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Phytochemical and Pharmacological Properties of Medicinal Plants from Uzbekistan: A Review

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ABSTRACT

Medicinal plants are a reservoir of biologically active compounds with therapeutic properties that over time have been discovered and used by diverse groups of people for treatment of various ailments. In this regard, Uzbekistan has an excellent historic research base of herbal medicines with about 70% of Uzbek households using medicinal plants to meet their health needs for several centuries. The flora of Uzbekistan includes more than 4500 species of vascular plants and over 600 of these plants are used in traditional or conventional medicines, significantly surpassing other areas by the absolute number of endemics and the percentage of endemism. The plants are a reservoir of secondary metabolites, suitable for use in pharmacological studies with a high possibility of observing biologically active constituents. The present review provides an up-to-date a report on the phytochemicals and pharmacological activity of the medicinal plants widely used in Uzbekistan. As a country, Uzbekistan appears to be a source of novel herbal drugs that have not yet been fully evaluated. We trust the present report will be useful for further investigations on the medicinal activity of indigenous plant species in Uzbekistan.

INTRODUCTION

The idea that plants are a reservoir of biologically active compounds with therapeutic properties has been well established, and since ancient time they have been used worldwide for the treatment of various ailments, including asthma, gastro-intestinal problems, skin disorders, respiratory and urinary complications, and hepatic and cardiovascular disease (Cousins and Huffman, 2002; Tian et al., 2014). The interest on demand for more plant derived drugs, which sometimes are considered as safe when compared to synthetic drugs, is increasing rapidly.

The medicinal value of these plants lies in chemical substances that produce a positive physiological action on the human body (Edeoga et al., 2005), and since plants synthesize an extremely diverse range of chemical compounds, they represent a great potential for the discovery and development of new pharmaceuticals (McChesney et al., 2007).

While numerous studies have validated the traditional use of medicinal plants by investigating the

phytochemicals present in active extracts (Van-Wyk and Wink, 2005; Palombo, 2006), many plants have not yet been scientifically studied to provide reports on their phytochemical constituents and their potential medicinal applications.

Traditional medicine of Central Asia is not widely known, and only in recent times has the scientific community focused attention on these plants and the medicinal uses developed in Uzbekistan. Until now, few sources of information are available in the literature (Mamedov et al., 2004; Sezik et al., 2004; Egamberdieva et al., 2013; Mamedov and Craker, 2001), and the sources of information in the literature make evident that new additional investigations and new scientific reports are necessary.

The flora of Uzbekistan includes more than 4500 species of vascular plants of which 9% are considered endemic. Over 600 of these plants have traditionally been used with many continuing to be used in traditional and conventional medicine for treatment of medical problems (Mamedov et al., 2004; Aripov, 1995a; National Biodiversity Strategy Committee 1998).

The diverse nature of the flora native to Uzbekistan has left many plants relatively unstudied that may well contain compounds with potential usefulness in new pharmaceuticals. The traditional use of medicinal plants in Uzbekistan is widespread and over 70% of Uzbek households have used medicinal plants for centuries, coming from a variety of plant families and suggesting that pharmacological studies would have a high probability of detecting active compounds. The majority of these plants, however, grow under harsh environmental conditions that limited access to plant material.

Investigative studies have demonstrated that many of the endemic plants of Uzbekistan contain flavonoids, alkaloids, tannins, saponins, phenolic compounds, coumarins, terpenes and ecdysteroids that could be potential sources for several effective drugs (Tulyaganov and Kozimova, 2005; Gapparov et al., 2007; Mamadalieva et al., 2011; Gapparov and Aripova, 2011; Siddikov et al., 2011; Yuldasheva et al., 2014). For example, Kogure et al. (2004) reported that plant species such as *Ferula pallida*, *F. penninervis*, *Inula macrophylla*, *Prangos pabularia*, *P. tschimganica*, and *Rheum maximowiczii* contain previously unknown antioxidants. Some of these antioxidants seem to have a unique mechanism of action. Several pharmacological activities of medicinal plants and their constituents, such as antimicrobial (Mamadalieva et al., 2008), anti-inflammatory, and antioxidative (Mulaudzi et al., 2013), cytotoxic (Manosroi et al., 2014), along with anabolic activity and cholagogic action (Abdukadirov et al., 2004).have been reported.

The purpose of this report is to summarize to date scientific studies on the phytochemical and pharmacological properties of plants native to Uzbekistan that may have significant medicinal attributes (Table 1).

Phytochemical Profile

The pharmacological benefits of medicinally important plants are primarily due to bioactive phytochemicals produced in the plant tissues as primary and secondary metabolites. These constituents have been identified as alkaloids, (Varsha et al., 2013), gylcosides (Firn, 2010), flavonoids (Varsha et al., 2013), phenolics (Puupponen-Pimiä et al., 2001), saponins (Vashist and Sharma, 2013), tannins (Varsha et al., 2013), and essential oils (Martinez et al., 2008), steroids (Madziga et al., 2010).

