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MEDICINAL FLORA OF THE CHOLISTAN DESERT: A REVIEW

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Abstract

The Cholistan desert can be divided into two distinct regions on the basis of topography, soil type and texture, and vegetation structure: the northern Lesser Cholistan and southern Greater Cholistan. The desert is characterized by large saline compacted areas with alluvial clay, sandy ridges and dunes, and semi-stabilized to frequently shifting dunes. The climate is sub-tropical, harsh, hot and arid, and influenced by seasonal monsoons. Vegetation cover on the sand dunes is comprised by a few tussock-forming grasses including *Cenchrus ciliaris*, *Panicum turgidum* and *Lasiurus scindicus*, along with perennial shrubs *Calligonum polygonoides, Leptadenia pyrotechnica* and *Aerva javanica.* Interdunal flats are dominated by grasses, mainly *Cymbopogon jwarancusa*, *Sporobolus ioclados*, *Panicum antidotale*, and *Ochthochloa compressa*, and tall shrubs *Calligonum polygonoides* and *Capparis decidua*. Vegetation of saline patches is specific, dominated by halophytes mainly belonging to family Chenopodiaceae (Amaranthaceae). Many plants of the Cholistan desert, including *Neurada procumbens, Aerva javanica, Capparis decidua, Cleome brachycarpa, Dipterygium glaucum, Gisekia pharnacioides, Suaeda fruticosa, Achyranthes aspera, Aerva javanica, Alhagi maurorum, Calotropis procera, Capparis decidua, Zaleya pentandra, Mollugo cerviana, Ziziphus mauritiana, Boerhavia procumbens, Cressa cretica* and *Crotalaria burhia*, are frequently used by the local inhabitants to cure chronic and acute diseases. A variety of medicinally important chemical compounds have been extracted and identified from the plants of the Cholistan desert, including terpenes and triterpenoids, sterols and steroids, phenolics, flavonoids, gums and resins, quinones, anthocyanidines, saponins, antioxidants and fatty acids. Habitat degradation, intensive agricultural practices and overexploitation of resources pose a serious threat to the diversity of ethnobotanically important plant species. Allopathic medicines are generally highly priced and out of reach for many of the desert inhabitants. Herbal medicines are preferentially used by local people because they are cheaper than allopathic medicines and have relatively few side effects. Therefore, it is imperative to devise strategies to meet the increasing demand for medicinal plants, not only for the local inhabitants but also for international markets. Institutional support, therefore, can play a decisive role in improving the medicinal plant sector while providing financial support, cultivation and conservation of some important medicinal plants and promoting the domestic and international market systems.

The Cholistan desert, Pakistan

Geography and historical background: The Cholistan desert is a part of the world's seventh largest desert, the Great Desert, which is stretched along the south border of Punjab province, Pakistan (Rao *et al*., 1989). The total area of the Cholistan desert is about 26,000 km^2; it lies between 27º 42' and 29º 45' North and 69º 52' and 75º 24' East (Fig. 1; Arshad *et al*., 2007) at an altitude of about 112 m above sea level (Ali *et al*., 2009). Topography, soil type and texture, and vegetation structure divide this desert into two distinct regions: the northern region (Lesser Cholistan) covers about 7,770 km^2 and the southern region (Greater Cholistan) about 18,130 km^2.

One of the important geological features of the Cholistan is the old Hakra River, which dried out about 600 years ago. The Hakra riverbed forms the dividing line between the two eco-regions of the desert. The Lesser part forms the northern portion of the desert margin and includes areas north of the Hakra along the bank of the Sutluj River, while the Greater part is found to the south of the riverbed. The Greater Cholistan extends from the most recent course of the extinct Hakra River to the border with India (Akhter & Arshad, 2006).

Historically, the Cholistan received heavy monsoon downpours along with the Indus Valley, which is the home of world's oldest civilizations, Mohenjo Daro and Harappa, that date to about 5000 years ago. A gradual change in climate caused a shift in monsoon winds away from the area, resulting in a decline in precipitation, and ultimately converting the area into a desert (Leopold, 1963).

Soil and climate: Soil of the Cholistan desert can be rated as poor, because it contains negligible amounts of organic matter. The Lesser Cholistan is characterized by large saline compacted areas with alluvial clay (interdunal flats or Dahars) in between low sandy ridges and dunes, which are generally stabilized to semi-stabilized, or less frequently shifting dunes (Arshad *et al*., 2007). Soil of interdunal flats varies in texture, structure, and the extent of salinity and sodicity with pHs ranging from 8.2 to 9.6 (Arshad *et al*., 2008). Sand dunes are much lower (less than 100 meters) than those found in the Greater part. The Greater Cholistan is comprised by large wind-shifting sandy dunes and ridges, interspaced with greatly reduced interdunal plains (Arshad *et al*., 2003).

The climate is sub-tropical, harsh, hot and arid, and influenced by seasonal monsoons. One of the most remarkable features of the Cholistan desert is the occurrence of dry years in clusters, i.e., for 4-6 years continually. Annual and even daily temperature varies greatly. Mean summer temperature varies from 35 to 50 ºC during May to June and winter from 15 to 20 ºC during December to February (Arshad *et al*., 2007). Annual rainfall is low and erratic, ranging from 100-250 mm annually, with its maxima during July to September during monsoons and January to March during winters (Arshad *et al*., 2006). High temperatures, low humidity, strong winds and a high rate of evaporation transform the desert into a death valley with extremely harsh environments during summers (Akram *et al*., 1986).

