*[25]	Pakistan	Alzheimer's disease and brain diseases with deficiency in cholinergic function
Z. coccienium[9,26]	Egypt, Kuwait, Saudi Arabia	Gout, Rheumatic pain and hypertension
Z. cornutum[10]	Algeria	Diabetes, hypertension and dermatitis
Z. decumbens[27]	Egypt, Syria, Sudan	Hypotension, fever and GIT spasm
Z. dumosum[23,28,29]	Egypt	Rheumatism, gout, asthma and hypertension
Z. fabago[19]	China, Spain, Turkey, Iran, Kazakhstan and Iraq	Fungal infections, Parasitic worms, constipation, product cough, inflammation, and asthma
Z. gaetulum[11]	Morocco	GIT spasms, hyperglycemia accompanying diabetes and eczema
Z. geslini[12]	Algeria	Hyperglycemia accompanying diabetes
Z. hamiense[30]	Deserts of Asia and Africa	As hepato-protective
Z. macropodum[31]	China	Pain and inflammation
Z. melongena[20]	Mongolia	Snake poisoning (as it inhibits of the snake venom phosphodiesterase)
Z. qatarense[13]	Iran	Fungal infections
Z. simplex[32]	Egypt, Saudi Arabia, India and Pakistan	Glaucoma, inflammation, fungal infections and hyperglycemia accompanying diabetes

MATERIALS AND METHODS

This review covers the peer reviewed articles between 1977 and August, 2018, retrieved from PubMed, Science Direct, Sci-Hub, Springer and Wikipedia.

RESULTS AND DISCUSSION

Distribution and traditional use

Data reported on *Zygophyllum* species used mostly in folk medicine is summarized in **Table 1** according to their geographical distribution and traditional uses.

Phytochemical constituents:

It was reported that the plants belonging to genus *Zygophyllum* are rich in essential oil, sterols, triterpenes, phenolic compounds, flavonoids and saponins. The previously isolated compounds from reported *Zygophyllum* species are labeled together with their chemical classes in **Table 2** and their chemical structures are shown below.

Biological studies

Reported biological activities of various *Zygophyllum* species included antioxidants, antidiabetic, antimicrobial, antitumor and other effects are illustrated in **Table 3**.

Antioxidant activity

One of the most remarkable effects of the members of *Zygophyllum* genus is their antioxidant activity (**Table 3**). Such activity is attributed to the presence of the phenolic compounds as reported in cases of *Z. cornutum*[10], *Z. album*[6,8,38], *Z. cocceniem*[7], *Z. hamiense*[28], *Z. simplex*[16,64] and *Z. fabago*[46]. The most active extracts with the highest antioxidant activity; were those of the alcohol (methanol and ethanol) ones followed by dichloromethane extracts while the hexane extracts were poorly active[6]. Consequently, *Zygophyllum* genus represents an important economical source of antioxidant agents.

Antidiabetic activity

The antidiabetic activity of members of the *Zygophyllum* genus have been reported in several studies (**Table 3**). The aqueous and butanol extract of *Z. gaetulum* in alloxan-induced diabetic rats (n=6) caused a continuous marked reduction of blood glucose levels particularly 6–9 hr {hours} after treatment. Significant difference was observed; (P<0.001) (52.82±6.54; 69.80± 3.86, respectively). The blood glucose level fell rapidly from 333±47 mg/dl at fasting to 205±34

Table 2. Reported *Zygophyllum* species; isolated compounds and chemical classes

***Zygophyllum* species**	**Identified compounds**	**Compound no.**	**Chemical classes**
Z. album[6,14,23,33-39]	Isorhamnetin	**1**	Flavonoids
	Isorhamnetin-3-*O*-*β*-*D*-glucoside	**2**	Flavonoids
	Isorhamnetin-3-*O*-*β* galactopyranoside	**3**	Flavonoids
	Isorhamnetin-3-*O*- *β* –rutinoside	**4**	Flavonoids
	Quercetin-3-*O*-*β*-glucopyranoside (Isoquercitin)	**11**	Flavonoids
	Kaempferol	**12**	Flavonoids
	Gentisic acid	**17**	Hydroquinone carboxylic acid
	β –sitosterol	**18**	Sterols
	Stigmasterol	**20**	Sterols
	Ursolic acid	**21**	Triterpenoid
	Oleanolic acid	**22**	Triterpenoid
	quinovic acid *3-α-L*-rhamnoside	**34**	Triterpenoid
	Malvidin 3-rhamnoside	**60**	Anthocyanins
	Linalool	**61**	Terpene alcohol
	Tricosane	**63**	Acyclic hydrocarbons
	Camphor	**64**	Bicyclic monoterpene ketone
	α-Terpineol	**65**	Monoterpene alcohol
	Carvone	**66**	Monoterpene
	Harmine (*β*-carboline alkaloid)	**67**	Alkaloids
	β –amyrin	**68**	Triterpenoid
Z. aeyptium[18,24]	Isorhamnetin-3-*O*- *β* –rutinoside	**4**	Flavonoids
	Quinovic acid-3-*O*-*β*-*D*-glucopyranoside	**32**	Triterpenoid
	Quinovic acid-3-*O*-*β*-*D*-2-O-sulphonylquinovopyranoside	**33**	Triterpenoid
	Quinovic acid-3-*O*-*β*-*D*-glucopyranosyl-(28→1)-β-D-glucopyranosyl ester	**36**	Triterpenoid
	Quinovic acid-3-*O*-*β*-*D*-quinovopyranosyl-(28→1)-*β*-*D*-glucopyranosyl ester	**38**	Triterpenoid
	Quinovic acid-3-*[β*-*D*-xylopyranosyl (1→2) quinovopyranosyl]-(28→1)- *β*-*D*-glucopyranosyl ester	**52**	Triterpenoid
	(7R,8S,8′S)-4, 9, 4′-trihydroxy-3, 3′-dimethoxy-4′-sulfonyl-7, 9′-epoxylignan	**57**	Lignans
	Quinovic acid-3-*O*-*β*-*D*-quinovopyranoside	**69**	Triterpenoid
	Quinovic acid-3-*O*-*β*-*D*-quinovopyranosyl-(27 → 1)-*β*-*D*-glucopyranosyl ester	**70**	Triterpenoid
Z. atriplicoides (Synonym: *Z. eurypterum)*[25,40]	β-Sitosterol-3-*O*-*β*-*D*-glucopyranoside	**19**	Sterols
	Atricarpan A	**24**	Isoflavonoids
	Atricarpan B	**25**	Isoflavonoids
	Atricarpan C	**26**	Isoflavonoids
	Atricarpan D	**27**	Isoflavonoids
	Atriplicosaponin B	**37**	Triterpenoid saponins
Z. atriplicoides[25,40]	Atriplicosaponin A	**56**	Triterpenoid saponins
Z. coccienium[6,23,36,41,42]	Isorhamnetin-3-*O*- *β* –rutinoside	**4**	Flavonoids
	5,6,7,8,4`penta hydroxy flavone 7 -*β* - *D* glucoside	**15**	Flavonoids
	β –sitosterol	**18**	Sterols
	β-Sitosterol-3-*O*-*β*-*D*-glucopyranoside	**19**	Sterols
	Stigmasterol	**20**	Sterols
	Ursolic acid	**21**	Triterpenoid
	Oleanolic acid	**22**	Triterpenoid
	Zygophylloside S	**31**	Triterpenoid saponins
	3-*O*-[*β*-*D*-glucopyranosyl]-quinovic acid	**32**	Triterpenoid
	3-O-[*β*-*D*-(2-*O*-sulphonyl)-quinovopyranosyl] quinovic acid	**33**	Triterpenoid
	3-*O*-[*β*-*D*-glucopyranosyl] quinovic acid-28-*O*-*β*-*D*-glucopyranosyl ester	**36**	Triterpenoid