Early studies on native Uzbekistan plants detected anthocyanins and coumarins (Pulatova, 1969) and essential oils (Nuriddinov et al., 1997) in *Perovskia scrophularifolia* Bunge (Lamiaceae). Several alkaloids, iridoids, and secoiridoid glycosides, and flavonoid glycosides of *Gentiana olivieri* (Gentianaceae) have been reported (Rakhmatullaev et al., 1969; Ersöz et al., 1991). Another native plant from Uzbekistan, *Helichrysum* sp. (Asteraceae), contains flavonoids, phloroglucinol derivatives, and diterpenes (Suzgec et al., 2005). Su et al. (2000) identified several novel compounds from the roots of *Ferula pallida* (Apiaceae), a native plant of Uzbekistan that contains sesquiterpenes, phenylpropanoid derivatives, pallidones, and sesquiterpene chromone derivatives. The aerial part of *Crambe kotschyana* Boiss. (Brassicaceae), an endemic plant in Uzbekistan, has been reported to contain coumarins, vitamin C, and β-carotene (Nikonov et al., 1965).

Alkaloids

Alkaloids, a class of nitrogen-containing organic compounds, are widely distributed in nature with more than 18,000 alkaloids having been discovered. These compounds have a lot of structural diversity and, in some instances, having the presence of one or more nitrogen atoms seems to be the only common feature among molecules of different chemical structures and of different sources. Alkaloids can be of microbial, plant and animal origin (Cushnie et al., 2014).

Alkaloids are mainly present in higher plants, especially in dicots, whereas only a few have been noted in lower plants. The alkaloids can occur in the whole plant or be limited to specific plant organs. Although the function(s) for some alkaloids still remain unclear, alkaloids can play fundamental roles in plants as deterrents for herbivores, protection from pathogens, and inhibitions of competitors (Cushnie et al., 2014).

Plant alkaloids have been investigated and used in traditional medicine in different regions of various countries with possible health improvement being the main focus of the research in pharmacognosy and pharmaceutical applications. Earlier studies on 320 plant species of Uzbekistan (belonging to 33 families) were investigated for increasing an understanding on their alkaloid contents (Aripov, 1995) and more than 540 new compounds associated with quinoline, isoquinoline, indole, pyrrolizidine, amaryllis, steroid, quinazolone, sulfur-containing, pyrrolidine, diterpenes have been identified from 292 species (Aripov, 1995).

Ungernia victoris Vved (Amaryllidaceae), a widespread endemic plant on the Gissar and Alay ranges across the Fergana Valley south of western Tien Shan. Several alkaloids have been detected in the leaves and bulbs of the plant (Yunusov and Abduazimov, 1960; Berkov, 2009). Malikova and Rakhmanberdyeva (2013) have isolated and identified galacturonic anhydride from the plant leaves.

The tulip tree, *Liriodendron tulipifera* L. (Magnoliaceae), contains the aporphine alkaloids liriodenine, lysicamine, O-methylmoschatoline, lanuginosine and the alkaloid proaporphine (N-methylcrotsparine, remerine) (Ziyaev et al., 1987). Tulyaganov and Kozimova (2005) have isolated and identified many alkaloids from *Nitraria schoberi* L. (Zygophyllaceae), namely schoberine, nitraraine, nitraramine, dehydroschoberine, sibiridine, vasicinone, peganol along with others. *Convolvulus subhirsutus* (Convolvulaceae) contains the alkaloids convolvine, convolamine, convolidine, phyllalbine, phyllalbine N-oxide, nortropine, and conpropine (Gapparov et al., 2007). Another plant, *Convolvulus pseudocanthabrica* Schrenk, contains convolvine, convolamine, convolvidine, convolicine, phyllalbine, convolidine, and convoline (Gapparov and Aripova, 2011).

All of the above ground and below ground parts of *Arundo donax* L. (Poaceae), a native Uzbekistan plant, contains alkaloids, such as deoxyvasicinone, arundine, ardine, donaxarine, donaxanine, donaxaridine, donine, arundinine, arundamine, arundacine, arundarine, arundavine, arundafine, and bufotenine (Khuzhaev, 2004). Okhunov et al. (2011) observed that the aerial part of *Crambe kotschyana* Boiss. (Cruciferae), endemic for Uzbekistan, contains the alkaloids goitrin and goitridin, whereas the aerial parts of *Delphinium corymbosum* Rgl. (Ranunculaceae) contain diterpenoid alkaloids, such as corumdizine, corumdizinine, cordizine and delcorinine (Salimov, 2004).

Akhmedzhanova et al. (2010) identified alkaloids from the aerial part of *Haplophyllum leptomerum* Lincz. et Vved. (Rutaceae), indigenous to Uzbekistan, and reported several alkaloids, providing also quantitative data, such as skimmianine, γ-fagarine, N-methyl-2-phenylquinolin-4-one, lepto-merine, acutine, 2-heptylquinolin-4-one and dictamnine.

Lipids

Lipids, a broad class of organic compounds that includes fats, phospholipids, glycolipids, and sterols, are widely distributed in bacteria, plants, and animals. Many of these lipids are suitable for use in cosmetics and pharmaceuticals (Ramadan et al., 2009). Recently, pharmaceutical uses of lipids have been hypothesized as new therapeutic target for the treatment of cancer (Zhang et al., 2012).

*Scutellaria ramosissima*is is an endemic plant that contains glycolipids, neutral lipids, and phospholipids with palmitic and linoleic acids dominating the phospholipids (Yuldasheva et al., 2014). Mirzaeva et al. (2011) studied lipid composition on *Silybum*

marianum (Asteraceae) and identified parafinic, olefinic, and isoprenoid hydrocarbons along with fatty acid esters and triterpenols, sterols, triacylgly-cerins, chlorophylls, pheophytins, triterpene acids, and pheophytins. The qualitative compositions of the *Althaea nudiflora* and *A. armeniaca* (Malvaceae) lipids contained hydrocarbons and esters of sterols and triterpenes, triacylglycerines, free fatty acids, triterpenols, diacylglycerines, sterols, plus some unidentified components (Sagdullaev et al., 2001).