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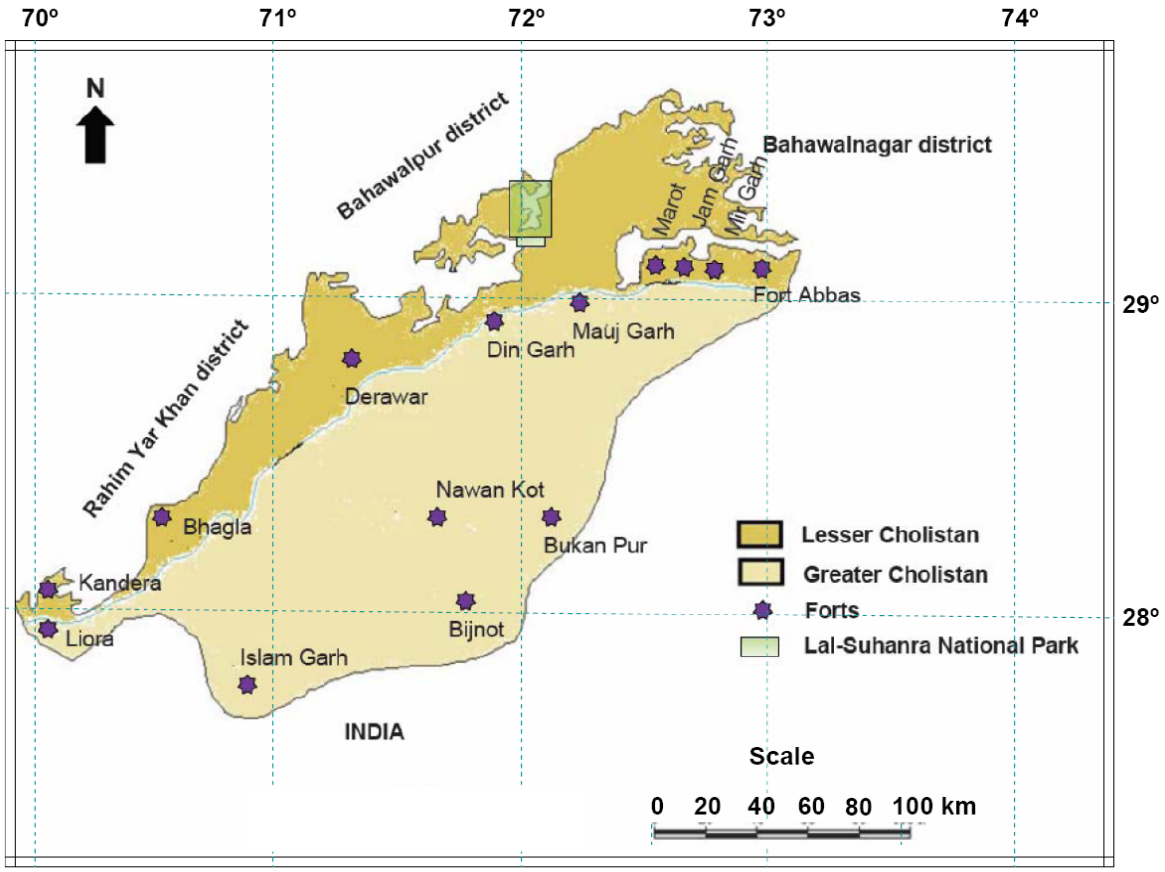

Fig. 1. Map of the Cholistan desert.

Distribution of plant species and community structure

Community structure: The vegetation is comprised of xeromorphic species, which are adapted to a variety of environmental stresses, particularly to extreme aridity, high salinity, high temperature and low nutrient availability (Naz *et al*., 2010). The eastern side of the desert, a relatively high-rainfall zone, receives up to 200 mm of precipitation annually, and so has relatively dense vegetation cover compared to that of the southern region (the hyper-arid region), which has less than 100 mm annual rainfall. However, soil topography, composition and other physio-chemical characteristics play an important role in the distribution of plant species and community structure (Table 1; Arshad *et al*., 2003; Noureen *et al*., 2008).

A number of studies have been conducted on the structure and composition of plant communities. For example, Baig *et al*., (1975) identified six major plant communities in the Cholistan desert, identified by the dominant species: *Haloxylon stocksii*, *Prosopis cineraria*, *Ochthochloa compressa*, *Tribulus terrestris* (more appropriately *T. longipetalus*), *Dipterygium glaucum* and *Calligonum polygonoides*. Khan (1992) classified vegetation on the basis of adaptability potential to extreme aridity and rated *Cenchrus ciliaris* and *Panicum turgidum* as highly adapted grasses, *Calligonum polygonoides, Ziziphus nummularia* and *Haloxylon stocksii* as highly adapted shrubs, and *Prosopis cineraria* and *Acacia jacquemontii* as highly adapted trees. Arshad & Rao (1995) classified soil into four categories along with dominant plant communities. Sand dunes were dominated by a *Calligonum polygonoides* community, sandy plains by a *C. polygonoides-Prosopis cineraria-Capparis decidua* community, compacted soils by a *Capparis decidua-P. cineraria* community, and saline areas by a *Haloxylon stocksii-Suaeda fruticosa-Tamarix dioica* community.

Sand-dune vegetation: Vegetation cover on the sand dunes is extremely low; however, the dominant grasses are *Cenchrus ciliaris*, *Panicum turgidum* and *Lasiurus scindicus* along with one sedge, *Cyperus conglomeratus*. *Calligonum polygonoides, Leptadenia pyrotechnica* and *Aerva javanica* are the dominant shrubs, and *Dipterygium glaucus* is a dominant herb (Rao *et al*., 1989; Chaudhary, 1992; Arshad & Akbar, 2002).

Interdunal vegetation: Soil of the interdunal flats is hard, compacted, and with or without sandy cover. The dominant grasses are *Cymbopogon jwarancusa*, *Cenchrus ciliaris*, *Sporobolus ioclados*, *Panicum antidotale*, and *Ochthochloa compressa*; herbs are *Aerva javanica* and *Dipterygium glaucum*; shrubs are *Calligonum polygonoides, Capparis decidua* and *Haloxylon stocksii*; and the dominant tree is *Prosopis cineraria* (Arshad *et al*., 2008).

Table 1. Dominance of medicinally important plant species in the Cholistan desert.

