Shrubs of Hot Arid Rajasthan: Economic and Ecological Imperatives – A review

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Abstract

About 62 % of total hot arid zone of India lies in Rajasthan with the woody perennials particularly the rangeland shrubs are main source of sustenance and ecological significance. Destruction of natural habitats, over exploitation and increased mechanization in agriculture during last couple of decades resulted into sharp decline in number and diversity of shrubs. There is urgent need for sustainable utilization of shrub diversity through scientific conservation as well as the management. In this paper an attempt has been made to compile the available information pertaining to significance, conservation and management of rangeland shrubs for sustainable management of shrub diversity in hot arid region of Rajasthan, India.

Key words: Conservation, Ethnobotany, Fodder, Fuel, Medicine, Rangeland shrubs, Soil degradation

Introduction

Land productivity and life support system in hot arid region are seriously constrained by environmental factors such as low and erratic rainfall, extreme temperature, high wind speed, high evapo-transpiration, light textured soils with poor fertility, low water retention capacity, and scarce water resources. The region is under stress due to rapid increasing human and livestock population coupled with frequent drought and desertification. Perennial plants and livestock are important component of farming systems of the region (Bhati and Joshi, 2007). Age old experience of inhabitants has established well-contained systems, which accrue maximum benefit by integration of woody perennials into farming systems. Among the perennial vegetation, shrubs are important as they cover 70 – 80 % of desert landscape from Aravalli to the Indian part of Thar Desert. The shrubs provide fodder, food, fuel wood, fiber, medicine, gums/resins, dye and tanning materials, oil and fats, thatching materials etc. They also play important ecological role i.e. arresting soil erosion, stabilization of sand dunes, phyto-remediation of degraded soils besides the micro-climate modification for creating favourable condition for associated flora and fauna. This paper is an attempt to present a comprehensive account pertaining to economic and ecological significance of hot arid shrubs

along with options for their conservation for sustainable utilization of shrubs and arid rangelands.

Materials and Methods

During last decade, a wide range of shrub germplasm was collected in the arid region for their *ex situ* evaluation. During the collection process, information pertaining to uses of shrubs was recorded after interviewing the local inhabitants. This information was further crosschecked and supplemented through secondary data collection in related fields.

Results and Discussion

The western Rajasthan is sparsely vegetated, and major part is scrubby thorny forest with stunted and half-nibbled shrubs. Indian arid zone has 682 species (Bhandari, 1990) of which 48 species are shrub, 40 are under shrub and 14 are climbing shrub, constituting 17 % of the total floristic composition (Kumar *et al*., 2005).

(A) Economic significance:

(a) Fodder:

Livestock sector has an important role in agrarian economy of the region because of their potential to reduce risk, alleviate poverty and imparting sustainability of household. Shrubs are an important source of fodder in region because of their palatability, higher level of nutrients and availability in lean period. In arid region animals fed more on shrubs and trees than on grasses and pasture legumes (Shankarnarayan, 1984); and assure fodder availability in drought situation (Narain and Kar, 2004). Singh and Rathore (2005) gave detailed account of important fodder shrubs of region (Table 1).

Table 1. Important fodder shrub of hot arid region

	Species	**Family**	**Fodder value (browsed by)**
1	*Acacia jacquemontii* Benth.	Leguminosae	camel and goats
2	*Abutilon fruticosum* Guillem & Perr.	Malvaceae	cattle, sheep, goat , camel
3	*Abutilon indicum* (L.) Sweet	Malvaceae	sheep, goat and camel
4	*Alhagi maurorum* Medic.	Leguminosae	camel
5	*Calligonum polygonoides* L.	Polygonaceae	camel and goat
6	*Capparis decidua* (Forsk.) Edgew.	Capparaceae	camel and goat
7	*Clerodendrum phlomidis* L.f.	Verbenaceae	camel , goat
8	*Crotalaria burhia* Buch-Ham.	Leguminosae	sheep, goat, camel
9	*Grewia tenax* (Forsk.) Fiori	Tiliaceae	goat and camel
10	*Grewia villosa* Willd.	Tiliaceae	goat and camel
11	*Haloxylon salicornicum* (Moq.) Bunge	Chenopodiaceae	camel & sheep
12	*Indigofera oblongofolia* Forsk.	Leguminosae	sheep and camel
13	*Leptadenia pyrotechnica* (Forsk.) Decne	Asclepiadaceae	camel & goat in scarcity
14	*Lycium barbarum* L.	Solaneacea	goat and camel
15	*Mimosa hamata* Willd.	Leguminosae	sheep, goat & camel

16	*Salsola baryosma* (R. &S.) Dandy	Chenopodiaceae	camel
17	*Suaeda fruticosa* (L.) Forsk.	Chenopodiaceae	goat and camel
18	*Ziziphus nummularia* (Burm.f.) Wt.	Rhamnaceae	all animals

Source: Singh and Rathore (2005)

