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TAMARIX PLANTS OF ISRAEL AND PALESTINE. A REVIEW

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ABSTRACT

Tamarix growing wild between the Mediterranean Sea and the Jordan river region (Israel and Palestine) are reviewed in this article mainly for medicinal properties-activities. Yet, some other properties are also presented especially in the discussion part of this review article. The gaps in the numbers of published studies about each one of these twelve species are very large, where some were extensively published while we found no published articles about some others. Activities-properties will be listed and highlighted in tables. Documented ethnobotanical uses of these plants will be presented, along with the few review articles that were published about them. In addition to the figures with the structures of selected natural compounds that these species contain, the discussion part of this article will elaborate on indirect activities-properties of these plants. Finally, despite being important botanical subject, the adaptation of these plants to various external conditions, and the impact on the plants on their environment, will be very shortly discussed.

KEYWORDS: *Tamarix*, *Tamarix aphylla*, ethnobotany, chemical composition, antioxidant, antimicrobial, anti-inflammatory, invasive plants, adaptability, nanoparticles.

Abbreviations: ahc and her/his colleagues, AChE acetylcholine esterase, BuChE butyrylcholine esterase, COX cyclooxygenase, DEE diethyl ether, DCM dichloromethane, DEE diethyl ether, DPPH 2,2-Diphenyl-1-picrylhydrazyl, EDTA ethylenediaminetetraacetic acid, EO essential oil, FRAP ferric reducing activity power, GCC general chemical composition, GC-MS gas chromatography mass spectrometry, GSH glutathione, HPLC high performance liquid chromatography, LPS lipopolysaccharide, MDA malondialdehyde, MPO myeloperoxidase, NPs nanoparticles, ORAC oxygen radical absorbance capacity, PE

petroleum ether, RR reviewed region, SOD superoxide dismutase, STZ streptozotocin, TFC total flavonoid content, TPC total phenolic content.

1) INTRODUCTION: Taxonomy, Archeology and Published Review Articles

Tamarix (Arabic أثل and Hebrew אשל, English common name, Tamarisk**)** is one of the genera of the Tamaricaceae (Arabic أثليات and Hebrew אשליים). Globally, this family includes five genera and 55 species,[1] but this data is strongly debated. For example, other publications state that this family includes four genera and about 120 species, where the difference is more than 100%.[2] However, in the RR, the Tamaricaceae plant family is represented by two genera, *Tamarix* (12 species) and *Reaumuria* (2 species).[3] The number of species that comprise the *Tamarix* genus is very highly debated: 54-90, about 200 taxa, including species, subspecies, varieties and forms.[4]

Tamarix plants are native to the "ancient world" but some of them were introduced (invasive) in the Americas (see **Discussion** part), and especially in the Middle East, they are excellently adapted to arid and semi-arid habitats.[5,6] In the Middle East, humans used *Tamarix* plants since ancient times. Archaeological evidence prove that Babylonians used them in various rituals, and bible mentions them several times.[7] Archaeologists of ancient Egypt discovered that *Tamarix* trees were utilized for construction, fuel and preparing coffins for nobility, and their tree rings helped researchers to determine the history of the artifacts.[8,9,10] In an interesting article, N.S. Geweely ahc used plants EOs for the preservation of biodeteriorated ancient Egyptian wooden artifacts made from *Tamarix gennessarensis*.[11]

Unexpectedly, the number of published review articles about the *Tamarix* genus is relatively low, and there are more articles about specific species. R. Bahramsoltani ahc published an excellent review article about the *Tamarix* genus plants: comprehensive, detailed, traditional uses, natural products structures and quality assessments.[12] Contrary to that, the very short article (four pages) of J.T. Mouhi reviewed *Tamarix aphylla*, and it hardly presents the properties of this extensively studied plant (see **Table 2**).[13] The same species was reviewed by S.A. Alshehri ahc, where their article is comprehensive, very detailed, with very good figures.[14] The review article of A.A. Abdelgawad presents the chemical composition of *Tamarix nilocita* in a very detailed fashion, less than that its medicinal activities-properties, and even less than this, traditional uses and botanical information.[15]

The twelve *Tamarix* species in the RR are: *Tamarix amplexicaulis*, *T. aphylla*, *T. chinensis*, *T. gennessarensis*, *T. hampeana*, *T. jordanis*, *T. negevensis*, *T. nilotica*, *T. palaestina*, *T. parviflora*, *T. passerinoides* and *T. tetragyna*.

2) Ethnobotany and Ethnomedicine of *Tamarix* Plants of Israel and Palestine

Traditional societies and their traditional ethnobotany and ethnomedicine used *Tamarix aphylla* almost exclusively, with very few documented uses of other *Tamarix* species. These uses are summarized in **Table 1**.

Table 1: Ethnobotany and Ethnomedicine of *Tamarix* Plants of Israel and Palestine.

Species	Country/Region; Plant Parts; Method; Uses; Reference
T. aphylla	Indonesia; all parts; unspecified; treat diarrhea, wounds, disinfectant and other uses (authors indicate it as one of the plants mentioned in the holy Quraan);[16] Iran; stem; topical poultice; eczema and other skin diseases;[17] Pakistan; leaves; decoction for enhancement of physical strength, poultice for wound healing, disinfectant;[18] Bark, leaves, twigs; unspecified; jaundice, rheumatism, wounds, abscesses;[19] Bark, topical: astringent, eczema and other skin disorders, powder: aphrodisiac, leaves, smoke: treat fever, decoction: swollen spleen., with ginger addition: uterus problems (authors indicate it as one of the plants mentioned in the holy Quraan);[20] Leaves; decoction, wounds;[21] Roots bark; decoction; toothache, anti-inflammatory;[22] Leaves, bark; paste; tied around broken animal bones;[23] Leaves, whole plant; paste, decoction; astringent, skin diseases and fuel;[24] Leaves; decoction; antidiabetic;[25] Leaves; cattle: decoction against digestive problems, wood: construction and fuel;[26] Aerial parts: decoction, diuretic, bark: decoction, hepatitis, leaves: decoction, fever, roots: paste, wound healing;[27]a Reviewed region; leaves, decoction; fever;[28] Saudi Arabia; bark: decoction, hepatitis, powder paste: skin diseases, poultice: wound healing, leaves: decoctions, fever, smoke: wound healing, rubbed externally: headache, roots: paste, wound healing, decoction: stomach ache.[29] a) Table of uses is inserted in this article as very unclear image, the scientific name of the plant is incorrectly written and in the first page a misleading “DOI” is presented, while practically it does not exist.
T. nilotica	Reviewed region; leaves, stems; unspecified method(s); tooth inflammation, spleen edema, infections of the uterus, diaphoretic, diuretic, licicidal, hepatotonic, relieve headaches, wounds healing, fuel materials, charcoal, construction.[30]
Tamarix (general)	Afghanistan; based on knowledge found in five ancient books and local people practices, the following activities are listed: antidiarrheal, anti-inflammatory, wound healing, astringent and hemostatic.[31]

3) Published Activities-Properties of *Tamarix* Plants of Israel and Palestine

Surprisingly, A summary of these findings is presented in **Table 2**.

Table 2: Published Activities-Properties of *Tamarix* Plants of Israel and Palestine.