Family	Plant species	SD	IDF	SP	Aq	CA	CB	LFP
Aizoaceae	*Gisekia pharnacioides*							
	Trianthema triquetra							
	Zaleya pentandra							
Amaranthaceae	*Achyranthes aspera* var. *aspera*							
	Aerva javanica var. *bovei*							
	Aerva javanica var. *javanica*							
	Amaranthus viridis							
Asclepiadaceae	*Calotropis procera* ssp. *hamiltonii*							
	Leptadenia pyrotechnica							
Asteraceae	*Eclipta alba*							
Boraginaceae	*Heliotropium crispum*							
	Heliotropium strigosum							
Capparidaceae	*Capparis decidua*							
	Cleome brachycarpa							
	Cleome scaposa							
	Dipterygium glaucum							
Caryophyllaceae	*Cerastium fontanum*							
Chenopodiaceae	*Haloxylon stocksii*							
	Haloxylon salicornicum							
	Salsola baryosma							
	Suaeda fruticosa							
Convolvulaceae	*Cressa cretica*							
	Convolvulus prostratus							
Cucurbitaceae	*Citrullus colocynthis*							
	Mukia maderaspatana							
Cyperaceae	*Cyperus conglomeratus*							
	Cyperus rotundus							
Euphorbiaceae	*Euphorbia prostrata*							
	Euphorbia granulata							
	Euphorbia hirta							
Malvaceae	*Abutilon muticum*							
	Abutilon indicum							
Mimosaceae	*Prosopis cineraria*							
	Prosopis glandulosa							
	Acacia nilotica							
Molluginaceae	*Mollugo cerviana*							
Myrtaceae	*Eucalyptus camaldulensis*							
Nyctaginaceae	*Boerhavia procumbens*							
Papilionaceae	*Crotalaria burhia*							
	Indigofera argentea							
	Alhagi maurorum							
	Dalbergia sissoo							
Poaceae	*Aeluropus lagopoides*							
	Cenchrus ciliaris							
	Echinochloa colona							
	Cynodon dactylon							
Rhamnaceae	*Ziziphus mauritiana* var. *spontanea*							
	Salvadora oleoides							
Solanaceae	*Datura fastuosa*							
	Withania somnifera							
Tamaricaceae	*Tamarix aphylla*							
Tiliaceae	*Corchorus depressus*							
Typhaceae	*Typha domingensis*							
Verbenaceae	*Phylla nodiflora*							
Zygophyllaceae	*Fagonia indica* var. *indica*							
	Fagonia indica var. *schweinfurthii*							
	Tribulus longipetalus ssp. *longipetalus*							
	Zygophyllum simplex							

Aq: aquatic, CA: cultivated areas, CB: Cholistan border, IDF: interdunal flats, LFP: Lal-suhanra forest plantation SD: sand dunes, SP: Saline patches

Abundant	Frequent	Moderate	Less frequent	Rare	Absent

Vegetation on saline patches: The dominant vegetation component of halophytic communities in the saline area of the Cholistan includes the tree *Tamarix dioica*, shrubs *Haloxylon stocksii, H. salicornicum, Suaeda fruticosa*, and *Salsola baryosma*, and grasses *Aeluropus lagopoides, Sporobolus ioclados, Ochthochloa compressa, Cymbopogon jwarancusa* and *Lasiurus scindicus* (Naz *et al*., 2009).

Aquatic vegetation: Permanent water bodies are rare in the Cholistan desert; however, a desert canal passes across the Lal-suhanra National Park, Bahawal and possesses aquatic vegetation to some extent. Along the canal, a few permanent swamps are formed due to seepage. The dried-out Patisar lake is one such example. Vegetation is completely dominated by *Cynodon dactylon* on the banks with small patches of *Phyla nodiflora*. Tussocks of tall grasses (*Saccharum bengalense* and *S. spontaneum*) along with *Calotropis procera* are also part of the dominant vegetation. The submerged vegetation is composed of *Vallisneria spiralis* and *Nelumbo nucifera* in deeper waters, and *Typha domingensis* and *Phragmites karka* in shallow waters (Hameed *et al*., 2002).

Cultivated areas: Agricultural practices are usually carried out at desert margins, where the commonly cultivated crop is cotton, along with some cereals (wheat, maize, barley, sorghum and oats) and legumes (guar, mothbean and chickpea). Weedy species are the major component of vegetation in this region (Ahmad *et al*., 2001). Dominant species among grasses and sedges are *Cynodon dactylon, Echinochloa colona* and *Cyperus rotundus,* while herbaceous weeds mainly include *Amaranthus viridis, Euphorbia prostrata, E. hirta, Eclipta alba*, and *Phyla nodiflora* (Hammed *et al*., 2002).

Border vegetation: Vegetation structure is more or less similar to that of Lesser Cholistan at interdunal flats with dominant grasses including *Cenchrus ciliaris, Lasiurus scindicus, Ochthochloa compressa* and *Cynodon dactylon*, and shrubs including *Calotropis procera, Capparis decidua,* and *Leptadenia pyrotechnica.* However, a few tree species (i.e. *Prosopis cineraria, Acacia nilotiva,* and *Salvadora oleoides*) are the major component of border vegetation (Ahmad *et al*., 2001).

Lal-suhanra Forest plantation vegetation: Irrigated forest plantations are characterized by monocultures and mixtures of mainly *Eucalyptus camaldulensis*, *Dalbergia sissoo*, *Prosopis cineraria* and *Acacia nilotica*. The dominant components of the ground cover flora are grasses including *Dichanthium annulatum, Desmostachya bipinnata, Imperata cylindrica* and *Saccharum bengalense* and annual dicots including *Achyranthes aspera, Alhagi maurorum, Diclyptera bupleuroides, Heliotropium crispum* (Arshad *et al*., 2002; Hameed *et al*., 2002).

Use of medicinal plants by local inhabitants: A lot of work has been done on medicinal properties and folk uses of medicinal plants in neighboring countries, particularly in India, which shares habitats similar to the Cholistan desert. Unfortunately, while many plants of the Cholistan desert are frequently used by the local inhabitants, their medicinal importance is still not documented. One of the most striking examples is of *Neurada procumbens,* and over-exploitation of this important plant makes its local status critically endangered. This plant is extensively used as a cooling agent, a strong tonic and a strong stimulant for debility and impotency (Qureshi *et al*., 2010). There are many other examples of native species whose uses and chemical constituents are not yet documented.