	3-*O*-[*β-D*-quinovopyranosyl] quinovic acid-28-*O*-*β*-*D*-glucopyranosyl ester	**38**	Triterpenoid
	3-*O*-[*α-L*-arabinopyranosyl-(1→2)-*β*-*D*-quinovopyranosyl] quinovic acid	**39**	Triterpenoid
	3-*O*-[*α-L*-arabinopyranosyl-(1→2)-*β*-*D*-quinovopyranosyl] quinovic acid-28-*O*-*β*-*D*-glucopyranosyl ester	**40**	Triterpenoid
	2-(3, 4-Dihydroxyphenyl)-3, 5, 7-trihydroxy-6-methoxy-4-benzopyrone (Patuletin)	**59**	Flavonoids
Z. cornutum [6,43]	Isorhamnetin-3-*O*- *β* –rutinoside	**4**	Flavonoids
	β –sitosterol	**18**	Sterols
Z. decumbens[6,27]	Isorhamnetin-3-*O*-*β*-*D*-glucoside	**2**	Flavonoids
	Isorhamnetin-3-*O*- *β* –rutinoside	**4**	Flavonoids
Z. dumosum[6,23,28,36]	Isorhamnetin 3-(4"-sulfatorutinoside)	**5**	Flavonoids
	Isorhamnetin 3-[6"-(2(*E*) butenoyl)-glucoside]	**6**	Flavonoids
	Isorhamnetin-3-*O*-*β*-glucopyranoside-7-*O*-*α*-rhamnopyranoside	**7**	Flavonoids
	Quercetin	**8**	Flavonoids
	Rutin	**9**	Flavonoids
	Quercetin-3,7-di-*O*-*β*-glucopyranoside	**10**	Flavonoids
	Quercetin-3-*O*-*β*-glucopyranoside (Isoquercitin)	**11**	Flavonoids
	Kaempferol	**12**	Flavonoids
	kaempferol-3-*O*- *β*-rutinoside (Nicotiflorin)	**13**	Flavonoids
	Ursolic acid	**21**	Triterpenoid
	Oleanolic acid	**22**	Triterpenoid
	3-*O*-[*β-D*-glucopyranosyl]-quinovic acid	**32**	Triterpenoid
	3-*O*-[*β-D-2-O*-sulphonyl quinovopyranosyl]-quinovic acid-27-*O-[β-D*-glucopyranosyl] ester	**35**	Triterpenoid
Z. eichwaldii[44]	Pomolic acid 3-*O*-*α*-*L*-arabinoside	**28**	Triterpenoid saponins
	28-*O*- *β* -*D*-glucopyranosyl ester of pomolic acid 3-*O*- *β* -*D*-2-*O*-sulfonyl-galactopyranoside.	**29**	Triterpenoid saponins
	28-*O*- *β*- *D*- glucopyranosyl ester of pomolic acid-3-*O*-*α*-*L*-arabinoside	**30**	Triterpenoid saponins
Z. fabago[19,21,45-48]	Isorhamnetin	**1**	Flavonoids
	β –sitosterol	**18**	Sterols
	β-Sitosterol-3-*O*-*β*-*D*-glucopyranoside	**19**	Sterols
	3-*O*-[*β-D*-glucopyranosyl] quinovic acid-28-*O*-*β*-*D*-glucopyranosyl ester	**36**	Triterpenoid
	3-*O*-[*β-D*-quinovopyranosyl] quinovic acid-28-*O*-*β*-*D*-glucopyranosyl ester	**38**	Triterpenoid
	Zygophyloside E	**44**	Triterpenoid saponins
	Zygophylosides O	**48**	Triterpenoid saponins
	Zygophylosides P	**49**	Triterpenoid saponins
	3*β*,4*α* -3,23,30-trihydroxyurs-20-en-28-al 3,23-di(sulfate) sodium salt	**53**	Triterpenoid
	3*β*,4*α* -3,23,28-trihydroxyurs-20-en-30-yl *β*-*D*-glucopyranoside 3,23-di(sulfate) sodium salt	**54**	Triterpenoid
	Zygofaboside A	**55**	Triterpenoid saponins
	Eicosane	**62**	Alkane
	1-hydroxyhinesol	**72**	Sesquiterpenoid
	Hinesol	**71**	Sesquiterpenoid
	Atractylenolactam	**73**	Sesquiterpenoid
	β-eudesmol	**74**	Sesquiterpenoid
	5-α-hydroperoxy-*β*-eudesmol	**75**	Sesquiterpenoid
	11-hydroxy-valenc-1(10)-en-2-one	**76**	Ketone
	Pubinernoid A	**77**	Sesquiterpenoid

	(6S,7E)-6-hydroxy-4,7-megastigmadien-3,9-dione	**78**	Sesquiterpenoid
	(3S,5R, 6S, 7E)-3, 5, 6-trihydroxy-7-megastigmen-9-one	**79**	Sesquiterpenoid
	(6R,7E,9R)-9-hydroxy-4,7-megastigmadien-3-one	**80**	Sesquiterpenoid
	Blumenol A	**81**	Carotenoids
	(S)-3-hydroxy-beta-ionone	**82**	Ketone
	3-hydroxy-5-α-6-α-epoxy-beta-ionone	**83**	Ketone
	Z-lanceol acetate	**84**	Sesquiterpene
	(E, Z)-geranyl linalool	**85**	Terpene alcohol
	β-bisabolenol	**86**	Sesquiterpene
	Menthol	**87**	Alcohols
	Geranyl valerate	**88**	Esters
	(E)-*β*-damascenone	**89**	Cyclic monoterpene ketone
	α-inone	**91**	Ketones
	butylated hydroxyl toluene	**92**	Phenols
	(E)-2-hexen-1-ol	**93**	Alcohols
	Phytol	**94**	Acyclic diterpene
	Octadecane	**95**	Alkane
	σ-deca lactone	**105**	Ketones
	Zygocaperoside	**58**	Triterpenoid saponins
Z. gaetulum [49,50]	3-*O*-[*β*-*D*-glucopyranosyl] quinovic acid-28-*O*-*β*-*D*-glucopyranosyl ester	**36**	Triterpenoid
	Zygophyloside G	**43**	Triterpenoid saponins
	Zygophyloside E	**44**	Triterpenoid saponins
	Zygophyloside I	**45**	Triterpenoid saponins
	Zygophyloside L	**46**	Triterpenoid saponins
	Zygophyloside M	**47**	Triterpenoid saponins
	Linalool	**61**	Terpene alcohol
	Eicosane	**62**	Alkane
	Camphor	**64**	Bicyclic monoterpene ketone
	α-Terpineol	**65**	Monoterpene Alcohol
	3β- O- α- L rhamnopyranosyl (1→2) - *α*- L-arabinopyranosyl – (1→2) – *β* – *D*- glucopyranosyl) urs -20(21)-en-28-oic acid 28-*O-[β* – *D*-glucopyranosyl] ester	**96**	Triterpenoid
	3β- O- β- D-quinovopyranosyl – 27 – nor – olean – 12- en – 28 – oic acid 28 - *O- β* – *D*-glucopyranosyl ester		Triterpenoid
	3β – *O- α*- L rhamnopyranosyl (1→2) - *α*- L-arabinopyranosyl – (1→2) – *β* – *D*- glucopyranosylurs -20(21)-en-28-oic acid 28-*O*-[*β* – *D-2-O*-sulphonylglucopyranosyl] ester	**97**	Triterpenoid
Z. geslini [51]	3-*O*-[*α*-*L*-arabinopyranosyl-(1→2)-*β*-*D*-glucopyranosyl] quinovic acid 28-(*β*-*D*-glucopyranosyl) ester	**41**	Triterpenoid
	3-*O*-[*β*-*D*-(2-*O*-sulphonyl) glucopyranosyl] quinovic acid	**42**	Triterpenoid
	(3*β*)-3-{[6-deoxy-*α*-*L*-mannopyranosyl-(1→2)-*α*-*L*-arabinopyranosyl (1→2)-*β*-*D*-glucopyranurosonyl] oxy} urs-20-en-28-oic acid 28-(2-*O*-sulfo-*β*-*D*-glucopyranosyl) ester	**50**	Triterpenoid
	3*β*-3-[(2-O-sulfo-*β*-*D*-glucopyranurosonyl) oxy]-urs-20-en-28-oic acid 28-(2-O-sulfo-*β*-*D*-glucopyranosyl] ester.	**51**	Triterpenoid
Z. melongena [6,20]	kaempferol 3-*O*-*β*-*D*-glucoside	**14**	Flavonoids
	D-pinitol	**23**	Cyclic polyol
	3-*O*-[*β*-*D*-glucopyranosyl]-quinovic acid	**32**	Triterpenoid
	3-*O*-[*β*-*D*-glucopyranosyl] quinovic acid-28-*O*-*β*-*D*-glucopyranosyl ester	**36**	Triterpenoid
Z. propinquum [52]	3-*O*-[*β*-*D-2-O*-sulphonyl-quinovopyranosyl]-quinovic acid.	**33**	Triterpenoid
	3-*O*-[*β*-*D-2-O*-sulphonyl-quinovopyranosyl]-quinovic acid-27-*O-O-[β-D*-glucopyrosyl] ester	**35**	Triterpenoid