Activity-Property, Testing Method(s), Result(s), Reference
Tamarix amplexicaulis
Flowers ethanolic extract was chromatographed affording seven sulphated flavonols, one of them was new (**Figure 1**)[32]
Follow-up of previous study yielded ten derivatives of known phenolic acids, whee three of these compounds were new (**Figure 1**)[33]
Seeds ethanolic extract had **hepatoprotective** activity against toxicity of carbon tetrachloride, paracetamol or D-galactosamine in rats, with silymarin as a reference. Effect was measured with several biomarkers: alanine aminotransferase, aspartate aminotransferase, GSH and MDA[34]
Tamarix aphylla
Whole plant ethanolic extract was analyzed for GCC and tested for **antimicrobial** (bacteria and fungi strains) activity[27]b
Bark 80% aqueous ethanolic extract was analyzed for TFC, TPC and GCC. It was tested for **antimicrobial** (six bacterial and fungal strains) and **antioxidant** (DPPH method) activities showing significant results in both tests[29]
Fruits and aerial pats were separately and successively extracted *n*-hexane, DCM, ethyl acetate and methanol, and the four extracts were analyzed for TFC and TPC. Analysis of ethyl acetate extract for chemical composition yielded mainly previously well known phenolics. The **antioxidant** activity was tested with Fe^{+2} chelating activity (EDTA was reference) and the **enzyme inhibition** activity was tested against α-amylase, α-glucosidase, AChE, BuChE and tyrosinase. Molecular docking was performed for some of the isolated natural products.[35]
EO (hydrodistillation) was analyzed (GC-MS) and the eight major compounds (%) were: β-vinylnaphthalene 3.67, sabinene 4.14 (unspecified stereochemistry), *cis*-sabinene hydrate 5.32, limonene 5.65, *cis*-β-ocimene 7.11, bornyl acetate 7.63, α-terpinolene 8.56 and β-pinene 29.87 (**Figure 2A**). EO was tested for **anticancer** (against HL60 and NB4 leukemia cell lines) and **antioxidant** (ABTS and DPPH methods) activities, showing significant results in both tests.[36]
Aerial parts were separately extacted with ethanol and water and both extracts were analyzed for GCC and tested for **antiproliferative** activity against MCF-7, Caco-2 and Panc-1 cell lines (doxorubicin and cisplatin were reference dugs). EO was obtained by hydrodistillation and analyzed for chemical composition and the three major components were (%): dodecanoic acid 6.00, β-ionone (**Figure 2A**) 13.74 and 6,10,14-trimethyl-2-pentadecanone 32.39.[37]
Leaves 80% aqueous methanolic extract had **antidiabetic** activity against STZ- and nicotinamide-induced diabetes in rats. Effect was measured with several biomarkers, especially blood glucose levels. The extract was also separately tested for **toxicity** in rats and found nontoxic.[38]
Aerial parts EO (hydrodistillation) had **anti-inflammatory** activity against carrageenan-induced paw edema in rats and separately found **nontoxic** for the same rats. The anti-inflammatory effect was tested with leukocyte migration into the peritoneal cavity, MPO activity, nitrate/nitrite concentrations, lipid peroxidation *in vitro* and nitric oxide radical scavenging activity. The EO was analyzed by GC-MC and the five major components (%)

were: *trans*-β-caryophyllene 10.1, α-caryophyllene 6.1 (**Figure 2A**), β-ionone 20.1, dodecanoic acid 12.2 and 6,10,14-trimethyl-2-pentadecanone 20.2.[39]

Aerial parts methanolic extract had **anti-inflammatory** activity against carrageenan-induced paw edema in rats and separately found **nontoxic** for the same rats. The anti-inflammatory effect was measured with several biomarkers (*in vivo* and *in vitro*) and a mechanism of action is proposed.[40]

Leaves and stems were combinedly extracted with 85% aqueous methanol and the extract was fractionized with PE, ethyl acetate, *n*-butanol and water. The crude extract and the four fractions were analyzed for TFC and TPC, and the ethyl acetate, *n*-butanol fractions were qualitatively analyzed for chemical composition. The crude extract and the four fractions were tested for **anti-inflammatory** (in RAW 264.7 macrophage cell line) and **antimicrobial** (two bacterial and three fungal species) activities.[41]

Stem bark methanolic extract was tested for **anti-inflammatory** (carrageenan-induced paw edema, xylene-induced ear edema in mice), **antipyretic** (brewer yeast-induced pyrexia) and **antinociceptive** (hot plate and acetic acid-induced writhing) activities.[42]

Leaves 70% aqueous methanolic extract was analyzed for TFC, TPC and GCC. It was tested for **anti-inflammatory** activity with the following methods: protein denaturation, proteinase inhibition and LPS-induced inflammation in mice (SOD and MDA levels were measured) and in RAW 264.7 cells. The **antioxidant** activity was tested using DPPH and hydrogen peroxide inhibition.[43]

Leaves 90% aqueous ethanolic extract was tested for **toxicity** in rats (nontoxic), **anti-inflammatory** activity (carrageenan-induced paw edema with diclofenac sodium as a reference drug, **antioxidant** activity (DPPH and H_2O_2 scavenging methods). A gel that contained this extract had **wound healing** activity in rats.[44]

Leaves 70% aqueous methanolic extract was partitioned with water, *n*-hexane, DCM, ethyl acetate and *n*-butanol. The **antioxidant** activity was tested with hydrogen peroxide and superoxide radical scavenging methods. **Antiulcer** and **anti-inflammatory** activities were tested against indomethacin-induced gastric ulcer in rats, where effect was measured by nine biomarkers for both tests. Ethyl acetate fraction was chromatographed affording eight previously known kaempferol and quercetin derivatives that were also tested for the same activities. A detailed mechanism of action is presented.[45]

Leaves 80% aqueous ethanolic extract was partitioned with water, *n*-hexane, DCM, ethyl acetate and *n*-butanol. Ethyl acetate fraction was chromatographed affording four previously known phenolics. These were tested for **anti-inflammatory** and **antioxidant** activities were tested against LPS-induced inflammation in several cell lines.[46]

Leaves 90% aqueous ethanolic extract was tested against fourteen bacteria and five fungi species showing none (2 bacteria) to moderate **antimicrobial** activity.[47]

Stem bark ethanolic extract had **antifungal** activity against *A. flavus*, *A. fumigatus*, *A. niger*, *F. oxysporum*, *P. notatum* and *S. cerevisiae*.[48,49]

Leaves and stems were separately extracted with ethanol and GCCs of the extracts were determined. It is stated that the extracts were tested against some bacteria species and against corona virus, but no experimental part is presented.[50]

Leaves ethanolic extract had **antibacterial** activity against *S. mutans*.[51]

Leaves were separately extracted with ethanol and water and the extracts had **antifungal** activity against plant pathogenic fungi: *F. verticilliodes M. phaseolina C. spicifera F. moniliforme F. solani F. proliferatum*. The ethanolic extract was qualitatively analyzed resulting seven compounds (**Figure 2A**).[52]

Leaves 96% aqueous ethanolic extract had **antibacterial** activity against *S. aureus*. It was analyzed (GC-MS) for chemical composition and the major components (%) were: phytol, acetate 18.93, 6-octen-1-ol, 3,7-dimethyl-, formate 5.66, 6-octen-1-ol, 3,7-dimethyl-,

acetate 9.34 (**Figure 2A**), hexadecanoic acid, methyl ester 12.14, hexadecanoic acid, ethyl ester 7.48, 9,12-octadecadienoic acid, methyl ester 20.06, heptadecanoic acid, 10-methyl-, methyl ester 6.97.[53]

Leaves 70% aqueous methanolic extract had **antifungal** activity against human mucormycosis.[54]