A number of species, including *Abutilon* spp., *Aerva javanica, Capparis decidua, Cleome brachycarpa, Crotalaria burhia, Dipterygium glaucum, Gisekia pharnacioides* and *Suaeda fruticosa* are used for vermicidal and anthelmintic properties against intestinal worms or for antimicrobial activities against bacteria and other microorganisms (Table 2). Herbs used for stomach and intestinal complaints including diarrhoea, dyspepsia, constipation, bloating, and diminished appetite are *Achyranthes aspera, Aerva javanica, Alhagi maurorum, Calotropis procera, Capparis decidua,* and *Zaleya pentandra* (Immanuel and Elizabeth, 2009; Jabeen *et al*., 2009; Khan, 2009; Marashdah & Al-Hazimi, 2010; Qureshi *et al*., 2010). *Mollugo cerviana, Ziziphus mauritiana* and *Boerhavia procumbens* are used as blood purifiers (Immanuel & Elizabeth, 2009; Padmavathy & Anbarashan, 2011), while *Acacia nilotica, Calotropis procera* and *Cressa cretica* are used as tonics (Chopra *et al*., 2006; Jabeen *et al*., 2009). Quite a few herbs, including *Capparis decidua, Cleome scaposa, Crotalaria burhia* and *Euphorbia prostrata*, are known for their wound healing and pain relieving properties (Dalziel, 1948; Natarajan *et al*., 2005; Bose *et al*., 2007; Kataria *et al*., 2010). Some herbs are well known for their excellent treatment of chronic diseases: *Trianthema triquetra* is antihepatotoxic, *Haloxylon salicornicum* is hepatoprotective and *Cleome scaposa* has anticancer properties (Chitra & Nithyanandhi, 2007; Bala *et al*., 2010; Ahmad & Eram, 2011).

Local inhabitants of the Cholistan desert use many plant species as folk remedies (Table 3). They frequently use *Gisekia pharnacioides, Achyranthes aspera* and *Cressa cretica* for respiratory tract illnesses like common cough, bronchitis and asthma (Rizk & El-Ghazaly, 1995; Stella *et al*., 2004; Immanuel and Elizabeth, 2009). *Leptadenia pyrotechnica, Cyperus conglomeratus, Zaleya pentandra,* and *Withania somnifera* are used for digestive tract problems like constipation, stomach upset and gastrointestinal discomforts. *Boerhavia procumbens, Mollugo cerviana,* and *Prosopis cineraria* are used for blood purification and heart and circulatory system problems like anaemia and cardiac troubles (Goyal & Sharma, 2009; Immanuel & Elizabeth, 2009). *Gisekia pharnacioides, Salsola imbricata* and *Cressa cretica* are useful for diseases such as hypertension and leprosy (Chopra *et al*., 2006; Hammiche & Maiza, 2006; Nandagopalan *et al*., 2011). *Citrullus colocynthis, Aerva javanica* and *Haloxylon stocksii* are extremely useful for urinary system problems, especially for kidney and bladder stones (Khan *et al*., 2003; Dagar, 2005; Sharif *et al*., 2011).

A number of herbs are used for aches, pains and cuts and wounds (Table 4). Important among them are *Leptadenia pyrotechnica, Aerva javanica, Mukia maderaspatana, Ziziphus mauritiana* and *Euphorbia hirta* (Mahesh & Satish, 2008; Goyal & Sharma, 2009; Immanuel & Elizabeth, 2009; Qureshi *et al*., 2010). For diseases relating to eyes, *Withania somnifera* is useful for sore eyes, *Suaeda fruticosa* for ophthalmia, *Mollugo cerviana* for improving eyesight, and *Achyranthes aspera* for night blindness (Parvathamma & Shanthamma, 2000; Rashid *et al*., 2000; Mahesh & Satish, 2008; Immanuel & Elizabeth, 2009). *Alhagi maurorum* is useful for liver inflammation, *Cleome scaposa* for cancer and tumors, and *Cyperus conglomeratus* for hair loss and baldness (Bala *et al.*, 2010; Atta *et al.*, 2011).

Table 2. Herbal properties of some important medicinal plants in the Cholistan desert.

Abutilon indicum	Antioxidant, antibacterial, antidiarrhoeal, anticonvulsant, anticonvulsant (Golwala *et al*., 2010).
Abutilon muticum	Antimicrobial, antioxidant, antibacterial (Khadabadi and Bhajipale, 2010)
Acacia nilotica	Tonic, febrifuge (Jabeen *et al*., 2009)
Achyranthes aspera	Diuretic, dyspepsia (Immanuel & Elizabeth, 2009)
Aerva javanica	Purgative, anthelmintic (Qureshi *et al*., 2010)
Alhagi maurorum	Diaphoretic, diuretic, expectorant, laxative (Marashdah & Al-Hazimi, 2010)
Amaranthus viridis	Emollient (Jabeen *et al*., 2009)
Boerhavia procumbens	Blood purifier (Immanuel & Elizabeth, 2009)
Calotropis gigantea	Tonic, sudorific, alterative, antispasmodic, expectorant, emetic, digestive, stomachic, purgative (Jabeen *et al*., 2009)
Capparis decidua	Anthelmintic, analgesic, aphrodisiac, carminative, diaphoretic, emmenagogue, laxative (Dalziel, 1948)
Cenchrus ciliaris	Anodyne, diuretic, emollient (Katewa & Jain, 2003)
Cleome brachycarpa	Vermicides (Khan, 2009)
Cleome scaposa	Analgesic, antipyretic, anti-inflammatory (Narendhirakannan *et al*., 2006; Bose *et al*., 2007), anticancer (Bala *et al*., 2010)
Convolvulus prostratus	Purgative (Jabeen *et al*., 2009)
Cressa cretica	Anthelmintic, stomachic, tonic, aphrodisiac (Chopra *et al*., 2006), antibilious, antitubercular, expectorant (Rizk & El-Ghazaly, 1995)
Crotalaria burhia	Antimicrobial, anti-inflamatory, wound healing, anti-oxidant (Kataria *et al*., 2010)
Cyperus rotundus	Stomachic, diuretic (Kumar *et al*., 2010)
Dalbergia sissoo	Aphrodisiac, expectorant (Singh *et al*., 2010)
Dipterygium glaucum	Antileishmanial, insecticidal, cytotoxocity, antibacterial, antifungal (Ahmed *et al*., 2006)
Euphorbia granulata	Antibacterial activity, anthelmintic, diuretic, purgative (Natarajan *et al*., 2005).
Euphorbia hirta	Antiasthmatic, febrifuge, narcotic (Kumar, 2010), expectroant (Immanuel & Elizabeth, 2009)
Euphorbia prostrata	Anti-inflammatory, antibacterial activity (Natarajan *et al*., 2005)
Gisekia pharnacioides	Aperient, anthelmintic, astringent (Stella *et al*., 2004)
Haloxylon salicornicum	Hepatoprotective (Ahmad & Eram, 2011)
Heliotropium crispum	Cooling agent (Qureshi *et al*., 2010)
Mollugo cerviana	Antiseptic (Parvathamma & Shanthamma, 2000), blood purifier (Immanuel & Elizabeth, 2009)
Neurada procumbens	Nerve tonic, cooling agent (Qureshi *et al*., 2010)
Suaeda fruticosa	Antibacterial (Rashid *et al*., 2000)
Trianthema triquetra	Antihepatotoxic (Chitra & Nithyanandhi, 2007)
Zaleya pentandra	Stomach ailment (Khan *et al*., 2009)
Ziziphus mauritiana	Blood purifier (Padmavathy & Anbarashan, 2011)