Z. simplex [6,22,53,54]	Isorhamnetin	**1**	Flavonoids
	Isorhamnetin-3-*O*-*β*-*D*-glucoside	**2**	Flavonoids
	Isorhamnetin-3-*O*- *β* –rutinoside	**4**	Flavonoids
	Isorhamnetin 3-[6″-(2(*E*) butenoyl) glucoside]	**6**	Flavonoids
	Isoquercetin	**11**	Flavonoids
	kaempferol-3-*O*- *β*-rutinoside (Nicotiflorin)	**13**	Flavonoids
	Luteolin-7- *O*-*β*-*D*-glucoside	**16**	Flavonoids
	Gentisic acid	**17**	Hydroquinone carboxylic acid
Z. simplex [6,22,53,54]	*β* –sitosterol	**18**	Sterols
	β-sitosterol-3-*O*-*β*-*D*-glucoside	**19**	Sterols
	Ursolic acid	**21**	Triterpenoid
	Oleanolic acid	**22**	Triterpenoid
	Quinovic acid *3-α-L*-rhamnoside	**34**	Triterpenoid
	Stigmast-3,6-dione	**90**	Sterols
	Isorhamnetin-3, 7-diglucoside	**98**	Flavonoids
	Isorhamnetin-3-O- *β* – D- (6'-malonyl) glucoside	**99**	Flavonoids
	Quercetin-3-O-(6"-malonyl) glucoside	**100**	Flavonoids
	P-hydroxy acetophenone	**101**	Phenols
	Vanillic acid	**102**	Dihydroxy benzoic acid
	Ferulic acid	**103**	Hydroxyl cinnamic acid
	Androsin	**104**	Aromatic ketone

mg/dl at 3 hr and to 182±34 mg/dl at 6 hr[11,61]. In another study , the ethanol extract of *Z. album* to diabetic mice significantly decreased the level of blood glucose and increased plasma insulin gain to near normal level by ($p < 0.05$, post hoc Dunnett's test)[14,35,56]. The ethanol extract of *Z. album* with IC_{50} {concentration of 50% inhibition} value (43.48 µg/ml) evidenced a better pancreatic α-amylase inhibition than that of the other fractions. Meanwhile, it was observed that the pancreatic α-amylase inhibitory activities increased in the order of hexane fraction, butanol fraction & ethanol extract[14]. The pancreatic and serum α-amylase activities of essential oil of *Z. album* in treated diabetic rats were noted to undertake considerable reductions of 43 and 38%, respectively[35]. The IC_{50} value of essential oil of *Z. album* against α-amylase was 43.17 µg/ml and that against pancreatic lipase was 85.95 µg/ml[56]. Also, diabetic rats treated with methanol extract of *Z. cornutum*, a significant decrease of glycaemia was noted from the second week and the value recorded after six weeks was 145 ± 12.3 mg/dL. The hypoglycemic effect of methanol extract of *Z. cornutum* may be attributed to its saponins content[58].

Antimicrobial and antifungal activities

One of the most attracting activities of the extracts of genus *Zygophyllum* is the antimicrobial activity against gram positive, gram negative bacteria and several fungi (**Table 3**). A good example is the effectiveness of the aqueous methanol roots extracts of *Z. dumosum*, *Z. coccineum* and *Z. qatarense* on inhibition of the spore germination of *Verticillium albo-atrum* and *Fusarium oxysporum*[13,15,29].

The shoot extract using the same solvent showed variable toxicity among the extracted *Zygophyllum*[13,15,29] such that the extracts of *Z. dumosum* were suppressive only to *Fusarium oxysporum*[29]. On the other hand, the extract of *Z. coccineum* was inhibitory only to *Verticillium albo-atrum*[15]. In another study, the ethanol extract of *Z. coccineum* has antimicrobial activity against *Bacillus subtilis*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Candida albicans*, *Microsporum canis* and *Trichophyton mentagrophytes*[57]. The antifungal activity of the isolated compounds of *Z. coccineum* was investigated against *Colletotrichum acutatum*, *Colletotrichum fragariae*, *Colletotrichum gloeosporioides*, *Botrytis cinerea*, *Phomopsis obscurans*, *Phomopsis viticola*, and *Fusarium oxysporum*. The observed results were recorded against *Phomopsis* viticola after 144 hr exposure[57]. The methanol extract of *Z. simplex* showed marked antimicrobial activity against seven standard bacteria (*Proteus vulgaris*, *Escherichia coli*, *Bacillus cereus*, *Salmonella typhi*, *Klebsiella pneumonia*, *Pseudomonas aeruginosa* and *Staphylococcus aureus*) and one standard fungus (*Candida albicans*)[17]. Also, the nanoparticles of the methanol extract of *Z. qatarense* leaf exhibited antifungal activity against *Aspergillus nigra* and *Penicillium digitatum* was evaluated by standard disk diffusion, the results showed minimum inhibitory concentration {MIC} and minimum fungal concentration {MFC} against *Aspergillus nigra* equal to 16 and 128 µg/ml respectively and against *Penicillium digitatum* equal to 32 and 64 µg/ml respectively[13]. Leaves', seeds' and roots' extract of *Z. fabago* were evaluated evaluated their antimicrobial activities against

Table 3. Reported *Zygophyllum* species; their biological activities

Zygophyllum species	Biological activities
Z. album	Antioxidant[6,8,38] Anti-acetylcholinesterase[8] Antidiabetic[35,55,56] Antiinflammatory[14] Antihyperlipidemic[56] Anti-hypertensive[14] Weight lowering[37]
Z. cocceniem	Antioxidant[7] Anti-hypertensive[9] Antimicrobial and antifungal[15,57] Cytotoxic activity[15]
Z. cornutum	Antioxidant[10] Antidiabetic[58]
Z. dumosum	Antimicrobial and antifungal[29]
Z. fabago	Antioxidant[46] Antimicrobial and antifungal[59] Urease inhibitor[60]
Z. gaetulum	Antidiabetic[11,61] Antispasmodic[62]
Z. gaetulum	Hepatoprotective[11]
Z. geslini	Antidiabetic[12,63]
Z. hamiense	Antioxidant [28]
Z. macropodum	Analgesic and anti-inflammatory[31]
Z. qatarense	Antimicrobial & antifungal[13]
Z. simplex	Antioxidant[16,64] Anti-inflammatory[64,65] Analgesic[65] Antimicrobial and antifungal[17] Antihyperlipidemic[66] Cytotoxic activity[6]

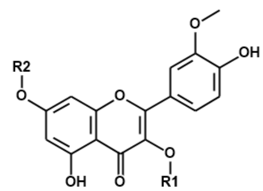
Bacillus subtilis showing MIC equal to 10, 1, 20 mg/ml respectively, *Staphylococcus* aureus showing MIC equal to 20, 1, 30 mg/ml respectively, *Escherichia* coli showing MIC equal to 30, 10, 50 mg/ml respectively, *Pseudomonas* aeruginosa MIC were 50, 20, 30 mg/ml respectively and *Candida albicans*, which was the most resistant for all extracts[59]. The ethyl acetate extract of *Z. cocceniem* showed antibacterial activities against; *Pseudomonas aeruginosa* with inhibition zone 20 mm, *Fusarium moniliforme* with inhibition zone 22 mm, and *Klebsiella pneumonia* showed inhibition zone 22 mm[57].