Gleditsia triacanthos L. (Cesalpinaceae) contains neutral lipids, glycolipids, and phospholipids (Rakhmanberdyeva, et al. 2002), whereas *Solenanthus turkestanicus* (Regel and Smirn.) and *Onosma irrigans* Popov. (Boraginaceae) contain neutral lipids, glycolipids, and phospholipids (Yuldasheva et al., 2013). The fatty-acid compositions in all lipid groups included the presence of γ-linolenic and stearidonic lipid.

The phospholipid composition of *Crataegus* phosphatidylcholine, phosphatidyl glycerol, phosphatidic acid, phosphafidylethanol-amin (Gazizov et al., 1995). Bakker et al. (2003) studied lipid components of *Crambe kotschyana* Boiss. (Cruciferae) and reported the presence of hydrocarbons along with waxy ethers, triterpenol, and sterol fatty-acid esters, acetates of cyclic alcohols, triacylglycerols, isoprenes, triterpenes, and sterols. *Capparis spinosa* L. (Capparidaceae) contained glycolipids (monogalactosyldiacylglyerides, digalactosyldiacylglycerides, sterolglycosides, and their esters (Yili et al., 2009) along with phospholipids (phosphatidy-linositols, phosphatidylethanolamines, and phosphatidylcholines) (Yuldasheva et al., 2008).

Essential oils

Essential oils, also known as volatile oils, ethereal oils, aetherolea, or oil of the plant from which the oil was isolated, are hydrophobic liquids that can be extracted from many plants. An essential oil is a complex mixture of volatile plant constituents characterized by low molecular weight components, such as terpenes, terpenoids, and other aromatic and aliphatic chemical compounds associated with the plant material from which the oil is extracted, the time of harvest, and the extraction procedure. The lipophilic nature of essential oils enables the oil to cross the cell membrane and reach the cytoplasm (Gautam et al., 2014), thus interacting with organelles and cytoplasmic compounds to play an active biological role. Many medicinal plants contain useful essential oils and have been widely used in traditional medicine for respiratory tract infections (Gautam et al., 2014), for anticancer treatment (Russo et al., 2013), for anti-inflammatory activity (Ramos et al., 2013) for antimicrobial properties (Nikolić et al., 2014) 2013), for antioxidant activity (Abdelhady and Aly, 2012), and analgesic-like activity (Chandrashekar and Prasanna, 2010).

Hypericum scabrum and *H. perforatum* (Hypericaceae) are native plants of Uzbekistan that have been reported to contain about 0.2% essential oil (Baser et al., 2002a), consisting of β-caryophyllene, caryophyllene oxide, spathulenol, and α-pinene, whereas *H. scabrum* contains α-pinene, spathulenol, *p*-cymene, acetophenone, and carvacrol. In later studies, Baser et al. (2002b) investigated the essential oil of *Arischrada korolkowiithat* Regel et Schmalh. Pobed. (Lamiaceae), a plant that grows in Uzbekistan. The oil analysis characterized 88 constituents, representing 98% of the essential oil. Major oil components were 1,8-cineole, camphor, β-caryophyllene, bornyl acetate, caryophyllene oxide, and borneol.

Dzhumaev et al. (1990) isolated and identified essential oil from leaves of *Hyssopus seravschanicus* (Lamiaceae). The composition of the essential oil included sabinene, β-pinene, myrcene, *p*-cymene), 1,8-cineole, pinocamphone, and carvacrol. *Artemisia balchanorum* Krasch. (Compositae) yielded 1.2% oil with 60 components that included 1,8-cineole, α-thujone, camphor, β-thujone, and cis-2,7-dimethyl-4-octen- 2,7-diol as the major constituents (Baser et al., 1997).

The essential oil of *Anethum graveolens* (Apiaceae) seeds include carvone, limonene, cis-dihydrocarvone, diplaniol (1-allyl-2,5-dimethoxy-3,4-methylenedioxybenzene), and 1,2-diethoxyethane, that collectively accounted for 99.2% of the total essential oil composition (Yilli et al., 2009). The epigeal part of *Artemisia baldshuanica* Krasch. et Zarp. (Asteraceae) has an essential oil that contains α- and β-pinenes, tujilic alcohol, tujilacetate, and tujil-valerate (Goryaev

et al., 1962). The essential oil of *Origanum tyttanthum* Gontsch (Lamiaceae) contains thymol, carvacrol, ursolic and oleanolic acids, 15-methylhexadecanoic acid, and coumarin substances (Platova, 1972; Baser et al., 1997; Asilbekova et al., 2000). In other studies, several compounds, such as thymol-β-D-glucoside (Passreiter et al., 2004), naringenin (Ohmoto et al., 1997), eryodictiol (Rivero-Cruz et al., 2004), rosmarinic acid (Petersen and Simmonds, 2003) have been identified.