Animal rearers of the region placed leaves of *Ziziphus nummularia*, fruits of *Calligonum polygonoides*, fruiting twigs *of Haloxylon salicornicum* and leaves and pods of *Acacia jacquemontii* as good and phylloclades of *C. polygonoides*, green twigs of *Capparis decidua*, *Heliotropium rariflorum, Indigofera oblongifolia* as medium category of fodder (Singh *et al.*, 2007a). Bhatia (1983) assessed nutritive value (Crude protein, Ether extract, Nitrogen free extarct and ash content) and reported that the fodder of shrubs in general have higher crude protein. Hence, shrubs intake by animals will supplement the protein content of total feed intake. The fodder of shrubs also rich in minerals like Fe (35 - 50 ppm), Mn (10 – 30 ppm), Cu (8 -10 ppm), Zn (35 - 50 ppm), Ca (0.21 - 0.53 %), Mg (0.041 - 0.01 %) and K (0.5 - 0.7%) (Shankar *et al.*, 1988). *Z. nummularia* occurs extensively in rangelands and important woody component of silvi-pastoral system of region. It is a high valued species for its nutritive leaf fodder locally known as '*Pala*'. It has high leaf fodder production potential (125 kg ha^{-1} of dry leaf) and the combined yield of the leaf fodder and grass up to 1000 kg ha^{-1} was reported from the scrub grazing lands with its moderate (14%) density (Kaul and Ganguli, 1963). Muthana (1984) reported 170 kg ha^{-1}fodder yield in alluvial plain receiving 250-300 mm annual rainfall. Shankar and Kumar (1981) assessed its yield from 4 habitats, 5 soil types and 4 land use types and reported 6.36 -169.20 kg ha^{-1}fodder yields. Its leaf fodder contains 11.53 % crude protein, 33.82 % crude fiber and 80.6 % carbohydrates (Singh and Saini, 2002).

Dry phylloclades of *C. polygonoides* locally known as "*lasu*" have good digestibility and is potential top feed species of region (Gaur *et al.*, 1982). A mature plant yields about 1-2 kg dry fodder. Singh (2004) reported its total biomass production was higher on bare dune plantation (29.3 ± 2.2 kg plant $^{-1}$) followed by semi-stabilized dune (16.2 ± 1.0 kg plant $^{-1}$) and flatland plantation (10.6 ± 0.6 kg plant $^{-1}$). It is good fodder for camel and fed after mixing with other feed materials such as straw of *Cyamopsis tetragonoloba* and *Vigna aconitifolia* (Saxena, 1988). Its fodder is nutritive and contains 6.41 % crude protein, 23.13 % crude fiber, 81.99 % total carbohydrates and 62.1 % nitrogen free extract (Bishnoi and Gautam, 1991). *C. polygonoides* @ 30 % with cluster bean fodder significantly improved the intake and utilization of nutrients and overall performance of camel (Saini *et al.*, 2005).

H. salicornicum is an important browsing species and well-known camel fodder. It along with *Lasiurus sindicus* and *Panicum turgudum* grasses forms a very productive grazing land system (Shankar and Kumar, 1984). Phenology of these two groups of plant appears to complement each other with respect to availability of fodder, with forage from grasses during monsoon; the browse from *H. salicornicum* during lean period (December-March). Its fruiting tops contain higher protein (14-19%) and minerals (21-24%) compared to twigs (Mondal *et al.,* 2006). Farmer harvests its fruiting tops in November-December and preserve for further use as fodder. Singh *et al.*(2009) recorded seed (with perianth) yield up to 3.2 kg plant^{-1}and the seed with perianth contains 18.9 % crude protein, 13.89% crude fiber, 1.80 % ether extract, 35.91 % acid detergent fiber, 71.08 % neutral detergent fiber and 24.70 % ash. The seeds could replace the feed concentrate up to 25 and 50 % in cattle and goat, respectively. *Haloxylon recurvum, a* succulent halophytic shrub is also a potential alternate fodder during summer period. Its green foliage is rich in crude protein (13.20%), total carbohydrate (62.9%), crude fiber (20.7%), neutral detergent fiber (58.2%), and acid detergent fiber (25.2%). It could be fed to goats by mixing with groundnut haulm in 1: 3 ratios (Mondal *et al.,* 2005). Dry matter yield up to 4.2 t ha $^{-1}$ with 6666.6 plants ha $^{-1}$ was obtained under rainfed arid conditions (Rathore *et al.,* 2008a).

Sporadic evidences are available about use of *Leptadenia pyrotechnica* as fodder particularly for camel. Abdalla *et al.* (1995) reported that it contains 6.94 % CP with gross energy value of 4.89 k cal g $^{-1}$DM. Fronds of *Opuntia ficus –indica* are succulent, palatable and are relished by cattle, sheep and goat. Its green fodder contains 6.8 % crude protein and 0.16 % P. Its sole feeding provide near maintenance diet. Seeds of *Opuntia* are also nutritive (12.06 % protein) and can be used as animal feed after grinding.

(b) Food:

Different parts of shrubs viz. flower buds of *C. polygonoides* and *C. decidua*; unripe fruits of *C. decidua* and *L. pyrotechnica* ; ripe fruits of *Cordia gharaf, Z. nummularia, Grewia tenax, C. decidua* and seeds of *H. salicornicum* are used as food items in arid region (Singh *et al.,* 2008 b). Unripe fruits of *C. decidua* are consumed as vegetable and pickles and an important ingredient of famous "*Panchkutta*" prepration (Hocking, 1993). Its fruit contains fairly good amount of protein and mineral matter (Chouhan *et al.,* 1986). It contains 1.7 % sugars, 8.6 % protein (Sushila Rai and Rai, 1987). Rai (1987) reported that 15 natural products extracted and isolated from *C. decidua* could be used as emergency food. Its seed is rich source of oil (20.3%) of which 68.6 % is unsaturated fatty acids (Rai and Shekhwat, 2000).