Leaves were extracted by separate maceration in cyclohexane, DCM, PE, methanol, ethanol and *n*-butanol. They were also extracted using Soxhlet apparatus using ethyl acetate, DCM, PE, methanol and ethanol. Stems were extracted using Soxhlet apparatus using ethyl acetate, DCM and ethanol. Leaves cyclohexane, DCM, ethanol and *n*-butanol extracts were analyzed for TPC and tested for **antioxidant** activity using ABTS and DPPH methods. PE, DCM, ethyl acetate, methanolic and ethanolic extracts from both extraction methods were tested for **antimicrobial** activity against five bacterial and four *Candida* fungal species. The extracts had significant antibacterial but no antifungal activity.[55]

Leaves methanolic and ethanolic extracts were analyzed for TFC, TPC and alkaloids contents. They were tested for **antibacterial** activity against *S. aureus*, *S. typhi*, *E. coli* and *P. aeruginosa*.[56]

Leaves were separately extracted with cold water, hot water, *n*-hexane, PE, DEE, acetone, chloroform and methanol. These extracts had **antimicrobial** activity against seven bacterial strains and *Candida* species. The *n*-hexane extract was analyzed with GC-MC resulting previously known compounds including asarone (**Figure 2A**).[57]c

Leaves methanolic extract was analyzed for GCC and fractionized with *n*-hexane, ethyl acetate, *n*-butanol and water. The crude extracts and fractions were tested for **antibacterial** activity, where the activity order was crude-extract > ethyl-acetate extract > *n*-butanol extract > *n*-hexane extract. Ciprofloxacin was reference drug.[58]

Leaves 70% aqueous methanolic extract had notable **antioxidant** activity tested with DPPH method.[59]

Leaves 70% aqueous methanolic extract had notable **antioxidant** activity (DPPH method), separately, and showed synergetic effect with 70% methanolic extract of *allium sativum* (garlic) cloves.[60]

Follow up of previous study (**antioxidant**) with *Calotropis procera* leaves extract.[61]

Leaves ethyl acetate extract was analyzed for GCC, TPC and tested for **antioxidant** activity using DPPH method. It was also qualitatively analyzed by GC-MS.[62]d

Leaves 70% aqueous methanolic extract **antiparasitic** activity against *Leishmania tropica* was tested and compared to same extract of *Aloe vera* leaves.[63]

Leaves 70% aqueous ethanolic extract was chromatographed yielding a new rhamnetin glucuronide trisulphate (**Figure 2A**).[64]

Bark chloroform extract was chromatographed affording a new compound, isomyricadiol (1), its 3β isomer (myricadiol, 2) and its 3-ketone (3) (**Figure 2B**).[65]

Galls 75% aqueous ethanolic extract was chromatographed affording tamarixellagic acid and four previously known dehydrogallic acid, dehydrotrigallic acid, dehydrogallic acid xanthone and dehydrotrigallic acid xanthone (**Figure 2B**).[66]

Flowers 75% aqueous methanolic extract had **antioxidant** activity tested with DPPH method. It was chromatographed yielding three new compounds: aphyllin (isoferulic acid 3-*O*-β-glucopyranoside), tamarixetin 3,3'-di-sodium sulphate and dehydrodigallic acid dimethyl ester (**Figure 2B**).[67]

Galls were defatted with PE using Soxhlet apparatus, extracted with ethanol and the extract was dissolved in methanol and chromatographed, resulting isolation of three new acids: aphyllaoic acid, tamarixoic acid and dimethyleneoxy diferulic acid (**Figure 2C**).[68]

GCC of leaves methanolic extract is reported.[69]

Aerial parts 80% aqueous ethanolic extract was analyzed for TFC, TPC and chemical

composition (HPLC) showing high content of several known phenolic compounds (myricetin, sinapic acid, kaempferol and caffeic acid). It was tested for **antioxidant** (DPPH method, four biomarkers were measured) and **hepatoprotective** (against $NaAsO_2$ -induced liver toxicity in rats, three biomarkers were measured) activities.[70] Leaves 70% aqueous methanolic extract was tested for **toxicity** in mice (nontoxic) and analyzed for GCC. Charcoal meal gastrointestinal transit test and weight of the faeces matter were used for evaluation of the **laxative** potential of the extract.[71] Donated extract (plant part(s) unknown, solvent is indicated as "alcoholic") was tested for **toxicity** in rats (nontoxic), **anti-inflammatory** (against carrageenan-induced paw edema in rats), **analgesic** (acetic acid-induced writhing and hot plate tests) and **antipyretic** (against yeast-induced hyperpyrexia) activities..[72] Leaves 70% aqueous ethanolic extract had **wound healing** activity in rats, where effect was measured with five parameters.[73] Leaves 70% aqueous methanolic extract and it was analyzed for TFC, TPC and tested for **antioxidant** activity using DPPH method. It was used in the preparation on nanoemulsion that had **wound healing** activity in rabbits. Effect was measured with healing time and contraction rate.[74] b) Data of used plant part(s) and results presentation are very unclear. c) It is not indicated if its *cis* (β) or *trans* (α) asarone. d) The list of compounds presented on page 2259 is includes several misleading mistakes, here are three examples. Acetophenone formula is written C_8H_7CLO, beclomethasone is written $C_{22}H_{29}CLO_5$ and phenylmercuric salicylate formula of $C_{13}H_{10}HGO_3$.
Tamarix chinensis Leaves and stems 95% aqueous ethanolic extract was analyzed affording two new flavonoid-polysaccharides. These were tested for **antioxidant** (ABTS and FRAP methods) and **anticomplement** (haemolytic assay, *in vitro*, with quercetin as reference compound) activities.[75] Follow up of previous study: a new flavonoid-polysaccharide was tested for **antiviral** activity against influenza virus.[76] Mineral composition (A*l*, B, Cu, Fe, K, Li, Mg, Mn, Mo, Na, P, Si, Sr, Ti, V, and Zn) was affected by neighbouring coal-fired power plant.[]77 Leaves and twigs EO (hydrodistillation) was analyzed with GC-MS showing hexadecanoic acid as major component, 22.22%.[78] Leaves and stems 95% aqueous ethanolic extract was chromatographed yielding 15 previously known compounds. Among these compounds were tamarixetin-7-*O*-β-*D*-glucoside and tamarixetin-3-*O*-α-*L*-rhamnoside (**Figure 3**).[79] Fruits *n*-hexane extract was prepared using two methods (Pharmacopoeia and Soxhlet) and was analyzed with GC-MS affording 67 previously known compounds.[80] Seasonal changes in the stoichiometry of C, N, P in leaves are reported.[81] Branches and leaves 80% aqueous ethanolic extract had **hepatoprotective** effect against ethanol-induced liver injury in rats.[82]
Tamarix gennessarensis **No reported medicinal properties-activities.**
Tamarix hampeana Flowers methanolic extract was partitioned with water and DCM, then chromatographed affording two new compounds, hexatetacontan-19-ol, laserine, along with previously known compound, epilaserine (**Figure 4**).[83]
Tamarix jordanis **No reported medicinal properties-activities.**
Tamarix negevensis