Cytotoxic activity

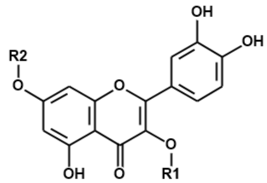
Recent study showed that the cytotoxic activity of dichloromethane fraction of *Z. simplex* showed powerful effect against cancer cell lines; Human lung carcinoma cells {A-549} and Human colon adenocarcinoma cells {DLD-1} with important IC_{50} values of 37 and 48 µg/ml, respectively[6]. Also *Z. coccinium* extracts showed maximum cytotoxic activity of the acetone extract against Human cervix epithelioid carcinoma {HeLa cell line}, whereas methanol extract showed maximum cytotoxic activity on breast cancer cell line {MCF-7 cell line} with cell line viability 13.36 and 35.19%.[15]

Other effects

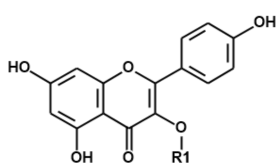
Other activities have also been reported on members of genus *Zygophyllum* **Table 3**. Anti-inflammatory activity best results were recorded for *Z. album* and measured by serum level of C-reactive protein and pancreatic tumor necrosis factor were decreased by 59 % and 64 %, respectively[14]. Also, the analgesic activity was reported for the ethanol extract of *Z. macropodum* (ZME) in acetic acid induced writhing method. The inhibition percentages of ZME 100, 300, and 600 mg/kg were 8.7%, 24.9%, 51.3%, respectively having significant inhibitory effect on increased vascular permeability induced by acetic acid in mice (P < 0.05 and P < 0.001, respectively) compared to normal control[31].

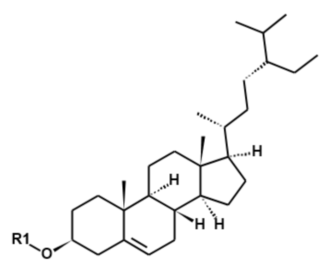


R₁	**R₂**	**Compound no.**
H	H	**1**
O-β-D-glucoside	H	**2**
O-β galactopyranoside	H	**3**
O- β –rutinoside	H	**4**
(4''-sulfatorutinoside)	H	**5**
6''-(2(*E*) butenoyl) glucoside]	H	**6**
O-β-glucopyranoside	*O-α*-rhamnopyranoside	**7**
O-β-D-glucoside	*O-β-D*-glucoside	**98**
O- *β* – D- (6'-malonyl)glucoside	H	**99**



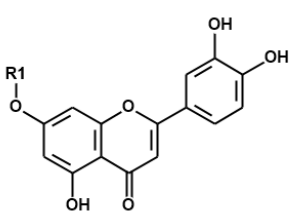
R₁	**R₂**	**Compound no.**
H	H	**8**
O- β –rutinoside	H	**9**
O-β-glucopyranoside	*O-β*-glucopyranoside	**10**
O-β-glucopyranoside	H	**11**
O-(6''-malonyl) glucoside	H	**100**

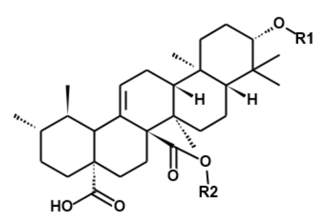




R₁	**Compound no.**
H	**12**
3-*O- β*-rutinoside	**13**
3-*O-β-D*-glucoside	**14**

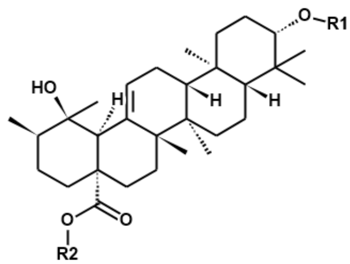
R₁	**Compound no.**
H	**18**
O-β-D-glucopyranoside	**19**



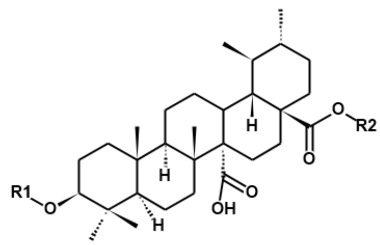


R₁	**Compound no.**
O-β-D-glucoside	16

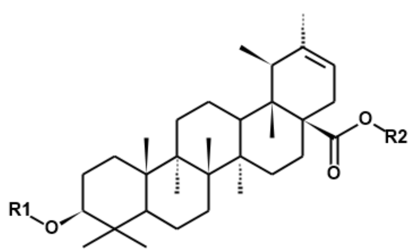
R₁	**R₂**	**Compound no.**
O-[β-D-2-O sulphonyl quinovopyranosyl	*O-β-D-* glucopyranosyl	**35**
O-β-D- quinovopyranosyl	*O-β-D-* glucopyranosyl	**70**



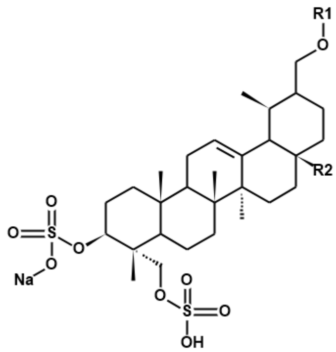
R1	R2	Compound no.
O- α-L-arabinoside	H	**28**
O- β -D-glucopyranosyl	*β -D*-2-*O*-sulfonyl-galactopyranoside	**29**
O- β- D- glucopyranosyl	*O-α-L*-arabinoside	**30**



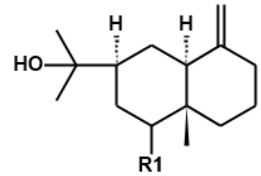
R1	R2	Compound no.
α-L-arabinopyranosyl-(1→2)-*β-D*-glucopyranosyl	H	**31**
β- D- glucose	H	**32**
β-D-(2-O-sulphonyl)- quinovo pyranosyl	H	**33**
α-L-rhamnoside	H	**34**
O-β-D-glucopyranosyl	*O-β-D*-glucopyranosyl	**36**
O-β-D-quinovo pyranosyl	*O-β-D* glucose	**38**
O-α-L-arabinopyranosyl-(1→2)-*β-D*-quinovopyranosyl	H	**39**
O-α-L-arabinopyranosyl-(1→2)-*β-D*-quinovo pyranosyl	*O-β-D* glucose	**40**
O-α-L-arabinopyranosyl-(1→2)-β-D-glucopyranosyl	*O-β-D* glucose	**41**
O-β-D-2-O-sulphonyl glucopyranosyl	H	**42**
O-β-D-2–*O*-sulphonyl glucopyranosyl	*O-β-D* glucose	**43**
O- β-D-2–*O*-sulphonyl quinovo pyranosyl	*O-β-D* glucose	**44**
O- β –D 2-*O*-sulfo- xylopyranosyl	H	**48**
O- β –D 2-*O*-sulfo- xylopyranosyl	*O-β-D* glucose	**49**
O- β{[6-deoxy-*α-L*-mannopyranosyl-(1→2)-*α-L*-arabinopyranosyl-(1→2)-*β-D*-glucopyranurosonyl]	2-*O*-sulfo-*β-D*-glucopyranosyl	**50**
2-*O*-sulfo-*β-D*-glucopyranurosonyl	2-*O*-sulfo-*β-D*-glucopyranosyl	**51**
O-β-D-xylopyranosyl (1→2) quinovo pyranosyl	*O-β-D* glucose	**52**
O-β-D-quinovo pyranosyl	H	**69**