Flower buds of C. *polygonoides* locally known as "*Phogla*" contain 16.87 % crude protein, 71.12 % total carbohydrate and 9.07 % crude fiber (Singh *et al.,* 2005), and used for preparation of local dish called "*Rayta*". Chaudhary and Goyal (2003) prepared different dishes using it; and overall acceptability of these dishes varied from 3.41 to 4.63 on five point scale. One serving of these products (consisting 5 – 30 g of flower buds) provide 3.01–25.23 g protein, 5.18–22.02 g fat, 1.36 – 6.67 g crude fibre, 8.21– 87.23 g carbohydrates, 83.56 – 226.4 K cal energy and 0.43 – 4.39 mg vitamin C.

Tender pods and tuberous roots of *L. pyrotechnica* are used as vegetables (Arora and Pandey, 1996; Singh *et al.,* 2007b); and are supposed to be delicious and nutritious. Its unripe tender pods contain ~ 23.18 % fiber, 9.83 % carbohydrates and 3.13 % protein with energy value of 68.4 kcal/100g. These are also fairly good source of minerals having 317, 226, 156, 125, 3.48 and 39 mg per 100 g of P, K, Ca, Na, Fe and vitamin C, respectively (Goyal and Choudhary, 2005). Fruits of *G. tenax, C. gharaf* and *Z. nummularia* are delicious and relished by inhabitants of the region. Seeds of *H.salicornicum* are used for making bread by mixing with pearl millet during famine period (Shankar, 1988; Singh *et al.,* 2003).

(c) Fuel wood:

Rangeland shrubs are major source of fuel wood in arid region (Rathore *et al.,*2008 b). *C. polygonoides, A. jacquemontii, Z. Nummularia, H. salicornicum* etc. are important fuel wood shrub species of arid region. The calorific value of *C. polygonoides, Ziziphus, Capparis, Salvadora* and *Euphorbia* spp. are 7590, 7900, 7810, 6770 and 7790 B.T.U. lb^{-1}, respectively (Muthana, 1984). Due to excellent fuel quality viz. instantaneous burning and providing intense heat, the wood from *C. polygonoides and A. jacquemontii* are preferred fuel wood shrub of region and extensively used by local gold smith, ironsmiths and in gypsum factories. *A. jacquemontii* after four years of planting produces 163.5 kg biomass plant $^{-1}$ consisting 80.0 kg hard wood and 69 kg twigs on deep (> 100 cm) soils (Mertia *et al.*, 2007).

Fuel wood production of *A. jacquemontii, B. aegyptica, C.polygonoides, C.procera and C.decidua* is 2.50, 6.28, 7.90, 5.11, 3.0 kg plant $^{-1}$, *P. juliflora and Z. nummularia* yields 11.50 and 8.95 kg fuel wood per thicket in 300 mm rainfall zone of arid Rajasthan (Narain et al., 2005).

(d) Medicinal Uses:

Though, shrub constitutes ~ 17 % of desert flora, they constitute 26.7% of total of 131 medicinally important plants of Rajasthan desert (Kumar and Parveen, 2004). Singh *et al.,* (2006) gave detail account of shrubs of medicinal importance in arid Rajasthan. *Withania somnifera* is an important medicinal plant with proven antistress, adaptogenic and general

tonic effect. Indian pharmacopoeias recognized *Commiphora wightii* as an important medicinal plant. Its resin is used for treatment of obesity and hyperlipidemia. Guggulpid a mixture of lipid steroids isolated from its oleo gum resin is a potent hypolipidemic (Kar *et al.*, 2000) and hypocholesterolemic (Dog *et al.*, 2001) agent. It is also known for its anti-inflammatory, antiseptic and astringent properties.

Aloe vera's therapeutic action as alterative, stomachache, cathartic, anti-helminthes is well established. *Cassia angustifolia's* leaves and pods contain anthra-quinone glycosides called sennoside A and sennoside B that are used for preparation of laxatives (Tripathi, 1999). *Calotropis procera /C. gigantea*'s latex has been used for processing medicated thread applied in re-innovated Ayurvedic para surgical techniques of treatment of fistulain- ano and piles (Singh and Sharma, 2005). Root extract of *C. gigantea* showed very strong cyto-toxic effect against KB cells lines in vitro (Ekramul Haque, 1994). Fresh juice of *Alhagi maurorum* is used as laxative, diuretic and expectorant. The oil extracted from its leaves is used to cure rheumatism, asthma and bleeding piles (Singh and Pandey, 1998). *Clerodendrum phlomidis's* root is an important ingredient of "Dashamul" a famous Ayurvedic drug. Decoction of its leaves is used to cure piles (Kumar et al., 2005).Leaves of *C. polygonoides* used as antiemetic and for curing dental and tumor problems (Kumar et al., 2005).The fruits of *C. decidua* has astringent properties and used in cardiac problems and biliousness. The fruits are used to cure stomach problems. Gum of *A. jacquemontii* is used to cure bodyache, joints pain and sunstroke (Singh et al., 2006). The fruits of *Z. nuumularia / Z.mauritiana* have emollient and pectoral properties and recommended in nausea and vomiting; its leaves are used in the treatment of asthma and flower in eye disease (Sinha and Sinha, 2003). It used as antidote, antiseptic, blisters, boils, cough, toothache, eye problems, rheumatism, stomache and tumor (Kumar et al., 2005). The backed fruits of *Opuntia elatior* are used in whooping cough and syrup of the fruit increase secretion of bile (Singh et al., 1990). *Leptadenia pyrotechnica* is used as antiabortion, antidote, anti-fever and to cure arthritis, flatulence, skin irritation, and typhoid (Kumar et al., 2005).