No reported medicinal properties-activities.
Tamarix nilotica Donated extract (plant part(s) unknown, solvent is indicated as "alcoholic") was tested for **toxicity** in rats (nontoxic), **anti-inflammatory** (against carrageenan-induced paw edema in rats), **analgesic** (acetic acid-induced writhing and hot plate tests) and **antipyretic** (against yeast-induced hyperpyrexia) activities.[72] Flowers 80% aqueous methanolic extract was tested for **cytotoxic** activity against human liver cancer (Huh-7) and breast cancer (MCF-7) cell lines. The *n*-butanol fraction of this extract was analyzed for chemical composition yielding 39 known compounds, especially nilotinins. The structures of three of these compounds are shown in **Figure 5**.[84] Flowers methanolic extract was prepared with two methods: maceration and ultrasound-assisted. Both extracts were analyzed for TPC, tested for **antioxidant** activity (DPPH method) and for **anticancer** activity against three cancer cell lines: breast (MDA-MB-231), colon (HCT-116), and lung (A-549). In all tests ultrasound-assisted extract was more active. Both extracts were analyzed for chemical composition and the ultrasound-assisted extract contained more compounds. All detected compounds are previously known.[85] Aerial parts from Egypt and Saudi Arabia were extracted with water and fractionized with ethanol and analyzed for TPC and tested for **antioxidant** activity (ORAC method), where in both tests the extracts from Saudi Arabia were more active. Extracts were tested for **hepatoprotective** activity (against carbon tetrachloride-induced hepatotoxicity in rats) and in this test the Saudi Arabia extracts were more protective. Effect was measured with several biomarkers of three parameters: oxidative stress (three), liver fibrosis (one) and inflammatory markers (two).The crude extracts were analyzed for chemical compositions yielding previously know natural products, mainly phenolics.[86] Leaves methanolic extract had **antimicrobial** (against *S. aureus, P. aeruginosa* and *C. albicans*) and **antioxidant** (DPPH method) activities.[87] Leaves *n*-hexane extract was analyzed for GCC and tested for **antibacterial** activity against nine bacterial strains.[88] Roots PE extract chromatography afforded two novel compounds, l-(*E*)-feruloyl-3-pentacosanoylglycerol and (*E*)-3-hydroxy4methoxycinnamaldehyde; and previously known (E)-4-hydroxy-3-methoxycinnamaldehyde (**Figure 5**).[89] Leaves 70% acetone aqueous extract was fractionized with several solvents and analyzed for chemical composition yielding nilotinins and nilotinin derivatives. In addition, some compounds like gemin D and hippomanin A (**Figure 5**), which are subunits of nilotinin M1, were isolated.[90] Flowers 70% methanolic extract was fractionized with chloroform, ethyl acetate, *n*-butanol and water. Each of these fractions was analyzed for TFC, TPC, GCC and tested for **antioxidant** (DPPH method) ad **anticancer** (against Huh-7 and A549 lung cancer cell lines) activities.[98]
Tamarix palaestina **No reported medicinal properties-activities**
Tamarix parviflora **No reported medicinal properties-activities**
Tamarix passerinoides Leaves were separately extracted with methanol, ethanol, acetone and chloroform, and each extract was analyzed for GCC.[91]
Tamarix tetragyna Leaves and stems were separately extracted with 70% aqueous methanol and both extracts were tested for **anticancer** against HepG2, A549, HCT-116 and MCF7 cancer cell lines.

Leaves extract was partially and quantitatively analyzed (GC-MS) for chemical composition resulting five known compounds like ingol-12-acetate (**Figure 6**). Molecular docking was performed for these compounds.[92]

Flowers, leaves and stems were combinedly extracted with ethanol and the extract was tested for **antibacterial** activity against fifteen bacterial strains. Extract was qualitatively and very partially analyzed for chemical composition.[93]

Fresh flowers 75% aqueous ethanolic extract was chromatographed affording new flavonoid disulphate (**Figure 6**) with other known compounds.[94]

Follow up of previous study (fresh flowers) yielded new sulphated flavonol, quercetin 3′,4′-dimethyl ether 3-*O*-KSO_3 as well as the new natural galloyl glucose, 2-*O*-galloyl-(α/β)-4*C1*-glucopyranose (**Figure 6**), in addition to previously known compounds.[95]

Aerial parts were analyzed for GCC, mineral composition, digestibility and palatability, and found appropriate as animal food.[96,97]

* Unless indicated otherwise, solvent mixtures are volume/volume, v/v.