Flavonoids

Flavonoids, a group of plant secondary metabolites in which the molecular framework is characterized by variable phenolic structures, are widely distributed in plants (Xia et al., 2013). Many flavonoids are known to possess anticancer activity (Kim et al., 2003). The indigenous medicinal plants of Uzbekistan *Thermopsis altherniflora* Rgl. et Schmalh (Fabaceae) contains flavonoids (Faizieva et al., 2003), flavones, isoflavones (Satimov et al., 1977), formononetin, chrysoeriol, apigenin, luteolin, thermopsoside, and cynaroside (Faizieva et al., 2003). Other plants native to Uzbekistan, such as *Vicia subvillosa* L. (Fabaceae), contain flavonoids. including asapigenin, luteolin, quercetin, and cinaroside (Yuldashev, 2005). *Ammothamnus lehmannii* Bunge (Fabaceae) contains ammothamnidin, lehmannin, Iuteolin, cynaroside, quercetin, and isoquercetin (Abdullaev et al., 1983).

Plants of the genus *Scutellaria* L. (Lamiaceae) are rich sources of flavonoids (Malikov and Yuldashev, 2002). For example *S. cordifrons* Juz. and *S. phyllostachya* Juz. contain baikalein, 5,7-dihydroxy-2′-methoxyflavone, and chrysin (Chemesova et al., 1994; Siddikov et al., 2006). *S. immaculate* and *S. ramosissima* contain scutellarin, chrysin, apigenin, apigenin-7-O-glucoside, cynaroside, and pinocembrine (Mamadalieva et al., 2011). S*cutellaria ocellata* Juz. contains oroxylin A, wogonin, apigenin, cinaroside, baicalin, and wogonoside (Yuldashev and Karimov, 2001). *Scutellaria nepetoides* M. Pop. contains apigenin-7-O-β-D-glucuronide, norwogonoside scutellarin, and flavoneglycoside nepetoside A, and 5,8-dihydroxy-7-O-β-D-galacturonidopyranosyl flavone (Yuldashev and Karimov, 2001), while *S. phyllostachya* contains chrysin-7-O-β-D-methylglucuronide, apigenin-7-O-β-D-glucuronide,baicalein-7-O-β-D-glucopyrano–side, oroxyloside, scutellarein-7-O-β-D-glucoside, apigenin-7-O-β-D-glycoside, norwogonine-7-O-β-D-glycoside, wogoniside (wogonine-7-O-β-D-glucuronide), luteolin-7-O-β-D-glucuronide (Siddikov et al., 2007).

Phenolic compounds

The phenolic compounds are important secondary metabolites of medicinal plants and show a wide range of pharmacological activities including anticancer, anti-inflammatory (Li et al., 2013), cardiovascular diseases, osteoporosis, diabetes mellitus, and neurodegenerative diseases (Daglia, 2012). In the human diet, the source of these plant constituents is mainly consumed by fruits and beverages, including tea, coffee, and red wine. Abdulladzhanova et al. (2001) studied phenolic compounds of a medicinally important plant, *Euphorbia ferganensis* B. Fedtsch. (Euphorbiaceae), and noted that the plant contains about 9.1% polyphenols in air-dried raw tissue. The polyphenols consisted of nine compounds, namely gallic acid, quercitrin, quercetin, kaempferol-3-O-glucoside, 3-O-.geraniin, 1-O-galloyl-4,6-trihydroxy-3,4,31-trimethoxy-diphenoyl-β-D-glucose, 2,3-di-O-galloyl-β-D-glucose, and 1,2,3-tri-O-galloyl-β-D-glucose. *Bergenia hissarica* Boriss. (Saxifragaceae), a rich source of phenolic compounds along with anthraquinones, aloe-emodin, physeion, aloe-emodin8-O-β-glucoside, chrysophanein, and emodin 1-O-β-D-glucopyranoside (Yuldashev, et al., 1993).

Other indigenous medicinally important plants namely *Rhodiola litvinovii* (Crassulaceae) contains *p*-tyrosol, salidroside, gallic acid, epigallocatechin-3-O-gallate (Melikuziev et al., 2013), *Geranium saxatile* Kar. (Geraniaceae) contains gallic acid, ellagic acid, quercetin-3-O-glucoside (Siddikov et al., 2011).

Glycosides

The term glycoside is a generic term for a class of natural products composed of two molecules, a sugar and the aglycone. The sugar molecule is primarily D-glucose, but also can be L-rhamnose and L-fructose. The aglycone can be any natural product,

such as a flavonoid or a terpene (Tian et al., 2014; Zahmanov et al., 2015).

Glycosides from native plants of Uzbekistan have been investigated in a few reports. In early studies, Takeda et al. (1999) isolated bitter secoiridoid glycosides, olivierosides, gentiopicroside, sweroside, 69-*O*-*β*-D-glucosylgentiopicroside, swertiapunimarin, eustomoside, eustomorusside, and septemfidoside from whole plants of *Gentiana olivieri* (Gentianaceae). Takeda et al. (2008) isolated and characterized a new phenolic glucoside, 4-*O*-β-D-glucopyranosylbenzyl-3'-hydroxyl-4'-methoxy-ben-zoate, from the aerial parts of *Origanum tyttanthum* (Lamiaceae). *Astragalus unifoliolatus* Bunge (Fabaceae) contains triterpene glycosides, namely oleanolic acid and cyclounifolioside A (Kucherbaev et al. 2002). *Ferula varia* (Schrenk) Trautv. (Umbelliferae) contains guaiane, eudesmane, and one new germacrane-type sesquiterpene lactone glucosides (Kurimoto et al., 2012).