Kumar et al., (2004, 2005) gave comprehensive account of ethno- veterinary importance of shrubs. They reported that *Aerva pseudotomentosa*'s warmed inflorescence is smeared on affected parts of camel's body to cure swelling and inflammation. The leaves of *C. polygonoides* are used to initiate curding process. Gynostegium of *Calotropis procera* is used to kill bacteria and worms in stomach. Roots of *C. decidua* and charcoal mixed with sesame oil are used to cure fractured bones and its fruits feed to goats to care gastric problems. Decoction of stem of *L. pyrotechnica* is used to expel placenta and it is used as

antiarthritic in sheep. Powdered roots of *Lycium barbarum* used to cure respiratory problems in horse.

(e) Fibre*:* Many shrub species like *L. pyrotechnica, C. procera, Crotalaria burhia, Abutilon indicum* etc of the region have fibrous nature and offerscope for the extraction of fiber. *L. pyrotechnica* is an important fiber-yielding shrub (Singh *et al.,* 2007b). It is used for making cordage and ropes. Being fairly resistant against rotting, its rope is used to draw water from wells, particularly in Sindh Provenience of Pakistan, where it is frequently mixed with fiber of *Periploca aphylla* (Watt, 1892). Its fiber has 78.96% cellulose with 40.5 mm mean staple length, 16.05 μ fineness, 90.42 % maturity with 6.36 mercerization value (Jamil, 1970).Owing to high α-cellulose and low lignin contents along with favorable length/breadth ratio of its fiber make it suitable for use in blending with cotton or polyester fiber to produce blended textile yarns and in pulp and paper industries (Mojumdar *et al.*, 2001). *C. procea*'s fiber is used for making cords and ropes. Floss from its seeds is soft and utilized in stiffing the pillows. *Crotalaria burhia* is low branched under shrub. Its stem fiber is traditionally used for making ropes and cordage in the region. In some instance ropes are made by twisting its live plants to tie the bundle of fuel wood (Singh and Pandey, 1998).

(f) Other uses:

(i) Gums and resins: *C. wightii* produces oleo-gum resin that contains 0.37 % essential oils (mainly myrecene, dimyrecene and polymyrecene) and used in pharmaceutical industries, used as incense in religious ceremonies and fixative in perfumes. The gum exudate from *A. jacquemontii* is edible and has traditional medicinal importance.

(ii) Oils and fats: *Balanites aegyptica* is potential source of diosegenin and oil (Ghanim *et al.,* 1980). Its seeds' kernel contains up to 45 % oil, which is suitable for manufacturing of soaps (Khan, 1998).

(iii) Saji: Dried plants of halophytic shrubs like *H. recurvum, Salsola barysoma* and *Suaeda fruticosa* after burning yields "*Saji"* (a mixture of sodium and potassium bicarbonate) which is used in papad (a salty confectionary snack items) making (Singh *et al.,* 2008b).

(iv) Dye and tanning materials: Lawsonia inermis is an important dye-yielding shrub, and used as herbal hair dye and staining body's skin. *A. jacquemontii and Cassia auriculata* are used in small-scale tanneries.

(v) Photosynthetic hydrocarbon: *Calotropis* species are emerged as potential source of photosynthetic hydrocarbon and recognized as substitution of commercial petroleum resources. The hexane extracts of whole plant yield a high density fluid rich in hydrocarbon.

The ratio of C and H in hexane extract is similar to the crude oil, fuel and gasoline (Kalita and Saikia, 2001; Padmaja *et al.,* 2009).

(vi) Bioactive compounds and alkaloids: Variety of bioactive compounds e.g. isophamnetin-3-O-rutinoside, isoharmnetin- 3-O-glycopyranoside, calotroposides (A&B) are isolated from *C. gigantea* (Sen *et al.,* 1992; Kitgawa *et al.,*1992). Alkaloids viz. piperdine alkaloids, aldoltrippierdine hasoline, haloxine and anabasine, pyranone, 5-hydroxy-3- methoxy-4-H-pyran-4-one is isolated from *H. salicornicum* (Gibbson *et al.,* 2000). Sperm dine alkaloids, 14-N- acetyl-isocodoncrpine and 15- N-acetyl-capparasine, n-nonacosane, n-hentiiacontane are isolated from *C. decidua* (Garg *et al.,* 1993).

(vii) Basket and mats: Number of shrubs is used to prepare baskets and mats in small scale rural and cottage industries. *A. jacquemontii, Alhagi maurorum, Grewia tenax, Tephrosia falciformis* etc are widely used for this purpose in the region.

(viii) Thatching materials/agricultural and household articles: the shrubs like *L. pyrotechnica, C. burhia, C. procera, Z. nummularia, C. phlomidis, C. decidua* are used as thatching materials. The wood of *C. decidua, Z. nummularia,* and *C. polygonoides* are used to prepare handle and beams of agricultural implements (plough, spade, sickles) and manufacturing of household articles viz. furniture, curd churners etc.

(B) Ecological significance:

The shrubs have resilient role in arresting soil erosion and combating desertification because of their ability to withstand biotic pressure, conserve soil, and promotion of biodiversity.