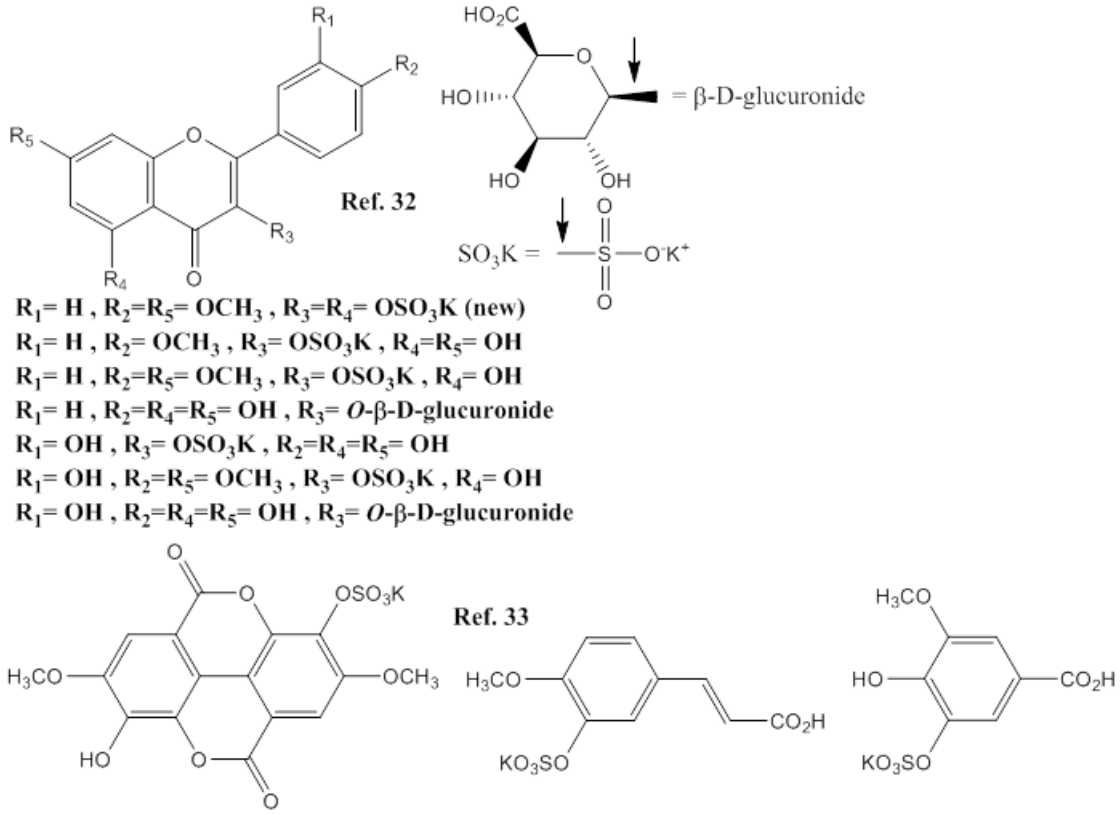

Figure 1: Natural products isolated from *Tamarix amplexicaulis.*

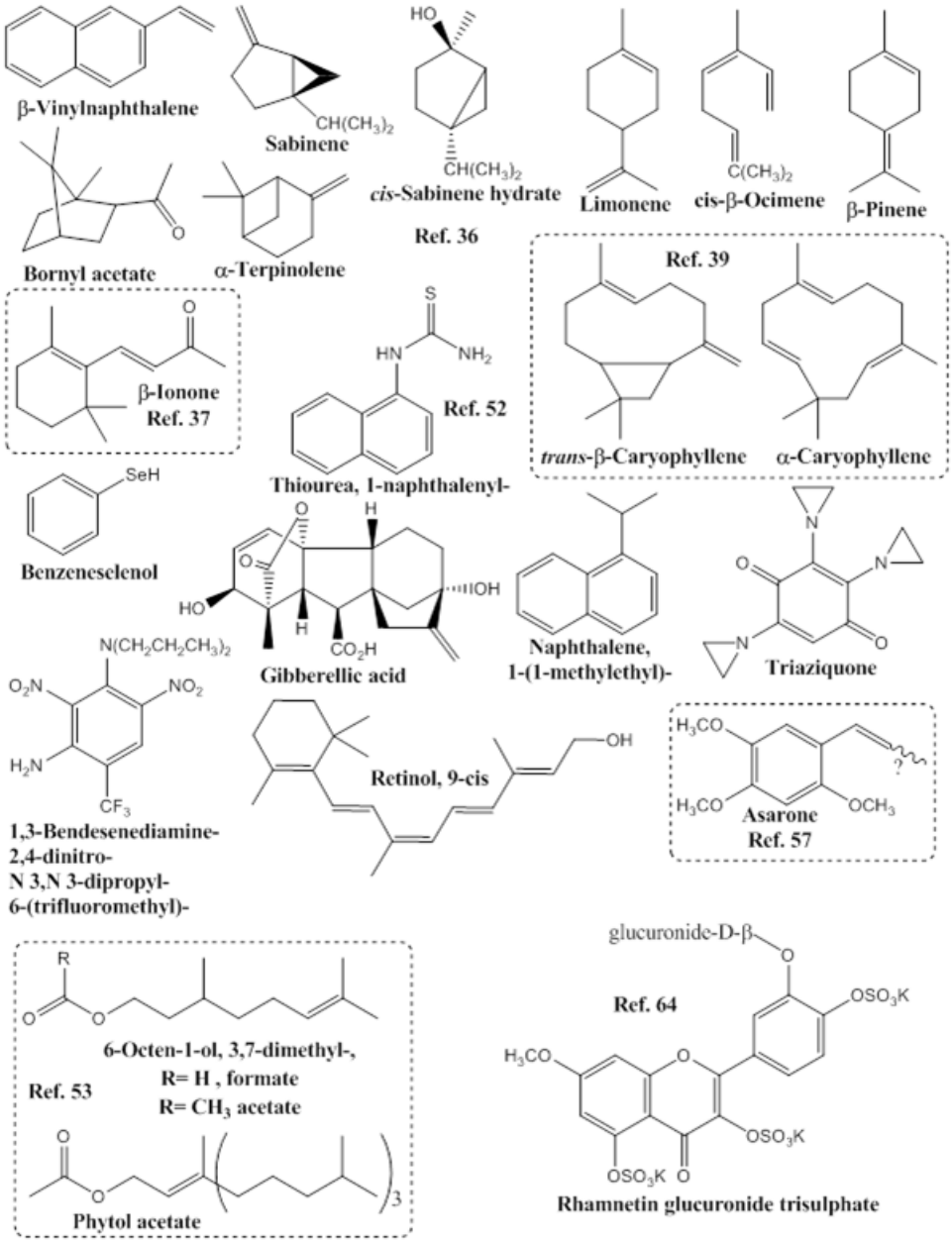

Figure 2A: Natural products isolated from *Tamarix aphylla.*

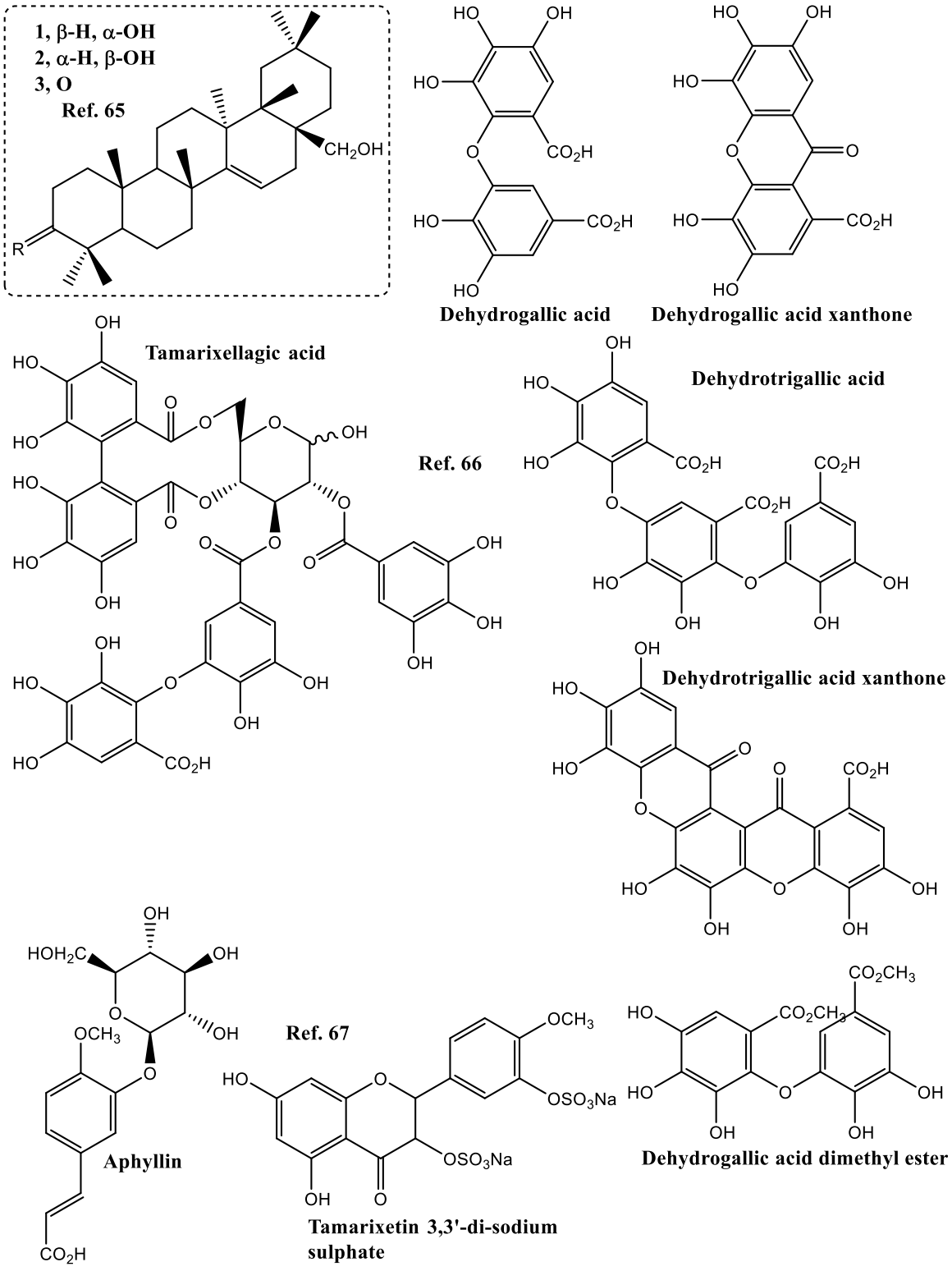

Figure 2B: Natural products isolated from *Tamarix aphylla.*

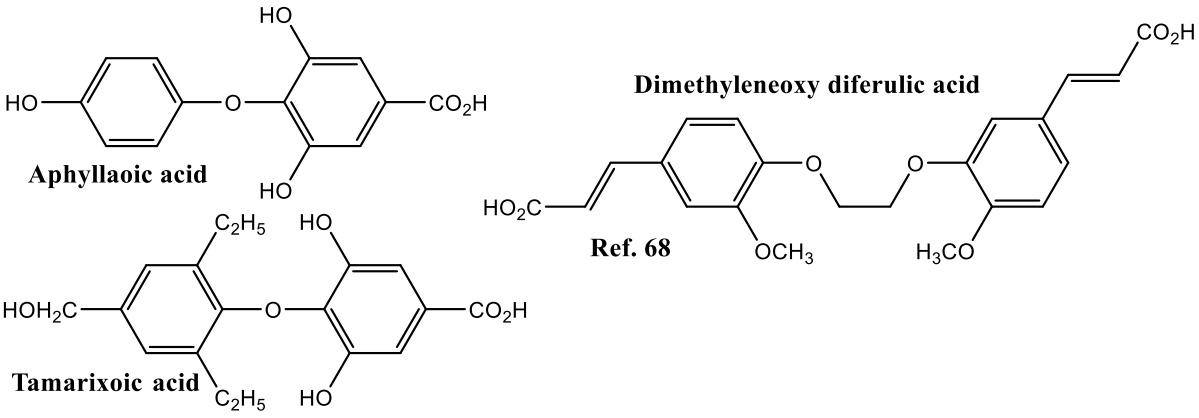

Figure 2C: Natural products isolated from *Tamarix aphylla.*

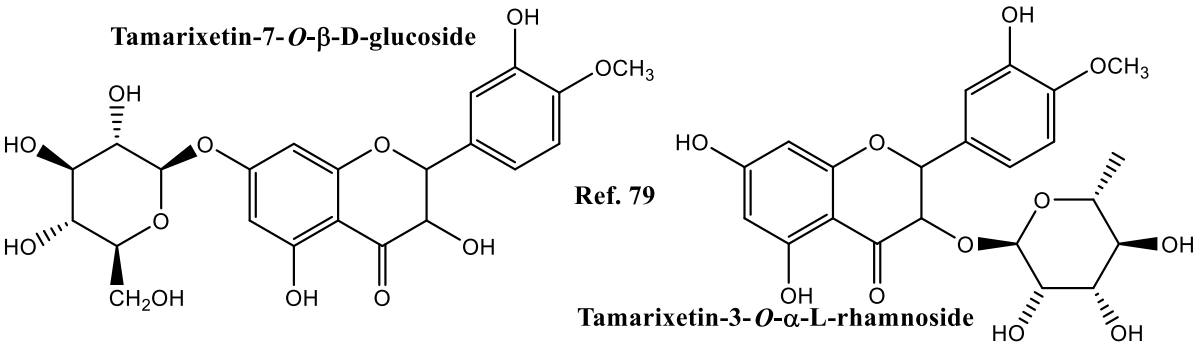

Figure 3: Natural products isolated from *Tamarix chinensis.*

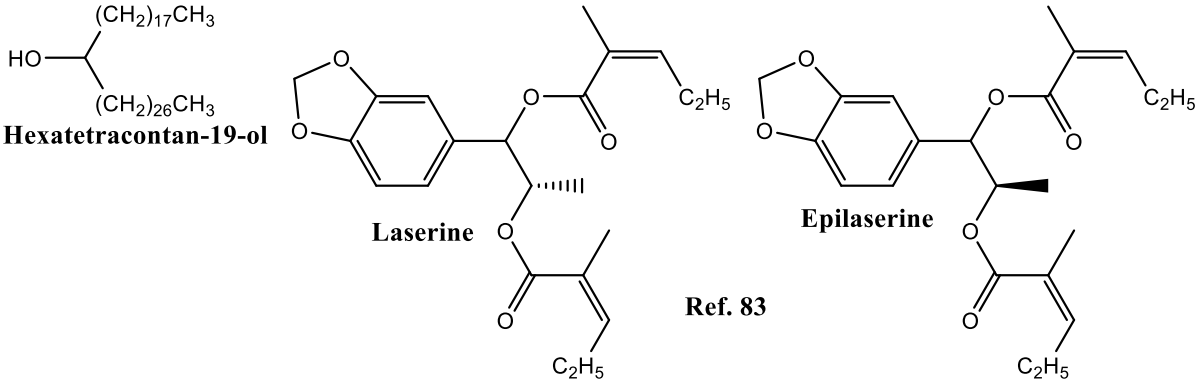

Figure 4: Natural products isolated from *Tamarix hampeana.*

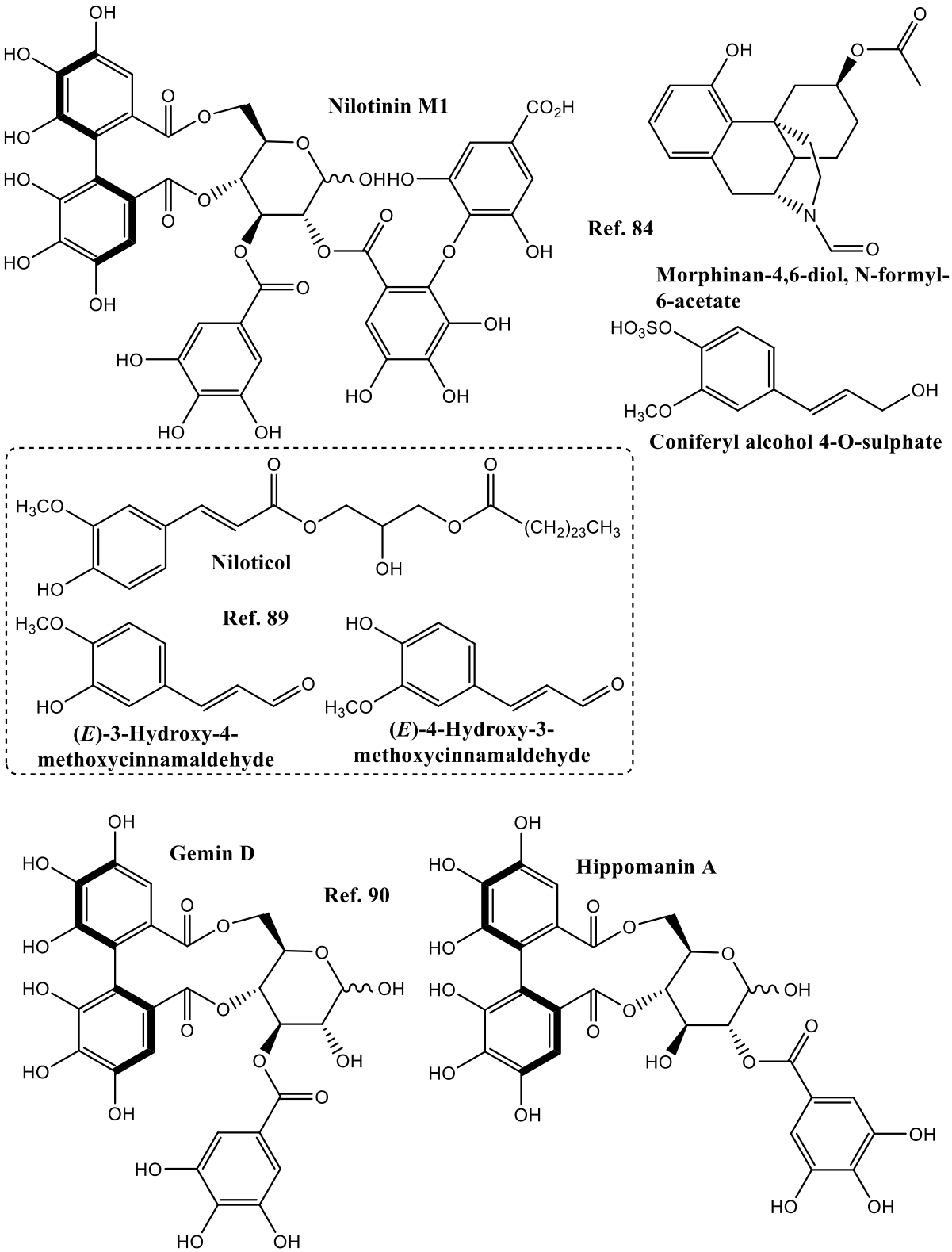

Figure 5: Natural products isolated from *Tamarix nilotica.*

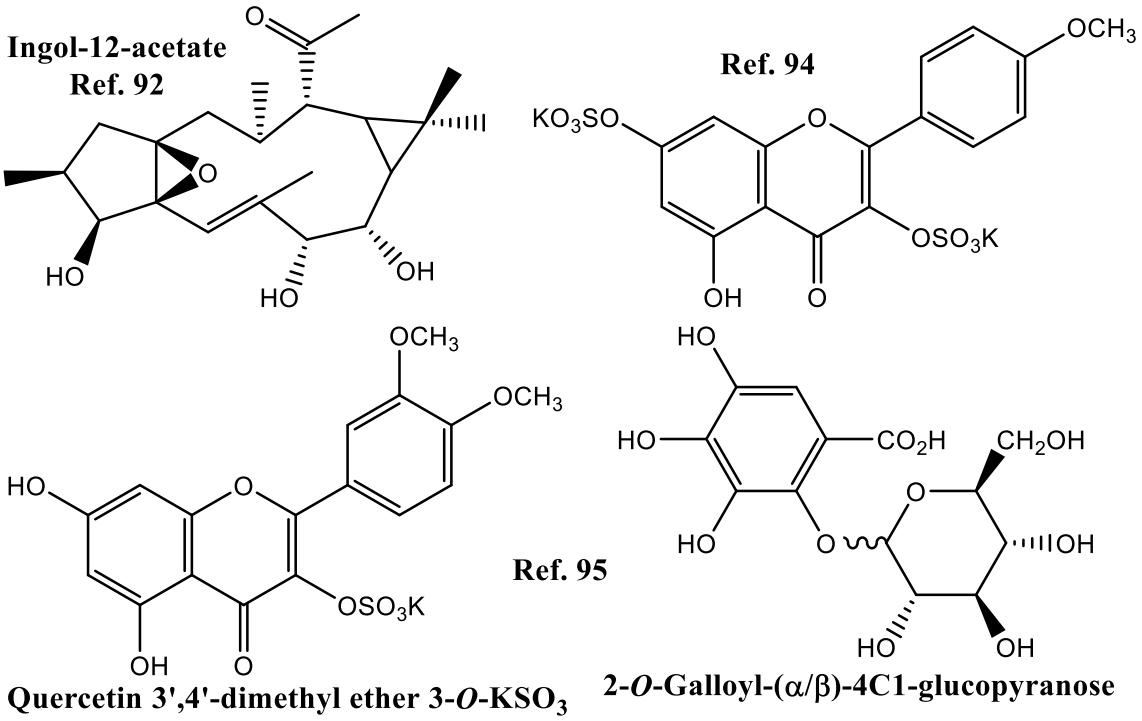

Figure 6: Natural products isolated from *Tamarix tetragyna.*

4) DISCUSSION

The data in **Table 2** draws a clear conclusion: *Tamarix aphylla* is the most studied and published among all species of the *Tamarix* genus of the reviewed region. Contrary to that, according to our literature search results, *T. gennessarensis*, *T. jordanis*, *T. negevensis*, *T. palaestina* and *T. parviflora* were never published for medicinal activities-properties.

Moreover, *T. aphylla* was studied and published in dozens of articles for properties-activities that are not directly related to those presented in **Table 2** but some of them will be presented in this discussion to complete the knowledge of this tree. I. M'berek ahc isolated cellulose from the stems via acetocell for cadmium adsorption.[99] Z. Mohammedi and F. Atik extracted leaves with 70% aqueous ethanol, 70% aqueous methanol, 70% aqueous acetone and water.