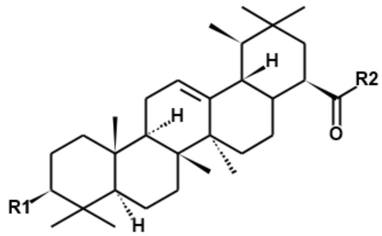
R1	R2	Compound no.
O-α-L-rhamnopyranosyl-(1→2)-*α-L*-arabinopyranosyl-(1→2)-*β -D*-glucopyranosyl	*O- β-D* (2-*O*-sulphonyl) glucopyranosyl	**45**
O- α-L-rhamnopyranosyl-(1→2)-*α-L*-arabinopyranosyl-(1→2)- *β -D*-glucopyranosyl	*O-β- D* glucose	**46**



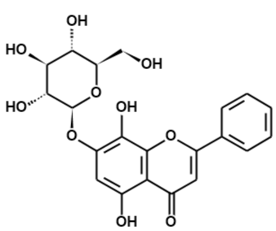
R_1	**R_2**	**Compound no.**
H	CHO	**53**
O-β- D glucose	CH_2OH	**54**



R_1	**Compound no.**
H	**74**
α-hydroperoxy	**75**



R_1	**R_2**	**Compound no.**
β – O- α- L rhamnopyranosyl (1→2) - *α-* L- arabinopyranosyl – (1→2) – *β – D-* glucopyranosyl	*O- β – D*-glucopyranosyl	**96**
β – O- α- L rhamnopyranosyl (1→2) - *α-* L- arabinopyranosyl – (1→2) – *β – D-* glucopyranosyl	*O- β – D-2-O-* sulphonylglucopyranosyl	**97**



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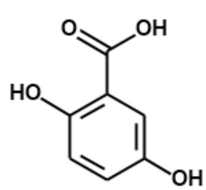

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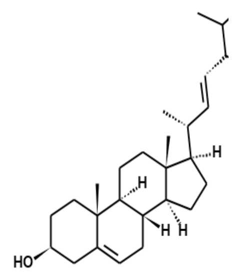

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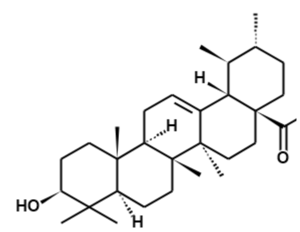

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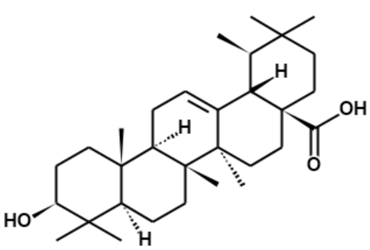

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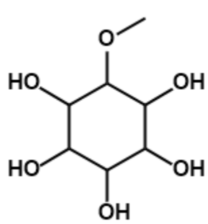

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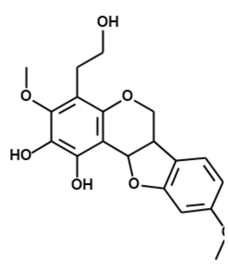

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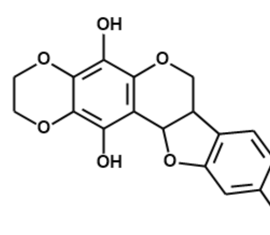

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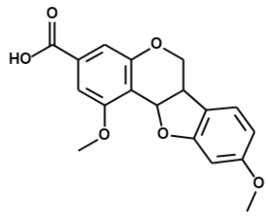

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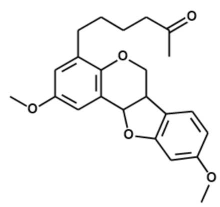

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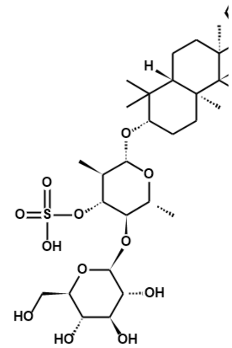

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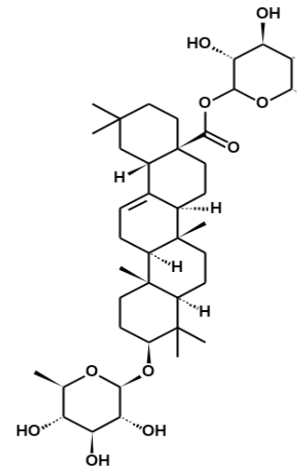

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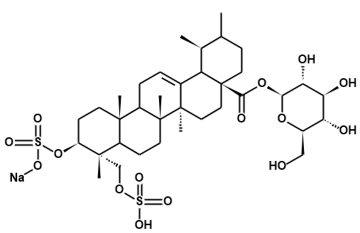

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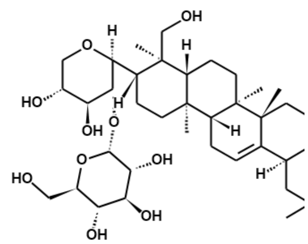

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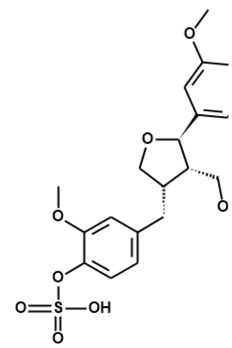

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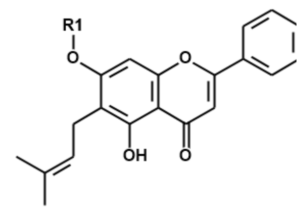
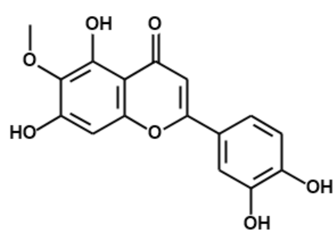


R1: *β-D-* 4'''-*O-* acetyl glucosyl (1'''-2'') *–β- D* – glucose

58



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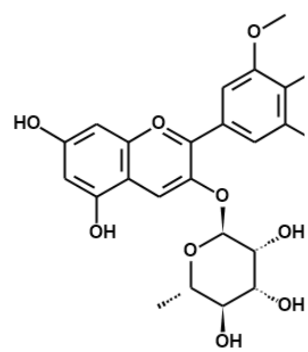

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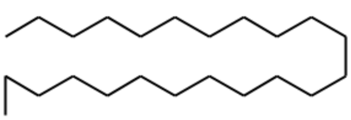

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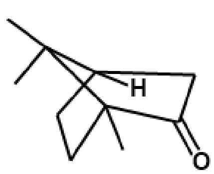

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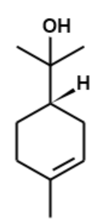

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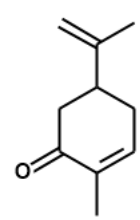

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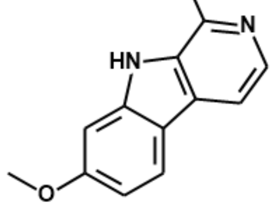

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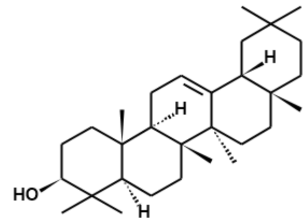

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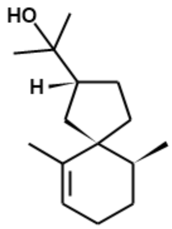

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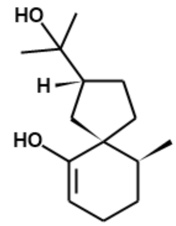

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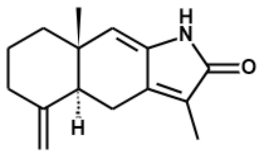

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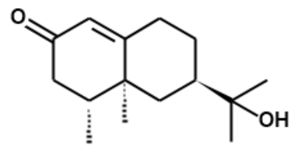

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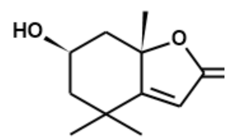

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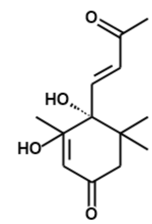

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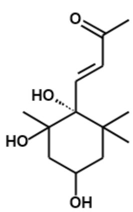

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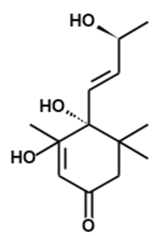