(a) Adaptations to edapho- climatic conditions of arid region: The shrubs of the region possess excellent adaptation to survive under moisture limited arid condions viz. reduced transpiration surface, modification of leaves into spines, shedding of leaves and leaflessness (species of *Ziziphus,Calligonum, Capparis*), canopy orientation to minimize radiation load (*C. decidua*). Most of shrubs have extensive and deep root system that helps to extract the moisture and nutrients from more volume of rhizosphere. Shrubs viz. *Suadea fruticosa, H. Recurvum, Salsola baryosma* etc have ability to survive under saline conditions. These species possess considerable plasticity in phenology, which add to their survival under arid climatic conditions.

(b) *Arresting soil erosion and stabilization of sand dunes***:** Shrubs are promising plant type in arresting sand movement (Kar, 2005). Shrub by virtue their low, compact canopy and covering the soil throughout year are effective in arresting soil movement. The *C. polygonoides* is good sand binder .Shrub species viz., *Acacia bivvenosa, Z. mauritiana* and *C. polygonoides* are suitable for flank rows of shelterbelt (CAZRI, 2007). Thorny branches of *Z.*

nummularia, twigs of *C. procera* and whole plant of *C. burihia, L. pyrotechnica* are used for creation of micro wind break. *C. polygonoides* and *A. jacquemontii* are suitable species for the re-vegetation of sand dune. Shrubs e.g. *Z. nummularia, Prosopis juliflora* and *Euphorbia caducifolia* are utilized as fence to restrict biotic interference.

(c) Improvement in soil quality: The organic carbon under canopy of C. *polygonoides, C. burhia, H. salicornicum and A. jacquemontii* was 78.6, 92.9, 115.4 and 130.0 % higher respectively compared to open area (Singh *et al*., 2008 a). *H. recurvum* accumulates high quantity of salt that makes it suitable for phytoremediation of highly saline areas (Ajmal Khan, 2000).

(d) *Creation of favourable microclimate for other vegetation*: *Z. nummularia* creates favorable microclimate for the perennial grasses in scrub grazing lands. Miniature dune formed around the base of *H. salicornicum* congenial growth conditions for other species (Brown and Porembski, 1998). *Haloxylon* and *Salsola* species are suitable for establishing new pasture or for improving degraded pastures in desert and semi-desert of Uzbekistan (Khassanov *et al.,* 1994).

Conservation of Shrub species

The number and diversity of shrubs is declining at alarming rate in the region. Degradation and conversion of their natural habitats, increased mechanization in agriculture (use of tractors for ploughing and sowing), over exploitation, use of unscientific harvesting methods and recurrent drought are important reasons of rapid depletion of diversity of shrubs (Singh *et al.,* 2008b).

The following measures should be undertaken for conservation and management of shrubs:

(i) Collection and characterization of diversity of shrub species and identification of promising strains. Quality assessment and standardization of the main product is also an important step to utilize them on commercial scale.

(ii) Integrated *in-situ* and *ex-situ* conservation of shrub species, in natural habitats by restricting biotic interference and collection of propagating materials and growing of these under protected site to conserve the diversity of species.

(iii) Development and fine tuning of agro techniques viz. propagation methods, pre-treatment of planting materials, sowing methods, spacing, water and nutrient management is important for their sustainable utilization

(iv) Standardization of suitable harvesting techniques having optimum balance between productivity and regeneration with objective to obtain sustained yield should be devised and disseminated among local inhabitants.

(v) Advance research for isolation and characterization of active chemical compounds, the value added products and their commercial utilization should be explored.

(vi) Development and creation of efficient marketing facilities to harness their potential and ensure optimum dividends to growers.

(vii) The major challenge in conservation of biological diversity in arid land lays not so much in the biology of species, rather in social, economic and political arena with which people operate (McNeely, 2003). Active participation of local people should be ensured by creating awareness among them.

(viii) There are three possible ways in which shrubs can be integrated in production system: permanent cover or sole cultivation, shrub as a part of rotation cropping, and shrubs in symbiosis with agriculture. Some of the shrubs e.g. *C. angustifolia, A.vera, L. inermis, H. recurvum etc*. are sole cultivated; for instance, systematically grown *H. recurvum* (Harsh *et al.*,1991) and *L. inermis* (Chand *et al.*, 2005) is profitable in region. Shrubs have been used traditionally as a part of rotation cropping as bush fallow system in region, which apart from restoring soil fertility and protection soil against wind erosion provides fodder and fuel woods. In the third way, shrubs can grow in symbiosis with agricultural crops co-existing with them for mutual benefits. The various possible avenues for integrating shrubs in ALUS are described by Singh *et al.* (2008 b) and are presented in Table 2 with slight modification.

Table 2. Suitable shrub species for different alternate land use systems/ habitats for arid region

System/ habitats	Species
(A) Alternate land use system	
1 Agri-hort system	*Capparis decidua, Cordia gharaf, Ziziphus nummularia, Salvadora oleoides*
2 Agri-silvi system	*Calligonum polygonides, Acacia jacquemontii, Z. nummularia*
3 Live fence/ boundary plantation	*Acacia jacquemontii, Calligonum polygonoides, Clerodendrum phlomidis, Grewia tenax, Lycium barbarum, Maytenus emarginatus, Euphorbia caducifolia*
4 Alternate strip plantations	*Cassia angustifolia, Aloe vera*
(B) Habitats	
1 Sand dune	*Acacia jacquemontii, Calligonum polygonides, Haloxylon salicornicum, Leptadenia pyrotechnica*
2 Sandy interdunal plains	*Calligonum polygonides, Ziziphus nummularia, Clerodendrum phlomidis*
3 Rocky	*Capparis decidua, Commiphora wightii, Cordia gharaf*
4 Salt affected areas	*Haloxylon recurvum, Salsola baryosma, Suaeda fruticosa, Salvadora persica, Tamarix troupii*

Source : Singh et al., 2008 b

References

Abdalla, O. M., A. E. S. Ibrahim, M. B. Aboul Ela, A. M. Soliman and M. A. Ahmed. 1995. Chemical composition of important range plants of United Arab Emirates, Trees and Perennial Plants. *Emirates J. of Agric. Science* 7: 65-86.