Other compounds

Other compounds with a wide range of pharmacological activities have also been sourced from indigenous plants of Uzbekistan. For instance, Takeda et al. (2007) isolated and characterized compounds, such as rosmanol, epirosmanol, carnosol, 12-*O*-methylcarnosic acid, diosmetin, eugenol β-D-glucopyranoside, salidroside, uridine, and (6S,9R)-roseoside from the aerial parts of *Perovskia scrophularifolia* (Labiatae). Among those compounds, rosmanol, epirosmanol, carnosol exhibit antioxidant activity (Nakatani and Inatani, 1984; Masuda, 2004). Shikishima et al. (2001a) isolated and characterized several compounds, including phenyl butanoids, stilbene dimers, rhododendrol, epirhododendrin, lindleyin, torachrysone, resveratrol, and physcion from *Rheum maximowiczii* (Polygonaceae). *Ferula sumbul* (Umbelliferae) contains furanocoumarin esters - fesumtuorin A, B, bicoumarin, fesumtuorin C, spirobicoumarins, fesumtuorin D, E, F, G, and H with some of these compounds exhibiting anti-HIV activity and a very weak inhibition of cytokine release (Zhou et al., 2000). Sdykov and Abduazimov (2000) investigated dioxanelignins (DLA) of soap root, *Allochruza paniculata* (Fabaceae), and licorice root, *Glycyrrhiza glabra* (Caryophyllaceae), and detected cresol, guaiacol, Guaiacyl ethane, Guaiacyl propan-1-ol.

Mukhamatkhanova et al. (2011) investigated the phytochemistry of the epigeal part of *Artemisia baldshuanica* Krasch (Asteraceae) and observed the main constituents were the hydrocarbons 5,5-dimethyl-1-ethyl-1,3-cyclopentadiene, tetratriacontane, and nonacosane; the monoterpenoids 1,8-cineole, α-thujone, β-thujone, and camphor; the sesquiterpenoid chrysanthenone; and the sesquiterpene lactone ambrosine. An endemic plant *Scutellaria holosericea* Gontsch ex Juz. (Lamiaceae) contains β-sitosterol, chrysin, 5-hydroxy-7-methoxyflavone, 3, 5-dihydroxy-7-methoxy-flavone, apigenin, 7-ketologanin, and chrysin-7-O-β-glucoside (Kamoldinov et al., 2012).

Ajuga turkestanica (Rgl.) Brig. (Labiatae) is an endemic plant of Uzbekistan and contains a number of effective biologically active compounds, such as phytoecdysteroids and natural glycosides (Mamatkhanov et al., 1998). Abdukadirov et al. (2005) identified ecdysterone, cyasterone, ajugalactone, ajugasterone, α-ecdysone, and turkesterone from *A. turkestanica.* Climati et al. (2012) isolated and identified an active antibacterial diterpene, methyl carnosate, against *Bacillus cereus* from ethanolic extracts of *Salvia officinalis* leaves,

The high diversity of ecdysteroid derivatives in medicinal plants of Uzbekistan has been reported. Saatov et al. (1999) described the distribution of phytoecdysteroids in the family: Laminaceae *(A. turkestanica*); Asteraceae *(Rhaponticum integrifolium* C.Winkl., *Rhaponticum nanum* Lipsky, *Serratula sogdiana* Bunge, *Serratula algida* lljin); and Caryophyllaceae (*Silene brahuica* Boiss., *S. scabrifolia* Kora., *S. wallichiana* Klotzch, *Meandrium turkestanicum* Rgl. and *Dianthus hoeltzeri* Winkl.).

Studies have shown that *A. turkestanica* has many diverse ecdysteroids, namely ecdysterone, cyasterone, ajugalactone, ajugasterone B, 22-acetyl-cyasterone, α-ecdysone, ecdysterone 2, 3-mono-aceto-nide, turkesterone (Saatov et al., 1999). *S. wallichiana* contains ecdysteroids, namely viticosterone E, 20-hydroxyecdysone-22-benzoate, 2-deoxycdysone-22-ben-zoate, viticosterone E-22-benzoate, 2-deoxy-20-hydroxy-ecdysone, 2-deoxyecdysone, 20-hydroxy-ecdy-sone, 3-benzoate-2-deoxy-20-hydroxyecdysone, 22-benzoate-2-

deoxy-20-hydroxyecdysone, integristerone and 25-acetate-2-deoxy-20-hydroxyecdysone (Mamadalieva, et al., 2000). Some phytoecdysteroids of *Silene wallichiana* (viticosterone E, 20-hydroxyecdysone-22-benzoate, 2-deoxy-20-hydroxyecdysone, 2-deoxyecdysone, 20-hydroxy-ecdysone and integristerone A) demonstrated antibacterial and antiproliferative properties (Mamadalieva et al., 2013).

Pharmacological Activities

Several pharmacological studies have confirmed that medicinal plants exhibit a broad range of biological activities and that plant species can contain a diverse range of bioactive molecules responsible for a collection of pharmacological properties (Polya, 2013). For example, Tada et al. (2002) identified coumarins, terpenoids, and glycosides from the roots of *Prangos pabularia* (Apiaceae), in which constituents exhibited anti-bacterial activity and inhibited release of cytokine.

Flavonoids of *Scutellaria immaculata* and *S. ramosissima* (scutellarin, chrysin, apigenin, apigenin-7-O-glucoside, cynaroside and pinocem-brine) significantly inhibit cell growth against HeLa, HepG-2, and MCF-7 cells, along with antimicrobial activity (Mamadalieva et al., 2011). Plant derived flavonoids, such as quercetin, herbacetin, luteolin, and 4-methoxyscutarellin, are characterized by antiulcer activity (Barnaulov et al., 1982). *A. turkestanica* contains many biological active compounds including ecdysteroids, iridoids (Soatov et al., 1994), and carbohydrates (Abdukadirov et al., 2004) that have anabolic activity and cholagogic action.