[100] They discovered that the different solvents resulted different extract yields, TPC's and consequently different antioxidant activity, tested with DPPH method. This effect was published numerously and reviewed several times like the publication of J-E. Lee ahc.[101]

The interactions of *T. aphylla* and its effects on the environment was extensively studied since this plant can tolerate tough growth conditions and introduced to many habitats. W.L. Berry studied the capability of this plant to grow in salty environments and composition and concentration of salts secreted by its salt glands.[102] According to L.R. Walker ahc, *T. aphylla*

was introduced to the state of Nevada as highly adaptable tree, and was meant to grow in confined areas, but it spread out and now it is considered invasive species.[103] Unlike L.R. Walker ahc that did not consider the invasive *T. aphylla* negative, L.R. Milbrath and C.J. Deloach indicated negative effects of this tree on the environment of Western USA and suggest Leaf Beetle *Diorhabda elongata* as a biological agent to control it.[104] Contrary to the USA scholars, Z. Han ahc from China see the anti-erosion capacity of this tree as positive effect on the landscape.[105] F. Tambone ahc, a multinational research group found that *T. aphylla* growing in Tunisian arid areas enriches them with organic matter and enhance growth of other plants.[106]

Several other *Tamarix* species were published for similar or closely related properties, and these publications are summarized in **Table 3** below, including those of *T. aphylla* that we presented before.