Ajmal Khan, M. 2000. Effect of sodium chloride treatments on growth and ion accumulation of the halophyte *Haloxylon recurvum*. *Communication in Soil Science and Plant Analysis* 31: 17-18.

Arora, R. K. and A. Pandey. 1996. *Wild Edible Plants of India: Diversity, Conservation and Use*. NBPGR, ICAR, New Delhi.

Bhandari, M. M. 1990. *Flora of the Indian Desert*. MPS REPROS, New Pali Road, Jodhpur.

Bhati, T. K. and N. L. Joshi. 2007. Farming System for sustainable agriculture in Indian arid zone. In: K. P. R. Vittal, R. L. Srivastava, N. L. Joshi, A. Kar, V. P. Tewari and S. Kathju (eds). *Dryland Ecosystem: Indian Perspective*. CAZRI, and AFRI, Jodhpur. pp. 35-52.

Bhatia, D. R. 1983. Feeding value of common top feeds of semi arid/ arid region for sheep. In: Proc. *Symposium on Top Feed Resources and Their Production, Utilization and Constraints*, CSWRI, Avikanagar, Rajasthan, India, pp. 158-173.

Bishnoi, S. and D. D. Gautam.1991. The reproductive capacity and nutritive value of *Calligonum polygonoides* Linn. *Ann. Arid Zone* 30: 139-144.

Brown, G. and S. Porembski. 1998. Flora and vegetation aspects of miniature dunes in sand – depleted *Haloxylon salicornicum* community in Kuwait *J. of Arid Environments* 37: 461-473.

CAZRI, 2007. *CAZRI Perspective Plan: Vision-2025*. CAZRI, Jodhpur, India.

Chand, K., B. L. Jangid and Y. V. Singh. 2005. Economic scrutiny of henna cultivation. In: M. Singh, Y. V. Singh, S.K. Jindal and P. Narain (eds). *Henna- Cultivation, Improvement and Trade*. CAZRI, Jodhpur. pp. 55-56.

Chaudhary, S. and M. Goyal. 2003. Nutritional composition of phog (*Calligonum polygonoides* L.): a potential arid food in Rajasthan. *Current Agriculture* 27: 53-55.

Chouhan, B. M., A. Duhan and C. M. Bhat. 1986. Nutritional value of ker (*Capparis decidua*) fruit. *J. of Food Science and Technology* 23: 106-108.

Dog, T. L., D. Riley and T. Carter. 2001. An integrative approach to menopause. *Alternative Therapies in Health and Medicine* 7: 45-55.

Ekramul Haque, M. 1994. Studies on the anticancer activity of some crude drug of Bangladesh using MTT assay method. *J. Bioscience* 2: 73-81.

Garg, S. P., S. Rai and S. Rai. 1993. Chemical examination of medicinal desert plant, *Capparis decidua*. Part I, Isolation and mass spectral studies of n-nonacosane and nhentriacontane from its flowers. *Current Agriculture* 17: 97-99.

Gaur, D. D., G. R. Purohit and C. S. Mathur. 1982. A note on the formulation of least cost balanced ration for the Indian desert. *Ann. Arid Zone* 21:263-265.

Ghanim, A., I. Jayaraman, H. A. Khan and V. A. Amalraj. 1980. *Balanites roxuburghii*: Fruit as a source of Diosgenin. *Indian J. Pharmaceutical Sciences* 42: 149-150.

Gibbson, S., B. J. Denny, S. Ali-Amine, K. T. Mathew, B. W. Skelton, A. H. White and A.I. Gray. 2000. NMR spectroscopy, X-ray crystallographic and molecular modeling studies on a new pyranone from *Haloxylon salicornicum*. *J. of Natural Products* 63:839- 840.

Goyal, M. and S. Choudhary. 2005. Nutritional composition of kheep (*Leptadenia pyrotechnica*) a dry land product. Abstract In: *National Seminar on Commercialization of Horticulture in Non-traditional Areas* (Feb.5-6, 2005), CIAH, Bikaner.

Harsh, L. N., I. C. Gupta and K. A. Shankaranarayana. 1991. *Kala lana* thrives on water soaked salt flats. *Indian Farming* 40: 7.

Hocking, D. 1993. *Trees for Dryland.* Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi.

Jamil, N. A.1970. Studies on physio-chemical characteristics of Kheep fibre (*Leptadenia pyrotechnica*). M.Sc. Thesis, University of Agriculture, Fasailabad, Pakistan.

Kalita, D. and C. N. Saikia. 2001. *Calotropis procera* and *Nerium indicum*: two potential plant sources of energy and hydrocarbon. *Indian J. of Chemical Technology* 8:20-24.