Scutellaria ramosissima is traditionally used in Uzbekistan folk medicine to treat epilepsy, allergies, inflammations, nervous disorders, and hypertension (Khodjimatov et al., 1995; Parajuli et al., 2009). The plant extract exhibits cytotoxic activity against several cancer cell lines (Mamadalieva et al., 2011). Ethanol extracts of *Geranium saxatile* exhibit antihypoxic properties for acute normobaric and hemic hypoxia (Siddikov et al., 2011). *Perovskia scrophularifolia* has been used for treatment of dermatitis and human intestinal parasites (Takeda et al., 2007).

The flavonoid dictamnine derived from *Haplophyllum leptomerum* exhibits cytotoxic activity against the human cancer-cell lines HeLa and HCT-116 (Akhmedzhanova et al., 2010), *Arctium lappa* is used in folk medicine for treatment of rheumatism, eczema, ulcers, skin eruptions, and festering wounds (Azizov et al., 2012), *Althaea nudiflora* and *A. armeniaca* are used to treat pneumonia, hemostasis, kidney problems, and as expectorants (Kholmatov and Kosimov, 1994). *Origanum tyttanthum*, which has antimicrobial, hypocholesterolemic, and hypolipidemic activity, is used for treating tuberculosis and human intestinal parasites (Tkachenko et al., 1999; Nuraliyev and Zubaidova, 1994).

Rheum maximowiczii is widely used for the treatment of stomach disorders (Shikishima et al., 2001b). The roots of *Ferula varia* have been traditionally used for the treatment of fever and intestinal parasites, and as a mouth rinse (Sakhobiddinov, 1955). *Bergenia hissarica* is used as an astringent, hemostatic, and as an antiphlogistic agent in diseases of the gastro-intestinal tract and in obstetric-gynecological practice (Yuldashev et al., 1993). *Euphorbia ferganensis* is used for treatment of dysentery, diarrhea, and viral infections, including AIDS. Milk thistle *Silybum marianum* has hepato-protective, antioxidant, and regenerative membrane-protective properties (Minakhmetov et al., 2001).

Crataegus turkestanica is used for the treatment of nervous and cardiovascular diseases (Yu et al., 1995), whereas *Helichrysum* sp. possess antimicrobial (Guida et al., 1999), anti-inflammatory, antioxidative (Sala et al., 2002), and cytotoxic activity (Bigović et al., 2011). Yagura et al. (2008) has noted that the methanol extract of *H. maracandicum* was the most effective as compared with other plants on transformed somatostatin (SST) signaling cells on SENCAR mouse skin. Satimov et al. (1998) noted that flavonoids isolated from *Thermopsis altherniflora* inhibited the development of hyperlipidemia induced in experimental animals by injections of Triton WR-1339. *G. olivieri*has has been used for treating wounds, diarrhea, common colds, and ease of digestion (Honda, 1999).

Lehmanin (a flavonone) and ammothamnidin (a chalcone) isolated from the endemic plant *Ammothamnus lehmannii*, have demonstrated an

ability to increase resistance of the gastric mucosa to neurogenic and toxic-dystrophic lesions (Syrov et al., 2010), thus, suggesting the use of these plant extracts in the treatment of gastric ulcers. *Vicia subvillosa* has a history of use in folk medicine for ascites, paralysis, epilepsy, and flu (Yuldashev, 2005). The essential oils of *Anethum graveolens* have demonstrated antimicrobial activity toward *Candida albicans* and *Staphylococcus aureus* (Yili et al., 2009).

In other studies, several plants of *Silene* genera, namely *S. walchiana*, *S. viridiflora*, and *S.brahuica* have shown antibacterial activity against gram positive and gram negative bacterial pathogens (Mamadalieva et al., 2008)

Conclusion

The medicinal plants of Uzbekistan reported can be considered as a potential source of useful drugs. Structurally diverse compounds isolated and identified from the indigenous plants have demonstrated biological activities. Extracts isolated from medicinal plants of Uzbekistan have been proven to have biological activity by *in vitro* and *in vivo* assays. Many plant extracts exhibit pharmacological activity, including antimicrobial, antioxidant, antiulcer, expectorant, anti-hemorrhagic, astringent, hemostatic, and antiphlogistic. These extracts are also used for the treatment of dermatitis, intestinal parasites, pneumonia kidney ailments, rheumatism, eczema, ulcers, skin eruptions, wound healing, dysentery, diarrhea, and viral infections, including AIDS. Based on many published reports, indigenous medicinal plants of Uzbekistan would appear to be a promising source of novel drugs and potentially useful new pharmaceuticals. Further investigations of endemic plants of Uzbekistan and their constituents are necessary to fully understand the molecular mechanisms of their action *in vitro* and *in vivo* and to assure the plant extracts are safe for human use.

Table. 1. Pharmaceutical properties of medicinal plants from Uzbekistan.