Table 3: Interactions of *Tamarix* Species the Reviewed Region with Their Environments.

Species	Major Thieme of the Study	Ref.
T. aphylla	Salt tolerance	[102]
	Invasiveness (USA)	[103]
	Invasiveness (USA), biological control	[104]
	Anti-erosion (China)	[105]
	Soil enrichment with organic matter (Tunisia)	[106]
	Salt and drought tolerance, effect on composition	[107]
	Salt tolerance, mechanism	[108]
	Salt tolerance, mechanism	[109]
	Utilizing aerial humidity, salt tolerance	[110]
	Invasive mainly in Australia and South Africa	[111]
T. chinensis	Invasive mainly in Australia and South Africa	[111]
	Drought and salinity tolerance, effect on physiochemical properties	[112]
	Severe invasiveness (USA)	[113]
	Negative effect on soil composition	[114]
	Positive effect on shallow soil water	[115]
	Positive effect on soil microbial composition	[116],[117]
	Salt tolerance	[118]
T. jordanis	Salt and drought tolerance, effect on composition	[107]
T. nilotica	Drought tolerance	[119]
	No competition for water with *Acacia* trees (Israel)	[120]
T. parviflora	Drought and salinity tolerance	[121]
	Negative effect on ground water	[122]
T. passerinoides	Forage quality in different growth stages	[123]
T. tetragyna	Salinity tolerance	[124],[125]

Preparation of nanoparticles (NPs) using and combining *Tamarix* materials, mainly extracts, was published in about a dozen of articles. These NPs were tested for various medicinal properties-activities. A summary of some selected articles is presented in **Table 4**.

Table 4: Nanoparticles prepared using *Tamarix* plants of Israel and Palestine and their activities-properties.