Kar, A. 2005. Role of shrubs in wind erosion control. In: P. Narain, M. Singh, M. S. Khan and S.Kumar (eds). *Shrubs of Indian Arid Zone*. CAZRI, Jodhpur. pp.121-124.

Kar, A., R. Chander, S. K. Mathur, B. K. Chaudhary, A. K. Khanna and A. K. Rastogi. 2000. Lipid lowering and anti-oxidant activities of some herbal preparations. *Ethnobotany* 12: 86-90.

Kaul, R. N. and B. N. Ganguli. 1963. Fodder potential of *Ziziphus* in scrub grazing lands of arid zone. *Indian Forester* 89: 623-630.

Khan, H. A.1998. Products of economic importance from arid zone plants. In: A. S. Faroda, and M. Singh (eds). *Fifty Years of Arid Zone Research in India*. CAZRI, Jodhpur . pp.121-126.

Khassanov, O. K., T. Rachimova and S. F. Tadzhiev. 1994. Biological characteristics of newly cultivated fodder plants for pasture of the arid zone in Uzbekistan. *Genetic Resource and Crop Evolution* 41: 125-131.

Kitgawa, I., R. S. Zhang, J. D. Park, N. I. Back, Y. Yakeda and M. Yoshikawa. 1992. Indonesian Medicinal Plants I. Chemical Structure of Calotrposides A and B, two new oxypregene-oligoglycosides from roots of *Calotropis gigentia* L. (Asclepiadacea). *Chemical Pharmaceutical Bulletin* 40: 2007-2013.

Kumar, S. and F. Parveen, 2004. Traditional Ethanomedicinal plants in the Indian Thar: Their status in nature and possibilities of their cultivation and trading. Final Report of DST project.

Kumar, S., F. Parveen and S. Goyal 2004. Ethanoveterinary plants in the Indian arid zone. *Ethnobotany* 16: 91-95.

Kumar, S., F. Parveen, S. Goyal and A. Chauhan. 2005. Ethnobotany of shrubs of arid Rajasthan. In: P. Narain, M. Singh, M. S. Khan and S. Kumar (eds). *Shrubs of Indian Arid Zone*. CAZRI, Jodhpur. pp. 15-26.

Mc Neely, J. A. 2003. Biodiversity in arid regions: values and perceptions. *J. of Arid Environments* 54:61-70.

Mertia, R. S., R. Prasad and B. K. Kandpal. 2007. Growth and biomass production potential of *Acacia jacquemontii* Benth. in different soil conditions in hot arid region of India. *Ann. Arid Zone* 46: 183-187.

Mojumdar, P., S. B. Mondal, S. Mukhopadhyay and K. K. Sen. 2001.Chemical characterization of Khimp fibre (*Leptadenia pyrotechnica*). *Journal of Scientific and Industrial Research* 60: 675-677.

Mondal, B. C., J. P. Singh and R. K. Beniwal, 2006. Chemical composition of desert shrub lana (*Haloxylon salicornicum*) used as animal feed in western Rajasthan. *Ann. Arid Zone* 45: 91-92.

Mondal, B. C., J. P. Singh, R. K. Beniwal and V. S. Rathore. 2005. Palatability of Khara Lana (*Haloxylon recurvum*) in goats. *Indian Journal of Small Ruminant* 11: 219-220.

Muthana, K. D. 1984. Selection of species for fuel wood plantation in arid and semi-arid areas. In: K. A. Shankarnarayan (ed). *Agroforestry in Arid and Semi-arid Zones*, CAZRI, Jodhpur (India). pp.243-252.

Narain P., S. Kumar, R. K. Goyal and J. C. Tewari. 2005. Shrubs for arid land management. In: P. Narain, M. Singh, M. S. Khan and S. Kumar (eds). *Shrubs of Indian Arid Zone*. CAZRI, Jodhpur. pp. 115-120.

Narain, P. and A. Kar. 2004. *Drought in Rajasthan: Impact, Coping Mechanism and Management Strategies*. Arid Agro-eco System Directorate, CAZRI, Jodhpur, India.

Padmaja, K. V., N. Atheya, A. K. Bhatnagar, K. K. Singh. 2009. Conversion of *Calotropis procera* biocrude to liquid fuels using thermal and catalytic cracking. *Fuel* 89: 780-785.

Rai, S. and N. S. Shekhwat. 2000. Biotechnological studies on *Capparis decidua*. In: *National Symposium on Prospects and Potential of Plant Biotechnology in India in the 21st Century and Annual Meeting of PTCA* (I). 18-21 October, p.56.

Rai, S.1987. Chemical examination of edible plants in Rajasthan desert with special reference to Capparidaceae. *Current Agriculture* 11: 15-23.

Rathore, V. S., J. P. Singh and R. K. Beniwal. 2008a. Growth and productivity of rainfed khara lana (*Haloxylon recurvum*) under hot arid conditions of north-western Rajasthan. *Indian Journal of Agricultural Sciences* 78:712-715.

Rathore, V. S., J. P. Singh and R.K. Beniwal 2008 b. Sushak barani khestron main jhariyon se indhan. *Kheti* 61: 20-21 (In Hindi).

Saini, N., B. D. Kiradoo, A. Bhardwaj and M. S. Sahani. 2005. Effect of phog (*Calligonum polygonoides*) feeding in combination with guar chara on intake and utilization of nutrients in camel. In: *Compendium of National Seminar on Conservation, Processing and Utilization of Monsoon Herbage for Augmenting Animal Production* (Dec.17-18, 2005) Bikaner.