Plant species & family	Pharmacological properties & treatments	Phytochemical constituents	References
Ajuga turkestanica (Regel) Briq. (Lamiaceae)	Anabolic activity and cholagogic action	Ecdysterone, cyasterone, ajugalactone, ajugasterone, α-ecdysone, turkesterone	[4, 5]
Althaea armeniaca Lindl. (Malvaceae)	Pneumonia, kidney ailments, anti-hemorrhagic agents	Hydrocarbons and esters of sterols, triacylglycerines, free fatty acids, triterpenols, diacylglycerines, & sterols	[39, 89]
Althaea nudiflora Lindl. (Malvaceae)	Pneumonia, kidney ailments, anti-hemorrhagic agents	Hydrocarbons and esters of sterols, triacylglycerines, free fatty acids, triterpenols, diacylglycerines, & sterols	[39, 89]
Ammothamnus lehmannii Burge (Fabaceae)	Gastric ulcer disease	Ammothamnidin, lehmannin, iuteolin, cynaroside, quercetin, & isoquercetin	[2, 103]
Amorpha fruticosa L. (Fabaceae)	Antibacterial, heart problems, atherosclerosis	Glycosides, aglycones, & amorphin	[38]
Anethum graveolens L. (Apiaceae)	Antimicrobial activity	Carvone, limonene, cis-dihydrocarvone, diplaniol, & 1,2-diethoxyethane	[119]

continued

Table. 1. Pharmaceutical properties of medicinal plants from Uzbekistan (continued).

Plant species & family	Pharmacological properties & treatments	Phytochemical constituents	References
Arctium lappa L. (Asteraceae)	Rheumatism, eczema, ulcers, skin eruptions	Polysaccharide inulin, protein, essential oil, carotenoids, flavonoids, & tanning agents	[10]
Arischrada korolkowii Regel et Schmalh. Pobed. (Lamiaceae)	Antimicrobial activity	1,8-cineole, camphor, β-caryophyllene, bornyl acetate, caryophyllene oxide, & borneol	[14]
Artemisia baldshuanica Krasch. et Zopr. (Asteraceae)	Antiplasmodial activity	α- and β-pinenes, thujol alcohol, & thujyl acetate, tetratriacontane, nonacosane, monoterpenoids, 1,8-cineole, camphor, sesquiterpenoids & chrysanthenone	[39]
Arundo donax L. (Poaceae)	Diaphoretic, diuretic, emollient, treatment of dropsy	Alkaloids, deoxyvasicinone, arundine, ardine, donaxarine, donaxanine, donaxaridine, donine, arundinine, arundacine, & bufotenine	[41]
Bergenia hissarica Boriss. (Saxifragaceae)	Astringent, hemostatic, antiphlogistic agents	Phenolic compounds, anthraquinones, aloe-emodin, physeion, emodin 8-O-β-glucoside, chrysophanein, & emodin-1-O-β-D-glucopyranoside	[121]
Capparis spinosa L. (Capparidaceae)	Healing wounds, asthma, gastrointestinal diseases, hepatitis	Monogalactosyldiacylglycerides, digalactosyldiacylglycerides, & sterolglycosides; Phospholipids, phosphatidylinositols, & phosphatidylethanolamines	[38, 39]
Convolvulus subhirsutus Regal & Schmalh (Convolvulaceae)	Gastrointestinal diseases, analgesic, anticonvulsant, asthma, lung tuberculosis	Convolvine, convolamine, convolidine, phyllalbine, phyllalbine N-oxide, nortropine, & conpropine)	[30, 38, 39]
Crambe kotschyana Boiss. (Brassicaceae)	Upper respiratory tract congestion	Goitrin & goitridin; coumarins, carotene, triterpenol, triacylglycerols, isoprenes, triterpenes, & sterols	[11, 72]
Crataegus turkestanica Pojaark (Rosaceae)	Nervous and cardiovascular diseases	Phosphatidylinositol, phosphatidylcholine, phosphatidylglycerol, phosphatidic acid, phosphafidylethanolamin	[32, 117]
Euphorbia ferganensis B. Fedtsch. (Euphorbiaceae)	Dysentery, diarrhea, and viral infections, including AIDS	Gallic acid, quercitrin, quercetin, kaempferol-3-O-glucoside, 2,3-di-O-galloyl-β-D-glucose, & 1,2,3-tri-O-galloyl-β-D glucose)	[3]
Ferula pallida Korvin (Apiaceae)	Antioxidant, skin wounds treatment	Sesquiterpene phenylpropanoid derivatives, pallidones, & sesquiterpene chromone derivatives	[42, 101]

continued

Table. 1. Pharmaceutical properties of medicinal plants from Uzbekistan (continued).