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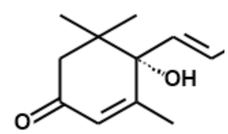

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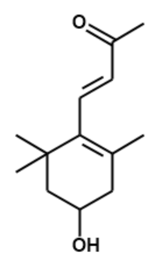

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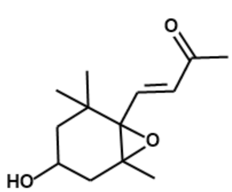

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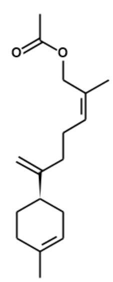

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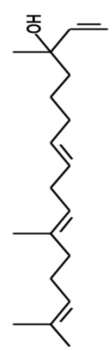

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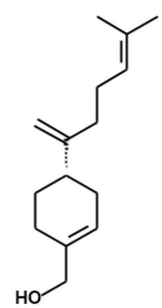

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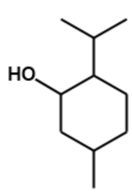

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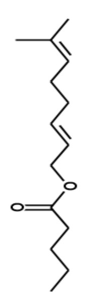

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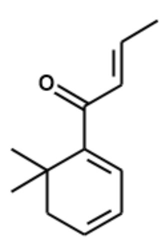

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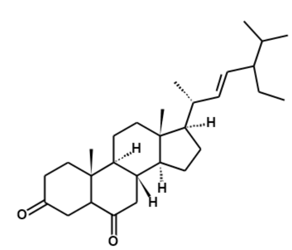

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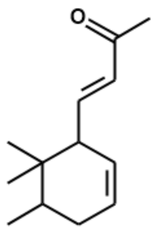

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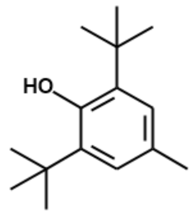

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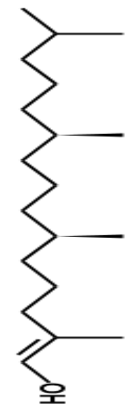

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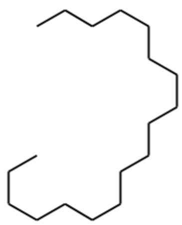

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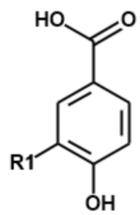
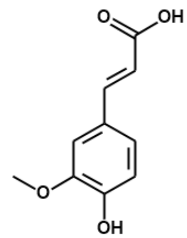
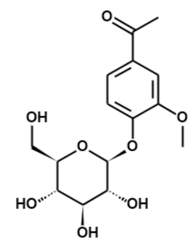


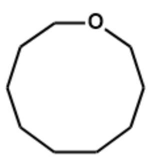
R$_1$	Cpd no.
H	101
OCH_3	102



103



104



105

Figure 1. Structures of isolated compounds from different *Zygophyllum* species

Hypoglycemic and hypolipidemic activities of the aqueous extract of *Z. gaetulum* showed hypoglycemic and hypolipidemic activities in Streptozotocin induced-diabetic rats[11,61], these effects may be due to the antioxidant potential of this plant. Moreover, *Z. gaetulum* aqueous extract prevented lipid peroxidation by enhancing PON1 {paraoxinase activity} and LCAT {Lecithin cholesterol acyltransferase} activities. In addition, it reduced oxidative stress in the liver and kidney by decreasing thiobarbituric acid reactive substances levels and increasing antioxidant enzyme activities[11]. Oral administration of *Z. simplex* to hyperlipidemic rats were appreciably effective in decreasing the levels of serum total cholesterol, low-density lipoprotein cholesterol, triacylglycerol and tissue lipid accumulation while increasing the levels of serum high-density lipoprotein cholesterol, adjusting the metabolic disturbance of lipoprotein and increasing the antioxidant enzyme activity and repressing the development of atherosclerosis [66].

CONCLUSION

In the review, chemical investigations and biological activity have been reported for only 16 out of 100 known *Zygophyllum* species. However, members of *Zygophyllum*, such as *Z. album* and *Z. simplex*, revealed significant biological activity, especially as anti-inflammatory and antioxidant. Investigation of the chemical constituents of plants of genus *Zygophyllum* showed diverse compounds, including triterpenes, saponins, flavonoids, sterols and simple phenolic compounds. It should be emphasized that phenolic compounds from *Z. cornutum*, *Z. album*, *Z. cocceniem*, *Z. hamiense*, *Z. simplex* and *Z. fabago* had particularly prominent anti-oxidant activity, in addition to some other biological properties. Also, the presence of essential oils and saponins in *Z. cornutum* contributed to its antidiabetic activity. Previous studies have provided a base for the medicinal use of *Zygophyllum* species. It is important to note that the safety and toxicity of *Zygophyllum* species have not been explored. Therefore, the toxicities of traditional remedies and isolated chemical compounds should be further assessed as well.

Conflict of Interest

The authors declare that they don't have any kind of conflict of interest.

REFERENCES

1. Hammoda, H.M.; Ghazy, N.M.; Harraz, F.M.; Radwan, M.M.; El Sohly, M.A.; Abdallah, I.I. Chemical constituents from Tribulus terrestris and screening of their antioxidant activity. *Phytochemistry* **2013**, 92, 153-159.
2. Nabiel, A.M.; Saleh, M. N. An approach to the chemosystematics of the *Zygophyllaceae*. *Biochem. Syst. Ecol.* **1977**, *5* (2), 121-128.
3. Hammad, I.; Qari, S.H. Genetic diversity among *Zygophyllum (Zygophyllaceae)* populations based on RAPD analysis. *Genet. Mol. Res.* **2010**, 9(4), 2412-2420.
4. Fatemeh, A. C.; Mohsen, E.; Mostafa, F.A.; Zarrin, T. B. Karyotype analysis and new chromosome number reports in *Zygophyllum* species. *Caryologia.* **2014**, *67* (4), 321-324.
5. Sheahan, D. F.; Cutler, F. L. S. Contribution of vegetative anatomy to the systematics of the Zygophyllaceae. *Bot. J. Linean. Soc.* 1993, *113* (3), 227-262.
6. Soumaya, B.; Wided, M.; Riadh, K. The Halophytic Genus *Zygophyllum* and *Nitraria* from North Africa: A Phytochemical and Pharmacological Overview In. *Medicinal and Aromatic Plants of the World - Africa*, 1st Edn.; Neffati, M.; Najjaa**,** H.; Máthé**,** Á.; Springer, Netherlands. **2017**, (3), pp. 345-356.
7. El-Shora, H. M.; El-Amier, Y. A.; Awad, M. H. Antioxidant Activity of Leaf Extracts from *Zygophyllum coccineum L.* collected from Desert and Coastal Habitats of Egypt. *Int. J. Curr. Micro. App. Sci*. **2016**, *5* (4), 635-641.
8. *Mouna, K.; Hichem, B. S.; Rania, M.; Noureddine, A.* Anti-oxidant and anti-acetylcholinesterase activities of *Zygophyllum album*. *Bangladesh J. Pharmacol.* **2015**, *11* (1), 54-62.
9. Gibbons, S.; Oriowo, M. A. Antihypertensive effect of an aqueous extract of *Zygophyllum coccineum L.* in rats. *Phytother. Res.* **2001**, *15* (5), 452-455.
10. Mahdi, B.; Hocine, D.; Zaouia, K.; Belfar, A.; Bensaci, C.; Mohamed, H. Antioxidant activities, phenolic, flavonoid and tannin contents of endemic *Zygophyllum Cornutum Coss.* From Algerian Sahara. *Der Pharma Chemica*. **2015**, *7* (11), 312 – 317.
11. Akila, G.; Djamil, K.; Samira, Z.; Sadia, B. *Zygophyllum gaetulum* aqueous extract protects against diabetic dyslipidemia and attenuates liver and kidney oxidative damage in streptozotocin induced-diabetic rats. *Int. J. Pharm. Sci. Res.* **2014**, *5* (11), 4709 - 4717.
12. Houria, M.; Tabti, B. Antidiabetic effect of the aerial part ethanolic extracts of *Zygophyllum geslini Coss.* in streptozotocin induced-diabetic rats. *Metabol. Func. Res.* **2012**, *5*, 17-20.
13. Ebrahim, T.; Rasoul, B. Z. N.; Saied, K. Green synthesis of silver nanoparticles using *Zygophyllum Qatarense Hadidi* leaf extract and evaluation of their antifungal activities. *JAPS.* **2018**, *8* (3), 168-171.
14. Mnafgui, K.; Kchaou, M.; Ben Salah, H.; Hajji, R.; Khabbabi, G.; Elfeki, A.; Allouche, N.; Gharsallah, N. Essential oil of *Zygophyllum album* inhibits key-digestive enzymes related to diabetes and hypertension and attenuates symptoms of diarrhea in alloxan-induced diabetic rats. *J. of Pharm. Biol.* **2016**, *54* (8), 1326-1333.
15. El Badry, M.A.; El Aasser, M. M.; El Shiekh, H. H.; Sheriff, M. M. Evaluation of Antimicrobial, Cytotoxic and Larvicidal Activity of *Zygophyllum Coccineum* North Sinai, Egypt. *J. Med. Aromat. Plants.* **2015**, *4* (214), 2167-0412.100021.
16. Varsha, S.; Kishan, G. R. Salt stress enhanced antioxidant response in callus of three halophytes *(Salsola baryosma, Trianthema triquetra, Zygophyllum simplex)* of Thar Desert. *Biologia.* **2014**, *69* (2), 178-185.
17. Emad, M. A.; Gamal, E. G. Screening for antimicrobial activity of some plants from Saudi folk medicine. *GJRMI.* **2013**, *2* (4), 210-218.
18. Ahmed, A. Z.; Zulfiqar, A. l.; Yasser, A. E.; Ikhlas, A. K. A new lignan from *Zygophyllum aegyptium*. *Magn. Reson. Chem.* **2016**, *54* (9), 771-773.
19. Jiangbo, H.; Xiaoman, L.; Yanfen, N.; Jian, T.; Bo, W.; Jing, J.; Weiwei, C. Four new compounds from *Zygophyllum fabago L. Phytochem. Lett.* **2016**, *15*, 116-120.
20. Ganbaatar, C.; Gruner, M.; Tunsag, J.; Batsuren, D.; Ganpurev, B.; Chuluunnyam, L.; Sodbayar,