Chemical constituents of native medicinal plants: Plants inhabiting the Cholistan desert are adapted to a variety of environmental stresses like extreme aridity, high salinity and temperature, and also to deficiencies in macro- and micro-nutrients (Naz *et al*., 2009). Many medicinally important chemical compounds have been extracted and identified from the plants of the Cholistan desert. These include terpenes and triterpenoids, sterols and steroids, phenolics, flavonoids, gums and resins, quinones, anthocyanidines, saponins, antioxidants and fatty acids (Table 5; Pengelly, 2004; Ahmad & Eram, 2011). However, there is still a lot of work to be done in this field, as the chemical nature and structure of secondary metabolites in many medicinal plants is unexplored.

Threats to indigenous medicinal flora

Threats to native vegetation: The Cholistan desert can be considered a unique habitat due to its biodiversity and endemism of a number of species (Akhter & Arshad, 2006). Habitat degradation due to intensive agricultural practices is a serious threat to the diversity of ethnobotanically important plant species. Agricultural communities may promote the cultivation of desirable species while destroying or ignoring others which they find undesirable. In contrast, some of the local communities may use these "undesirable" species extensively for their daily life. Furthermore, overgrazing by a large number of ruminants (camels, cattle, goats and sheep) has resulted in habitat degradation.

Loss of plant diversity has stimulated an urgent desire to conserve natural habitat and promote existing knowledge and documentation of medicinally important plant species. Moreover, local communities exploit medicinally important plant species for other economic uses, e.g. food, fodder, house construction and various other uses. Seeds and fruits of *Prosopis cineraria* are edible and extensively used in a number of local dishes (Arshad *et al*., 2006). An herbal aqueous extract of *Cymbopogon jwarancusa* is commonly used for relaxing and reducing thirst during summer. Each and every part of *Calotropis procera* is used to cure a number of diseases, and some parts have other economical uses, like fruit floss for stuffing in pillows and cushions (Chaudhry *et al*., 2004).

Table 3. Herbal remedies and plant parts from some important medicinal plants in the Cholistan desert used for respiratory, digestive, nervous, circulatory and urinary diseases.

System	Disease	Herbs used
Respiratory tract	Common cold, influenza	*Mukia maderaspatana* (Immanuel & Elizabeth, 2009), *Eucalyptus camaldulensis* (Kumar *et al.*, 2010)
	Respiratory problems	*Prosopis cineraria* (Goyal & Sharma, 2009)
	Chest disorders	*Gisekia pharnacioides* (Nandagopalan *et al*., 2011), *Ziziphus mauritiana* (Mahesh & Satish, 2008)
	Coughs	*Mukia maderaspatana* (Immanuel & Elizabeth, 2009), *Cyperus rotundus* (Immanuel & Elizabeth, 2009), *Euphorbia hirta* (Immanuel & Elizabeth, 2009), *Mollugo cerviana* (Parvathamma & Shanthamma, 2000)
	Nose infection	*Eucalyptus camaldulensis* (Kumar *et al.*, 2010)
	Nosebleed	*Dalbergia sissoo* (Kumar *et al.*, 2010)
	Rhinitis	*Gisekia pharnacioides* (Nandagopalan *et al*., 2011)
	Bronchitis	*Gisekia pharnacioides* (Nandagopalan *et al*., 2011), *Achyranthes aspera* (Immanuel & Elizabeth, 2009), *Eclipta alba* (Kasera & Shukla, 2004), *Euphorbia hirta* (Immanuel & Elizabeth, 2009)
	Asthma	*Achyranthes aspera* (Immanuel & Elizabeth, 2009), *Eclipta alba* (Kasera & Shukla, 2004), *Cressa cretica* (Chopra *et al*., 2006)
	Tuberculosis	*Abutilon indicum* (Immanuel & Elizabeth, 2009)
Digestive tract	Constipation	*Amaranthus viridis* (Khan *et al*., 2011), *Leptadenia pyrotechnica* (Goyal & Sharma, 2009), *Cressa cretica* (Chopra *et al*., 2006), *Cyperus conglomeratus*
	Irritable bowel syndrome	*Achyranthes aspera* (Immanuel & Elizabeth, 2009)
	Diarrhoea	*Cyperus rotundus* (Immanuel & Elizabeth, 2009), *Phyla nodiflora* (Nandagopalan *et al*., 2011)
	Piles	*Achyranthes aspera* (Immanuel & Elizabeth, 2009), *Euphorbia hirta* (Immanuel & Elizabeth, 2009)
	Stomach upsets, gastritis	*Zaleya pentandra* (Elkhalifa *et al*., 2006)
	Gastrointestinal discomforts	*Prosopis glandulosa* (Davidow, 1999), *Alhagi maurorum* (Atta *et al*, 2011)
	Indigestion	*Cyperus rotundus* (Kumar *et al.*, 2010)
	Digestive upsets	*Achyranthes aspera* (Immanuel & Elizabeth, 2009)
	Nausea, vomiting	*Euphorbia hirta* (Immanuel & Elizabeth, 2009)
	Dysentery	*Achyranthes aspera* (Immanuel & Elizabeth, 2009), *Calotropis procera* (Jabeen *et al*., 2009), *Cyperus rotundus* (Kumar *et al.*, 2010)
	Dyspepsia	*Achyranthes aspera* (Immanuel & Elizabeth, 2009)
	Biliousness	*Capparis decidua* (Dalziel, 1948)
	Cholera and flatulence	*Cyperus rotundus* (Immanuel & Elizabeth, 2009)
	Hiccups	*Withania somnifera* (Mahesh & Satish, 2008)
Heart and circulation	Anaemia	*Boerhavia procumbens* (Darsini *et al*., 2009)
	Cardiac troubles	*Gisekia pharnacioides* (Nandagopalan *et al*., 2011), *Capparis decidua* (Dalziel, 1948)
	Blood disorders	*Cyperus rotundus* (Kumar *et al.*, 2010)
	Blood purification	*Prosopis cineraria* (Goyal & Sharma. 2009), *Mollugo cerviana* (Immanuel & Elizabeth, 2009)
	Hypertension	*Salsola imbricata* (Hammiche & Maiza, 2006)
Brain and nervous system	Mental disorders	*Gisekia pharnacioides* (Nandagopalan *et al*., 2011)
	Leprosy	*Gisekia pharnacioides* (Nandagopalan *et al*., 2011), *Cressa cretica* (Chopra *et al*., 2006)
	Epilepsy	*Cyperus rotundus* (Immanuel & Elizabeth, 2009)
Urinary problems	Urinary troubles	*Gisekia pharnacioides* (Nandagopalan *et al*., 2011), *Achyranthes aspera* (Immanuel & Elizabeth, 2009), *Citrullus colocynthis* (Dagar, 2005)
	Hepatic injury	*Trianthema triquetra* (Chitra & Nithyanandhi, 2007)
	Bladder and Kidney stones	*Aerva javanica* (Sharif *et al*., 2011), *Haloxylon stocksii* (Khan *et al*., 2003)
	Kidney pain	*Cenchrus ciliaris* (Katewa & Jain, 2003)
	Urinary discharge	*Cressa cretica* (Chopra *et al*., 2006)
	Micturation and dysuria	*Phyla nodiflora* (Qureshi *et al*., 2010)