Saxena, S. K. 1988. 'Lasu' an exclusive top feed for camels during drought. *Indian Farming* 38:9 & 19-20.

Sen, S., N. P. Sahu and S. B. Mahto. 1992. Flavonol glycosides from *Calotropis gigantean*. *Phytochemistry* 31:2919-2921.

Shankar, V. 1988. Life support species in the Indian Thar Desert. In: R.S. Paroda, P. Kapoor, R. K. Arora and Bhag Mal (eds). *Life Support Plant Species: Diversity and Conservation*. NBPGR, New Delhi. pp. 37-41.

Shankar, V. and S. Kumar. 1984. Ecological distribution of *H. salicornicum* (Moq.) Bunge as an aid to the reconstruction of the lost courses of the Saraswati River in the Indian desert. *Tropical Ecology* 25:227-238.

Shankar, V., Kumar, S. 1981. Distribution pattern of Jharber (*Zizyphus nummularia*) and its leaf fodder and bush-wood production on different habitats and land use types. Forage Research 7, 119-126.

Shankar,V., S. Kumar and R. K. Tyagi. 1988. Grazing resources of semi arid and arid regions, In: Panjab singh (ed.) *Pasture and Forage Crops Research*- A state of Knowledge Report. RMSI, IGFRI, Jhansi, pp 63-85.

Shankarnarayan, K. A. 1984. *Agroforestry in Arid and Semi-arid Zone*. CAZRI, Jodhpur.

Singh, G. 2004. Influence of soil moisture and nutrient gradient on growth and biomass production of *Calligonum polygonoides* in Indian desert affected by surface vegetation. *Journal of Arid Environments* 56: 541-558.

Singh, G. P. and N. Saini. 2002. Role of anaerobic fungi in fibre digestion and its special significance in camel nutrition. *Indian Dairyman* 54: 64-68.

Singh, J. P, M. L. Soni and V. S. Rathore. 2008a. Role of shrubs in rehabilitation of degraded lands in hot arid region. In: Prasad, S. N., R. K. Singh, A. Kumar, A. K. Parandiyal, S. Ali, J. Somasundaram, B. K. Sethy and V. N. Sharda (eds). *Natural Resources Management for Sustainable Development in Western India*, Allied Publishers, Pvt. Ltd. Delhi. pp. 169-170.

Singh, J. P. and V. S. Rathore. 2005. Potential herbage resources and their availability in arid region. In: *Compendium of National seminar* on *Conservation, Processing and Utilization of Monsoon Herbage for Augmenting Animal Production* (Dec.17-18 2005) Bikaner.

Singh, J. P., B. C. Mondal and R. K. Beniwal. 2005. Phog (*Calligonum polygonoides* L.): underexploited shrubs with food potential in western Rajasthan. In: *National Seminar* on *Commercialization of Horticulture in Non-Traditional Areas* (Feb 5-6, 2005) Bikaner.

Singh, J. P., B. K. Mathur and V. S.Rathore. 2009. Fodder potential of Lana (*Haloxylon salicornicum*) in hot arid region. *Range Mgmt. & Agroforestry* 30: 34-37.

Singh, J. P., M. L. Soni, R. K. Beniwal, B. C.Mondal and S. Dasora. 2003. Lila Lana- Pashmi Rajasthan ki aanban. *Parti Bhumi Samachar*, April-June, 20-22 (In Hindi)

Singh, J. P., V. S. Rathore and R. K. Beniwal. 2007a. Sushak khestron main chara apurti ka ek vikalap- jharinya. *Kheti* Feb, 59 (11): 6-10. (In Hindi).

Singh, J. P., V. S. Rathore and R. K. Beniwal. 2006. Perennial medicinal plants for rainfed farming systems in arid region. *Indian Journal of Arid Horticulture* 1:8-14.

Singh, J.P., V. S. Rathore and R. K. Beniwal. 2007b. Kheep (*Leptadenia pyrotechnica*): potential rangeland shrub of western Rajasthan, India. *Journal of Plant Genetic Resources* 20:63-67.

Singh, J.P., V. S. Rathore and R. K. Beniwal. 2008b. Diversity and conservation of shrubs of hot arid region of Rajasthan, India. In: N. P. Singh and P. K. Chhonkar (eds). *Biodiversity for Sustainable Development*. Samakriti, New Delhi.pp.51-71.

Singh, R. H and G. G. Sharma. 2005. Arid shrubs for human health. In: P. Narain, M. Singh, M. S. Khan and S. Kumar (eds.). *Shrubs of Indian Arid Zone*. CAZRI, Jodhpur. pp. 39-43.

Singh, U., A. M. Wadhwani and B. M. Johri. 1990. *Dictionary of Economic Plants of India*. ICAR, New Delhi.

Singh, V. and R. P. Pandey. 1998. *Ethnobotany of Rajasthan, India*. Scientific Publishers, Jodhpur.

Sinha, R. K. And Sweta Sinha. 2003. *Ethnobiology*. Surabhi Publication, Jodhpur.

Sushila Rai and S. Rai. 1987. Oils and fats in arid plants with particular reference to *Capparis decidua*. *Transactions of Indian Society of Desert Technology* 12: 99-105.

Tripathi, Y. C. 1999. *Cassia angustifolia* -a versatile medicinal crop. *International Tree Crop Journal* 10: 121-129.

Watt, G. 1892. *A Dictionary of Economic Products of India*. Vol VI, London: W. H. Allen, 8-9.