B.; Schmidt, A. W.; Knölker, H. J. Chemical constituents isolated from *Zygophyllum melongena Bunge* growing in Mongolia. *Nat. Prod. Res.* **2016**, 30 (14), 1661-1664.

21. Abdel-Hamid, R. A.; Ross, S. A. ; Abilov, Z. A.; Sultanova, N. A. Flavonoids and Sterols from *Zygophyllum fabago*. *Chem. Nat. Compd*. **2016**, 52 (2), 318-319.
22. Hashim, A. H.; Ezz, K. D. An acylated isorhamnetin glucoside from *Zygophyllum simplex*. *Phytochemistry.* **1992**, 31(9), 3293-3294.
23. Hani, M.; Kamel, A. E.; Shaker, H.; Pöllmann, K.; Seifert, K. Triterpenoid saponins from *Zygophyllum species*. *Phytochemistry* **1995**, 40 (4), 1233-1236.
24. Ahmed, A. Z.; Yasser, A. E. A.; Zulfiqar, A.; Iftikhar, A. K. Triterpinoidal saponins from *Zygophyllum aegyptium. Planta Medica.* **2015**, 81 (5).
25. Ahmad, V. U.; Iqbal, S.; Nawaz, S. A.; Choudhary, M. I.; Farooq, U.; Ali, S. T.; Ahmad, A.; Bader, S.; Kousar, F.; Arshad, S.; Tareen, R. B. Isolation of four new pterocarpans from *Zygophyllum eurypterum (syn. Z. atriplicoides)* with enzyme-inhibition properties. *Chem. Biodiverse.* **2006**, 3 (9), 996-1003.
26. Yasser, A. E.; Hamed, E.S.; Hesham, M. Ecological Study on *Zygophyllum coccineum L*. in Coastal and Inland Desert of Egypt. *Agric. Ecol. Res. Inter.* **2016**, 6 (4), 1-17.
27. Karl, P.; Katja, S.; Ulrich, S.; Hani, M.; Ahmed, E.; Kamel, H. S.; Karlheinz, S. Triterpenoid saponins from *Zygophyllum decumbens*. *Phytochemistry* **1998**, 48 (5), 875-880.
28. Shehab, N.G.; Abu-Gharbieh, E.; Bayoumi, F.A. Impact of phenolic composition on hepatoprotective and antioxidant effects of four desert medicinal plants. *BMC complement. Altern. Med.* **2015**, 15 (1), 401.
29. Kaplan, D.; Maymon, M.; Agapakis, C. M.; Lee, A.; Wang, A.; Prigge, B. A.; Volkogon, M.; Hirsch, A. M. A survey of the microbial community in the rhizosphere of two dominant shrubs of the Negev Desert highlands, *Zygophyllum dumosum* (Zygophyllaceae) *and Atriplex halimus* (Amaranthaceae), using cultivation-dependent and cultivation-independent methods. *Am. J. Bot.* **2013**, 100 (9), 1713 – 1725.
30. Dhafer, A. A. Z.; Enas, J. A. B. Systematic studies on the Zygophyllaceae of Saudi Arabia: new combinations in Tetraena Maxim. *Turk. J. Bot*. **2017**, 41, 96-106.
31. Xiao-rong, Y.; Xiang-feng, Z.; Xue-mei, Z.; Hong-yan, G. Analgesic and Anti-inflammatory Activities and mechanisms of 70% ethanol extract of *Zygophyllum macropodum* in Animals. *CHM.* **2017**, *10* (1), 59-65.
32. Daradka, H.M. Evaluation of Hematological and Biochemical Activity of Ethanolic Extract of *Zygophyllum simplex Linn.* in Wistar Rats. *PJBS.* **2016**, *19* (4), 179 - 184.
33. Ksouri, W.M.; Medini, F.; Mkadmini, K.; Legault, J.; Magné, C.; Abdelly, C.; Ksouri, R. LC–ESI-TOF–MS identification of bioactive secondary metabolites involved in the antioxidant, anti-inflammatory and anticancer activities of the edible halophyte *Zygophyllum album Desf*. *Food Chem.* **2013**, *139* (1), 1073-1080.
34. Belmimoun, A.; Meddah, B.; Side, L. K.; Sonnet, P.Phytochemical study of *Zygophyllum album* extract. *JET-M* **2017**, *4* (5), 1-10.
35. Kchaou, M.; Ben Salah, H.; Kais, M.; Noureddine, A. Chemical Composition and Biological Activities of *Zygophyllum album (L.)* Essential Oil from Tunisia. *JAST.* **2016**, *18* (6): p. 1499-1510.
36. Rezuanul I.; Yong T. J.; Yong S. L.; Chi H. S. Isolation of antifungal compounds from some *Zygophyllum species* and their bioassay against two soil-borne plant pathogens. *Folia Microbial.* **1994**, *39* (3), 215-221.
37. Kais, M.; Khaled, H.; Hichem, B. S.; Mouna, K.; Mbarek, N.; Sadok, S.; Fatma, D.; Noureddine, A.; Abdelfattah, E. Inhibitory Activities of *Zygophyllum album*: A Natural Weight-Lowering Plant on Key Enzymes in High-Fat Diet-Fed Rats . *Evid. Based Complement. Alternat. Med.* **2012**, *10*, 384 – 392.
38. Amal, M.Y.; Mostafa, A. I. K.; Faiza, M. H.; Husseiny, A. H. Phytochemical and toxicological studies on *Zygophyllum album L.F. J. Pharmacol. Toxicol.* **2007**, *2* (3), 220-237.
39. Tigrine, K. N.; Meklati, B.Y.; Chemat, F. Contribution of microwave accelerated distillation in the extraction of the essential oil of *Zygophyllum album L*. *Phytochem. Anal.* **2011**, *22* (1), 1-9.
40. Ahmad, V.U.; Iqbal, S.; Kousar, F.; Bader, S.; Arshad, S.; Tareen, R. B. Two new saponins from *Zygophyllum atriplicoides*. *Chem. Pharm. Bull.* **2005**, *53* (9), 1126-1130.
41. Mamdouh, A.M.; Layth, M. S.; Menna Allah, H. A Comparative Study on Phytochemical Constituents of *Zygophyllum coccineum L.* in Coastal and Inland desert of Egypt. *IJSE* **2015**, 4 (5), 353.355.
42. Elham, A.; Seham, S. E. H.; Mohamed, M. F.; Imtaz, A. K. Zygophylloside S, a New Triterpenoid Saponin from the Aerial Parts of *Zygophyllum coccineum L. Planta Medica.* **2010**, *76* (5), 51.
43. Ayad, M. R.; Azouzi, S.; Louaar, S.; Akkal, H. D.; Medjroubi, K. Phytochemical investigation of the endemic plant *Zygophyllum cornutum*. *Chem. Nat. Prod.* **2012**, *48* (2), 313-314.