: Whole plant, : Root, : Leaves, : Stem, : Flowers, : Seeds, : Fruit

Allopathic medicines are generally highly priced and many desert inhabitants have no easy access to them. It is generally accepted that allopathic medicines may cure a number of diseases, but they can have serious side effects (Kala, 2005). Medicinal plants that are used for herbal remedies help to alleviate poverty among local people in two ways. Local nomads collect medicinal plants from the wild and sell them to the local markets to increase their income, and allopathic medicines are too expensive for the local people, so they rely on indigenous medicinal plants to cure common injuries and diseases, thereby saving money. Furthermore, remedies from medicinal

plants often have few or minimal side effects (Haq, 2004; Agarwal, 2005; Samy *et al*., 2008; Verma & Singh, 2008; Kavishankar *et al*., 2011). This is one reason for the growing popularity herbal remedies, even in developed countries in North America and Europe. Medicinal plants of the Cholistan desert have slow growth rates, low population densities and narrow geographic distributions. They are at a higher risk of extinction because of overexploitation (Kala *et al*., 2004). As a consequence, over-harvesting in the wild can result in irreparable losses to local biodiversity.

Table 4. Herbal remedies and parts of some important medicinal plants used for common diseases in the Cholistan desert.

System	Disease	Herbs used
Aches and pains	Rheumatism, arthritis	*Achyranthes aspera* (Immanuel & Elizabeth, 2009), *Leptadenia pyrotechnica* (Goyal & Sharma, 2009), *Citrullus colocynthis* (Dagar, 2005), *Acacia nilotica* (Jabeen *et al*., 2009)
	Joint pain, swelling	*Cleome brachycarpa* (Qureshi *et al*., 2010)
	Toothache	*Achyranthes aspera* (Immanuel & Elizabeth, 2009), *Aerva javanica* (Qureshi *et al*., 2010), *Mukia maderaspatana* (Qureshi *et al*., 2010)
	Abdominal pains	*Ziziphus mauritiana* (Mahesh & Satish, 2008)
	Muscular pains	*Phyla nodiflora* (Biswas *et al*., 2011)
Cuts and wounds	Wounds. sores	*Aerva javanica* (Qureshi *et al*., 2010), *Heliotropium strigosum* (Qureshi *et al*., 2010), *Cyperus rotundus* (Immanuel & Elizabeth, 2009), *Prosopis glandulosa* (Davidow, 1999), *Gisekia pharnacioides* (Stella *et al*., 2004), *Cenchrus ciliaris* (Katewa & Jain, 2003)
	Inflammation	*Aerva javanica* (Qureshi *et al*., 2010), *Euphorbia hirta* (Immanuel & Elizabeth, 2009)
	Burns, cuts, ulcers	*Eclipta alba* (Kasera & Shukla, 2004), *Haloxylon stocksii* (Khan *et al*., 2003), *Ziziphus mauritiana* (Padmavathy & Anbarashan, 2011)
	Boils	*Euphorbia hirta* (Immanuel & Elizabeth, 2009)
Eyes problems	Sore eyes	*Withania somnifera* (Mahesh & Satish, 2008)
	Eye diseases	*Eclipta alba* (Kasera & Shukla, 2004), *Suaeda fruticosa* (Rashid *et al*., 2000), *Prosopis glandulosa* (Davidow, 1999)
	Ophthalmia	*Suaeda fruticosa* (Rashid *et al*., 2000)
	Eyesight	*Mollugo cerviana* (Parvathamma & Shanthamma, 2000)
	Night blindness	*Achyranthes aspera* (Immanuel & Elizabeth, 2009)
Mouth disorders	Tooth decay	*Acacia nilotica* (Mahesh & Satish, 2008)
Skin problems	Skin diseases	*Leptadenia pyrotechnica* (Goyal & Sharma, 2009), *Heliotropium crispum* (Qureshi *et al*., 2010), *Convolvulus prostratus* (Jabeen *et al*., 2009), *Euphorbia prostrata* (Kumar *et al*., 2010)
	Skin eruption	*Fagonia indica* (Qureshi *et al*., 2010)
	Scabies, leucoderma	*Gisekia pharnacioides* (Nandagopalan *et al*., 2011), *Prosopis cineraria* (Kirtikar & Basu, 1975)
	Edema (dropsy)	*Achyranthes aspera* (Immanuel & Elizabeth, 2009), *Cynodon dactylon* (Jabeen *et al*., 2009)
	Athlete's foot	*Eclipta alba* (Kumar *et al*., 2010)
	Ringworm	*Eclipta alba* (Kumar *et al*., 2010), *Euphorbia prostrata* (Kumar *et al*., 2010)
	Erysipelas	*Cyperus rotundus* (Immanuel & Elizabeth, 2009)
	Allergies	*Achyranthes aspera* (Immanuel & Elizabeth, 2009), *Euphorbia prostrata* (Kumar *et al*., 2010)
Sexual diseases	Gynic disorders	*Withania somnifera* (Mahesh & Satish, 2008)
	Leucorrhoea	*Abutilon indicum* (Immanuel & Elizabeth, 2009), *Cynodon dactylon* (Biswas *et al*., 2011)
	Spermatorrhoea, urino-genital diseases	*Corchorus depressus*, *Tribulus longipetalus* (Qureshi *et al*., 2010)
Bites, worm infections	Snake/scorpion sting	*Zaleya pentandra* (Elkhalifa *et al*., 2006), *Amaranthus viridis* (Jabeen *et al*., 2009)
	Insect bite	*Achyranthes aspera* (Immanuel & Elizabeth, 2009)
	Worm infestation	*Gisekia pharnacioides* (Nandagopalan *et al*., 2011), *Convolvulus prostratus* (Jabeen *et al*., 2009), *Ziziphus mauritiana* (Padmavathy & Anbarashan, 2011)
	Helminthiases	*Zygophyllum simplex* (Hammiche & Maiza, 2006)
Fevers and other diseases	Muscle tremors	*Prosopis cineraria* (Kirtikar & Basu, 1975)
	Hangovers	*Mollugo cerviana* (Immanuel & Elizabeth, 2009)
	Syphilis	*Dalbergia sissoo* (Kumar *et al*., 2010)
	Liver inflammation	*Alhagi maurorum* (Atta *et al*., 2011)
	Intermittent fever	*Capparis decidua* (Dalziel, 1948)
	Common fever	*Cyperus rotundus* (Immanuel & Elizabeth, 2009)
	Jaundice and hepatitis	*Haloxylon salicornicum* (Ahmad & Eram, 2011), *Citrullus colocynthis* (Dagar, 2005), *Eclipta alba* (Kasera & Shukla, 2004)
	Cancers, tumors	*Cleome scaposa* (Bala *et al*., 2010), *Cenchrus ciliaris* (Katewa & Jain, 2003)
	Leprosy	*Prosopis cineraria* (Kirtikar & Basu, 1975)
	Baldness, hair loss	*Cyperus conglomerates* (Ayman *et al*., 2005)
	Diabetes	*Acacia nilotica*, *Echinochloa colona* (Mahesh & Satish, 2008)

: Whole plant, : Root, : Leaves, : Stem, : Flowers, : Seeds, : Fruit

Table 5. Major chemical compounds found in some important medicinal plants of the Cholistan desert.