Species	NPs; activities	Ref.
T. aphylla	Ag; antimicrobial, antiviral	[126]
	Ag; protein kinase and α-amylase inhibition, antibacterial	[127]
	Ag; anticancer, antioxidant	[128]
	Cellulose (NC), NC-Ag-NC-Fe; antioxidant, antimicrobial, antifouling	[129]
	Cu-Tamarixinin loaded; antimicrobial	[130]
	CuO; antifungal	[131]
T. chinensis	ZnO; anticancer, antimicrobial, antioxidant	[132]
T. nilotica	Ag; antibacterial, wound healing	[133]

Malic acid (or malate) dehydrogenase is a family of important enzymes that play a key role in the respiratory system of all living organisms. It was studied and published, especially in the last decade, in hundreds of publications: sources, compositions, mechanisms of action, kinetics and uses. Numerous review articles were published about these enzymes. For example, T. Takahashi-Íñiguez ahc[134] and M.J. Wolyniak ahc.[135] The kinetics and thermodynamics of the reaction in mitochondrial cellular environment was presented in large number of publications like the review article of L. de Lorenzo ahc (**Figure 7**).[136] In 1975, A. Kalir and A. Poljakoff-Mayber published the isolation of malate dehydrogenase from *T. tetragyna* roots.[137]

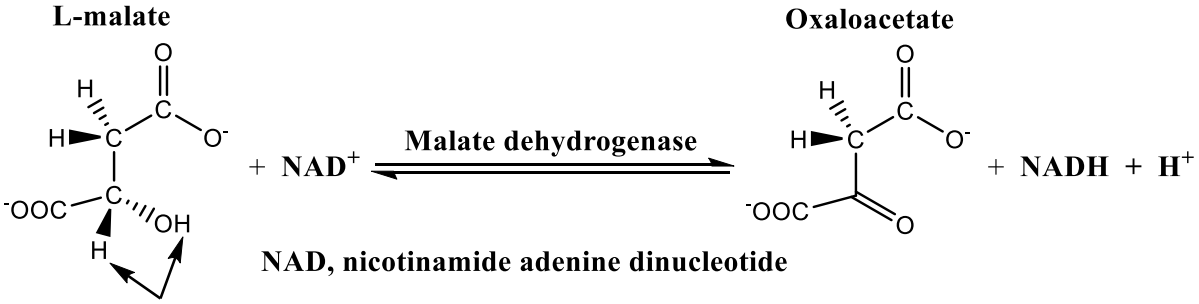

Figure 7: General scope of the mechanism of action of Malate dehydrogenases.[136]

Nilotinins are compound family isolated mainly from *T. nilotica*, and one of these compounds, nilotinin M1 is shown in **Figure 5**. They are ellagitannins that are found in monomeric and dimeric structures. However, more than a dozen nilotinins were isolated. M.A. Orabi ahc isolated nilotinins M4, D7, D8 and macrocyclic nilotinin D9 (**Figure 8**).[138]

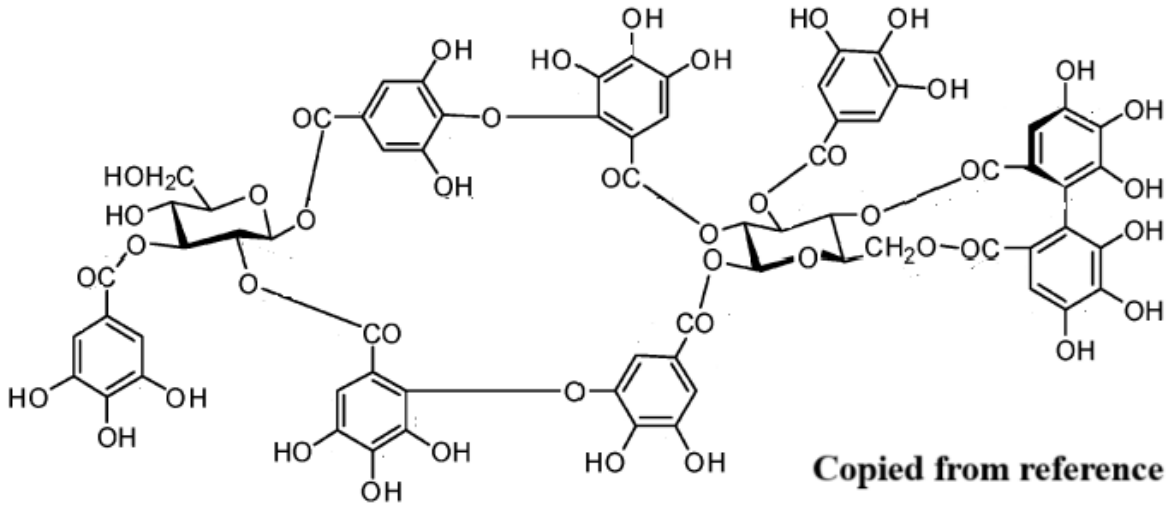

Figure 8: Nilotinin D9 isolated from *T. nilotica*.[138]

In a later publication, M.A. Orabi ahc reported the isolation of dimer nilotinin D3, trimers nilotinin T1-T3, the tetramer nilotinin Q1.[139] Some of these compounds showed cytotoxic activity. In a third publication six years later, M.A. Orabi ahc published the isolation an characterization of three new nilotinins M 8-10.[140]

In 2010, the year that M.A. Orabi ahc published the isolation of nilotinin D9,[138] they also published the isolation of two new monomers, nilotinins M2-3 and two new dimers, nilotinins D4, D5.[141] In 2021, H. Imai ahc published a total synthesis of nilotinin M3.[142]

Tamarixetin (and its derivatives) is one of the most active and published polyphenols found in the *Tamarix* plant. In this review article, it was mentioned several times so far, where the first was tamarixetin 3,3'-di-sodium sulphate (**Figure 2B**).[67] Structurally, it is 4'-methyl quercetin as can be seen in **Figure 9**.

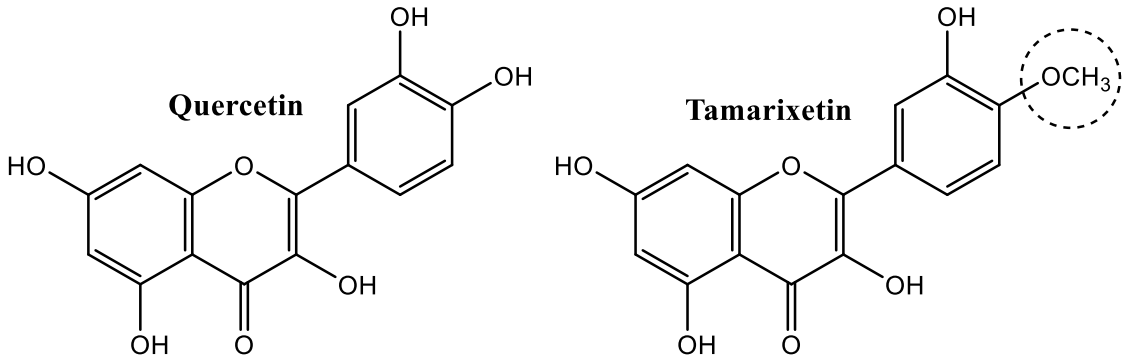

Figure 9: Tamarixetin and quercetin.

Tamarixetin was first isolated by in 1954 by S.R. Gupta and T.R. Seshadri from fresh leaves of *Tamarix troupii*.[143] In this publication authors reported its synthesis. Due to its high biological activity, special methods were developed to detect it,[144] and several studies were carried out to reveal its pharmacokinetics and bioavailability.[145] Some review articles were published about tamarixetin such as the article of C. Li ahc.[146]

Finally, here are some very selected examples of biological activities of tamarixetin published in the last decade: gastroprotective,[147] anti-inflammatory,[148] anticancer,[149] antiallergic, anti-inflammatory,[150] anticancer (and mechanism),[151] nephroprotective,[152] anti-osteoarthritis[153] and hepatoprotective.[154]

Obviously, there are many more active ingredients in *Tamarix* plants of Israel and Palestine that can be discussed like nilotinin and tamarixetin, but this will possibly be done in a separate publication.

5) CONCLUSIONS

1) *Tamarix* plants of Israel and Palestine possess important medicinal and other properties.
2) *Tamarix* plants of the reviewed region contain unique natural products.
3) The potential of most of these natural product is far from sufficiently investigated.
4) Several *Tamarix* species of the RR were either never or very partially published in research articles for medicinal and other properties.
5) Intense research efforts are needed for items 2 and 4 above.

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