44. Sobirdjan, A. S.; Putieva, Z. M. ; Kachala, V. V. ; Saatov, Z. ; Shashkov, A. S. Triterpene glycosides of *Zygophyllum eichwaldii. Ii.* Structure of zygoeichwaloside I. *Chem. Nat. Prod.* **2001**, *37* (4), 347-350.
45. Saleha, S. K.; Afsar, K.; Amir, A.; Viqar, U. A.; Umar, F.; Saima, A.; Sadia, B.; Aqib, Z.; Imran, N. S.; Bilge, S.; Nurgun, E. Two new disulfated triterpenoids from *Zygophyllum fabago*. *Helv. Chim. Acta*. **2010**, *93* (10), 2070-2074.
46. Yaripour, S.; Delnavazi, M. R.; Asgharian, P.; Valiyari, S.; Tavakoli, S.; Nazemiyeh, H. A survey on phytochemical composition and biological activity of *Zygophyllum fabago* from Iran. *APB.* **2017**, *7* (1), 109 - 114.
47. Hossein, M.; Mohmmad, V.; Reza, S. Chemical composition of essential oil of *Zygophyllum fabago L.* from North-West Iran. *Int. J. Herb. Med.* **2015**, *2* (6), 34-37.
48. He, J.H.; Niu, Y. F.; Li, J. X.; Wang, L. B.; Zi, T. P.; Yu, S.; Tao, J. Studies on terpenoids from *Zygophyllum fabago*. *Zhongguo Zhong Yao Za Zhi.* **2015**, *40* (23), 4634-4638
49. Khayari, M. E. A.; Benharref, A.; Abbad, A.; Bekkouche, K.; Larhsini, M.; Jamali, C. A.; Markouk, M.; Taourirte, M. Chemical Composition of Essential Oils and Mineral Contents of *Zygophyllum gaetulum (Emb. and Maire). J. Essent. Oil Bear. Pl.* **2017**, *20* (6), 1645-1650.
50. Omar, S.; Souad, F. T.; Nunziatina, D. T.; Rita, A. Saponins from *Zygophyllum gaetulum*. *Nat. Prod.* **1998**, *61* (1), 130 – 134.
51. Dalila, S.; Anne, C.; Mitaine, O.; Tomofumi, M. V. H.; Marie, A.; Lacaille, D. Ursane-Type Triterpene Saponins from *Zygophyllum geslini. Helv. Chim. Acta.* **2007**, *90* (4), 712-719.
52. Viqar, U. A.; Ghazala, S. U.; Mohammad, S. A. *Saponins from Zygophyllum propinquum*. *Phytochemistry.* **1993**, *33* (2), 453-455.
53. Sameh, H.; Mona, M.; Lamyaa, F. I.; Nabiel, A.M.S. Flavonoids of *Zygophyllum album Lf and Zygophyllum simplex L.*(Zygophyllaceae). *Biochem. System. Ecol.* **2011**, *39* (4-6), 778-780.
54. Elham, A.; Seham, S. E. H.; Mohamed, M. F.; Rabab, M.; Khan, I. A. A Phytochemical Study of *Zygophyllum simplex L. Planta Medica.* **2011**, *77*, 40
55. Mnafgui, K; Kchaou, M.; Hamden, K.; Derbali, F.; Slama, S.; Nasri, M.; Salah, H. B.; Allouche, N.; Elfeki, A. Inhibition of carbohydrate and lipid digestive enzymes activities by *Zygophyllum album* extracts: effect on blood and pancreas inflammatory biomarkers in alloxan-induced diabetic rats. *Physiol. Biochem.* **2014**, *70* (1), 93-106.
56. Ghoul, J. E.; Boughattas, N. A.; Ben Attia, M. Antihyperglycemic and antihyperlipidemic activities of ethanolic extract of *Zygophyllum album* in streptozotocin-induced diabetic mice. *Toxicol. Ind. Health.* **2013**, *29* (1), 43-51.
57. Ishrak, K. K.; Ahmed, D. The efficiency of random versus ethno-directed research in the evaluation of Sinai medicinal plants for bioactive compounds. *J. Ethnopharmacol.* **2000**, *71* (3), 365-376.
58. Awatif, B.; Samira, F.; Houda, S.; Fatima, K. T.; Cherifa, B. Therapeutic Effect of *Zygophyllum cornutum* on Metabolic Disturbances, Oxidative Stress in Heart Tissue and Histological Changes in Myocardium of Streptozotocin-induced Diabetic Rats. *Life Sci.* **2016**, *10*, 192-197.
59. AL-Qaissi, E. Antimicrobial activity of petroleum ether extracts from leaves, seeds and roots of *Zygophyllum fabago L.* towards some microorganisms. *Ibn AL-Haitham Journal for Pure and Applied Science.* **2017**, *21* (2), 1-14.
60. Saleha, S. K.; Ajmal, K.; Afsar, K.; Abdul, W.; Umar, F.; Amir, A.; Aqib, Z.; Viqar, U. A.; Bilge, S.; Nurgun, E. Urease inhibitory activity of ursane type sulfated saponins from the aerial parts of *Zygophyllum fabago Linn. Phytomedicine.* **2014**, *21* (3), 379-382.
61. Jaouhari, J. T.; Lazrek, H. B.; Jana, M. The hypoglycemic activity of *Zygophyllum gaetulum* extracts in alloxan-induced hyperglycemic rats. *J. Ethnopharmacol.* **2000**, *69* (1), 17-20.
62. Anna, C.; Safir, O.S; Fkih, T.; Ludovico, S.; Rita, A. Properties and effects on isolated guinea-pig ileum of *Zygophyllum gaetulum* species endemic in Moroccan Sahara. *Pharm. Biol.* **1998**, *36* (5), 320-326.
63. Kouadri, B. W.; Hammadi, K. Evaluation of Antidiabetic Activity of Two Plants *Berberis vulgaris and Zygophyllum geslini. J. Phys. Chem. Biophys.* **2017**, *7* (1), 236 -240.
64. Abdallah, H.M.; Esmat, A. Antioxidant and anti-inflammatory activities of the major phenolics from *Zygophyllum simplex L. J. Ethnopharmacol.* **2017**, 205, 51-56.
65. Kumar, H.; Kakrani, N.; Kakrani, P.; Kumar, A. S. Evaluation of analgesic and anti-inflammatory activity of Ethyl acetate extract of *Zygophyllum simplex Linn.* herb. *Int. J. Res. Phytochem. Pharmacol.* **2011**, 1, 180-183.
66. Haytham, M. D.; Kamal, M. S. M.; Bandar, R. A. S.;, Abdul Mannan, M.; Yaser, S. B. N.; Muwaffa, G. B.; Jalal, A. J. Antihyperlipidemic activity of *Zygophyullum Simplex* ethanolic extract on high cholestrol diet induced hyperlipidemia in rats. *IJBPAS.* **2017**, *6* (12), 2414-2430.