Plant species	Major chemical constituents
Abutilon indicum	Fatty acids (linoleic, oleic, stearic, palmitic, lauric, myristic, caprylic, capric), sitosterol (Rajurkar *et al.,* 2009*),* amyrin, sesquiterpene lactones, geraniol. caryophylline (Pengelly, 2004)
Abutilon muticum	Alkaloids, cardiac glycosides (Kumar & Gali, 2011), lupeol, β-sitosterol, stigmasterol, taraxacin, ursolic acid (Mhasker *et al.,* 2000)
Acacia nilotica	Tannins, saponins, flavonoid, terpene, sterol, phenol, alkaloid, anthraquinone (Alli *et al*., 2011)
Achyranthes aspera	Triterpinoid saponins, achyranthine, N-methyl pyrrolidine-3-carboxylic acid (Dwivedi *et al*., 2008), ecdysterone, oleanic acid (Aeri *et al*., 2010)
Aerva javanica var. *bovei*	Flavanoid glycosides, steroids (Rajesh *et al*., 2010)
Aerva javanica var. *javanica*	Isoquercetrin, 5-methylmellein, apigenin 7-O-glucuronide (Sharif *et al*., 2011)
Alhagi maurorum	β-sitosterol, cinnamic acid, coumaric acid, hydroxybenzoic acid (Ahmad *et al.,* 2009)
Amaranthus viridis	Flavonoids like rutin and quercetin (Kumar *et al.,* 2009)
Boerhavia procumbens	Punarnavine (Murti *et al*., 2010), boeravinone (Lami *et al.*, 1992), ursolic acid (Chaudhary & Dantu, 2011), punarnavoside (Jain & Khanna, 1989), glycoprotein (Verma *et al.*, 1979)
Calotropis procera	Calotropin and calotropagenin (Sharma *et al*., 2011)
Capparis decidua	Capparisine (Ahmad *et al*., 1989)
Citrullus colocynthis	Cytotoxic cucurbitacines (Gry *et al*., 2006)
Cleome brachycarpa	Trinortriterpenoid dilactone, deacetoxybrachycarpone, cabralealactone, ursolic acid (Ahmad & Alvi, 1986)
Convolvulus prostratus	Purgative resin (Qureshi *et al*., 2010)
Conyza bonariensis	Triterpene-steroids, phenolic compounds, flavonoids, quinones, anthocyanidines, saponins (Santana *et al*., 2011)
Corchorus depressus	Glucopyranoside (Ahmad *et al.,* 1998)
Cressa cretica	Triacontanoic acid, stigmasterol, ursolic acids, quercetin, umbelliferone (Hussain *et al*., 2005)
Crotalaria burhia	Alkaloids, phenols, polyphenols, saponins, tannins, triterpenes, anthraquinones, flavonoides, steroids (Kataria *et al.,* 2010)
Cyperus rotundus	Pinene (a monoterpene), cyperol, isocyperol, cyperone, rotundene, rotundenol, rotundone, selinatriene, sitosterol (Huang & Peng, 2003)
Dalbergia sissoo	Carbohydrates, glycosides, phytosterols, saponins, flavonoids, alkaloids, tannins (Brijesh *et al*., 2006)
Datura fastuosa	Hyoscyamine, hyoscine, meteloidine (Hashimoto & Yamada, 1986)
Eclipta alba	Demethylwedelolactone, ecliptal, β-amyrin, luteolin-7-O-glucoside, hentriacontanol, heptacosanol, stigmasterol (Jadhav *et al.*, 2009)
Eucalyptus camaldulensis	β-phellandrene, spathulenol, cryptone (Barra *et al*., 2010)
Euphorbia prostrata, Euphorbia granulata, Euphorbia hirta	Diterpene polyesters (Valente *et al*., 2003; Duarte & Ferreira, 2007) and other terpenes (Miyata *et al*., 2005)
Fagonia indica Burm	Glycosides, saponins, sterols, triterpenoids, alkaloids, cardiac glycosides, cyanogenic glycosides, flavonoids, coumarins, irodoids (Ghazanfar & Al-Sabahi, 1993).
Gisekia pharnacioides	Oxalic, succinic, tartaric, citric acids; triacontane, dotriacontane, myristone and tetracosano (Stella *et al*., 2004)
Haloxylon salicornicum	Piperidine, haloxynine, hordenine, aldotripiperideine, smipine, haloxine, halosaline, anabasine (El-Shazly *et al*., 2005), nicotine, tryptamine, dipterine, N-methylisosalsoline, carnegine, isosalsoline, salsolidine, dehydrosalsolidine isosalsolidine, *N*-ethyltyramine, oxedrine, tyramine, coumarins (Ahmad & Eram, 2011)
Haloxylon stocksii	Dillenic acid (Ahmed *et al*., 2004)
Leptadenia pyrotechnica	Triterpenoids, taraxerol, fernenol, β-sitosterol (Ghazanfar, 1994).
Mollugo cerviana	Tannins, saponins, alkaloids, glycosides (Pavithra *et al*., 2010)
Mukia maderaspatana	Alkaloids, glycoside, ascorbic acid, β-sitosterol, terpenoids (Dhanaraj & Jegadeesan, 2011)
Phyla nodiflora	β-sitosterol, nodiflorin, lippiflorin (Dodoala *et al*., 2010)
Prosopis cineraria	Methyl heptacosanoate, heneicosanoic acid, hydroxy-benzoic acid (Khan *et al.,* 2006)