Plant species & family	Pharmacological properties & treatments	Phytochemical constituents	References
Ferula sumbul (Kffm.) Hook, f. (Apiaceae)	Anti-HIV activity, kidneys disorders, gastric disease	Furanocoumarin esters, fesumtuorins, bicoumarin, & spirobicoumarins	[39, 126]
Ferula varia (Schrenk) Trautv. (Apiaceae)	Intestinal parasitosis, as mouth rinse	Eudesmane, guaiane-germacrane-type sesquiterpene lactone glycosides	[44, 88]
Geranium saxatile Kar. (Geraniaceae)	Antihypoxic for acute normobaric and hemic hypoxia	Phenolic compounds (gallic acid, ellagic acid, quercetin-3-O-glucoside)	[99]
Gleditsia triacanthos L. (Cesalpinaceae)	Spastic colitis, chronic cholecystitis, stomach ulcers, bronchial asthma	Neutral lipids (triacylglycerides, carotinoids, fatty-acid esters, sterols, diacylglycerides), glycolipids, phospholipids, alkaloids	[83]
Glycyrrhiza glabra L. (Fabaceae)	Antiviral, anti-inflammatory, antioxidant	Cresol, guaiacylethane, guaiacylpropan-1-ol, guaiacol	[50]
Haplophyllum leptomerum Lincz. et Vved. (Rutaceae)	Cytotoxic activity	Alkaloids, skimmianine, γ-fagarine, leptomerine, acutine, and 2-heptylquinolin-4-one, dictamnine	[8]
Helichrysum maracandicum M. Pop. (Asteraceae)	Antiproliferative activity , gall bladder disorders	Chalcone glycoside, isosalipurposide, naringenin chalcone	[116]
Helichrysum sp. Acc. (Asteraceae)	Antimicrobial, antiinflammatory, antioxidative	Flavonoids, phloroglucinol derivatives and diterpenes	[17, 38, 39]
Hypericum perforatum L. (Hypericaceae)	Anti-inflammatory, antimicrobial, diarrhea	Essential oil, β-caryophyllene, caryophyllene oxide, spathulenol, α-pinene	[13, 39]
Hyssopus seravschanicus (Dub.) Pazij (Lamiaceae)	Anti-inflammatory, rheumatism, gastrointestinal	Essential oil, sabinene, β-pinene, myrcene, p-cymene, 1,8-cineole, pinocamphone, carvacrol	[24]
Nitraria schoberi L. (Zygophyllaceae)	Antispasmodic, antineuropathic, anti-arrhythmic agent	Schoberine, nitraraine, nitraramine, dehydroschoberine, sibiridine, vasicinone, peganol)	[39, 104]
Origanum tyttanthum Gontsch (Lamiaceae)	Antimicrobial, intestinal parasites, tuberculosis, hypolipidemic activity	Thymol, carvacrol, ursolic, oleanolic, rosmarinic acids, coumarins, thymol, β-D-glucoside, naringenin, eryodictiol)	[15, 17, 68, 74, 77 85, 108,110
Perovskia scrophularifolia Bunge (Lamiaceae)	Dermatitis, intestinal parasites, antioxidant activity	Anthocyanin, coumarins, essential oils, rosmanol, epirosmanol, carnosol, diosmetin, eugenol b-D-glucopyranoside, salidroside	[59, 67, 69, 106)

continued

Table 1. Pharmaceutical properties of medicinal plants from Uzbekistan (continued).

Plant species & family	Pharmacological properties & treatments	Phytochemical constituents	References
Prangos pabularia Lindl. (Apiaceae)	Antibacterial, inhibition of cytokine release	Coumarins, terpenoids, glycosides, -pyrone, pabularin A, B, & C	[105]
Rhaponticum integrifolium C. Winkl. (Asteraceae)	Improving of the reparative functions of the organism	Ecdysteroids (Ecdysterone, Integristerone A, dehydromakisterone A)	[9]
Rheum maximowiczii Losins Polygonaceae)	Stomach disorders & antioxidant	Phenyl butanoids, stilbene dimers, rhododendrol, epirhododendrin, lindleyin, torachrysone, resveratrol	[42,96]
Rhodiola litvinovii Litvinov (Crassulaceae)	Treat tiredness & neurotic ailments, adaptogenic activity	*p*-Tyrosol, salidroside, gallic acid, epigallocatechin-3-O-gallate)	[60]
Scutellaria ramosissima Popov (Lamiaceae)	Epilepsy, allergy, inflammations, nervous disorders, hypertension, cytotoxic activity	Scutellarin, chrysin, apigenin, apigenin-7-O-glucoside, cymaroside and pinocembrine), lipids (glycolipids, neutral lipids, phospholipids)	[19, 38, 76, 115]
Serratula sogdiana Bunge (Asteraceae)	Heal wounds, liver diseases	Ecdysteroids (ecdysterone , viticosterone E , viticosterone E, sogdysterone)	[87]
Silene brahuica Boiss. (Caryophyllaceae)	Stress-protective effects	Ecdysteroids: (viticosterone E , polypodine B , ecdysterone , integristerone A , sileneoside A, α-ecdysone-22-sulfate)	[47, 87]
Silene wallichiana Klotzch (Caryophyllaceae)	Anabolic adaptogenic, tonic, antioxidant, antimicrobial	Viticosterone E, viticosterone E22-O-benzoate, 20-hydroxyecdysone-22-benzoate, 20-hydroxyecdysone 2-deoxy-20-hydroxyecdysone 2-deoxyecdysone,	[47, 48]
Silybum marianum (L.) Gaertn. (Asteraceae)	Hepatitis, gastrointestinal disorders, anti-inflammatory, antioxidant, & anti-metastatic activity	Parafinic, olefinic, and isoprenoid hydrocarbons, fatty acid esters with triterpenols and sterols, triacylglycerins, triterpene acids, pheophytins	[65]
Thermopsis altherniflora Rgl. et Schmalh. (Fabaceae)	Hypolipidemic, antisclerotic activity	Flavones and isoflavones, formononetin, chrysoeriol, apigenin, luteolin, thermopsoside, cynaroside),	[28]
Ungernia victoris Vved (Amaryllidaceae)	Bronchitis, ulcers, poliomyelitis, neurological diseases	Galanthamine, narwedine, lycorine, ungerine, ungeridine, hippeastrine, haemanthidine, tazettine, & nortazettine	[16, 38, 50]
Vicia subvillosa L. (Fabaceae)	Ascites, paralysis, epilepsy, flu	Flavanoids (apigenin, luteolin, quercetin, cinaroside)	[120]

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