Prosopis glandulosa	Triterpenes, flavonoids, glycosides, indolizidine, juliprosopine (Nakano *et al*., 2004)
Salsola imbricata	Coumarins, sterols (Rizq, 1986)
Trianthema triquetra	Thiobarbituric acid, reduced glutathione, glutathione peroxidase, catalase (Chitra & Nithyanandhi, 2007)
Tamarix aphylla	Alkenes, aromatic hydrocarbon, benzofuranone, oxirane (Mughal *et al*., 2011)
Tribulus longipetalus	Steroidal saponins, flavonoids, alkaloids, amides, lignanamids (El-Sayed *et al*., 2008)
Withania somnifera	Withanolides, cytotoxic lactones, piperidine, anaferine, anahygrine, alkaloids (withanine, somniferine, somnine, tropine) (Kapoor, 2001; Mirjalili *et al*., 2009)
Zaleya pentandra	Glycosides, saponins and steroids (Samiullah *et al*., 2011)
Zygophyllum simplex	Isorhamnetin, sitosterol glucoside, quinovic acid (Hassanean & Desoky, 1992)

Future strategies for sustainable propagation and use of important medicinal plants: There is an urgent need to devise strategies to meet the increasing demand for medicinal plants, not only for the local inhabitants but also for international markets. It is well known that about 70% of allopathic drugs are plant-based, so significant amounts of drugs are still being extracted directly from plant materials (Pattanaik *et al*., 2006).

The complete exploration of medicinal plants of the Cholistan desert will help to maximize the utility of pharmaceutical products, particularly from plants whose uses are not documented yet. Extensive ethnobotanical surveys may help identify suitable sources of medicinal flora, and ultimately bring them into domestication.

Farming and cultivation practices of some important medicinal plants are immensely helpful in minimizing the overexploitation pressure and also in meeting the rising demand for natural resources. Cultivation will also permit better species identifications and improved quality control. *Plantago ovata* is a good example in this regard (Aslam, 2008), and both its production and the quality of active ingredients have increased under controlled environmental conditions free of pests, diseases and abiotic stresses. *Plantago ovata* is native to the Himalayan foothill region (Kazmi, 1974) and extensively used for stomach complaints.

A number of stakeholders are involved in the medicinal plant sector in the Cholistan desert. These include collectors and gatherers (mainly local inhabitants and desert nomads), traders, wholesalers, drug manufacturers and herbal practitioners. On the whole, the current market system is inadequate in the sense that plant collectors are not getting proper income from middlemen or other herb-sellers. In addition, the quality of herbal collections can easily be degraded without proper collection and drying of the plant material.

Institutional support from organizations such as the Cholistan Institute of Desert Studies (CIDS) and Islamia University, Bahawalpur, can play a decisive role in improving the medicinal plant sector by soliciting projects from different funding agencies and by training individuals. Funding opportunities can be created to support capacity building of the medicinal plant sector, which can also promote major thrust areas of the sector. Of prime importance is the need for extensive surveys and the development of medicinal plant inventories for proper identification of the plant resources. Conservation strategies including *in situ* and *ex situ* propagation and cultivation of selected medicinal plants are vital for improving availability and quality of herbal material. Strengthening of research and development, training collectors, researchers and scientists, and promoting the domestic and international market system are among the main priorities of the institutions. Furthermore, documentation and certification of important medicinal plants can raise awareness and ultimately improve the community-based management of the medicinal resources of the region.

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