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Distribution, associated vegetation, conservation and utilization of *Grewia tenax*: an important underutilized shrub species of the Thar Desert of India

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Abstract

Grewia tenax locally known as '*Gangerun*', is an important multipurpose underutilized shrub and potentially threaten species of the Thar Desert of India. Owing to its importance, naturally available germplasm was collected and evaluated for its sustainable utilization in future. Data on individual mother plant, seed characters and soil profile were investigated. Habitat occurrence of *G. tenax* was found in patches with dominant association of *Euphorbia caducifolia* across the four districts of western Rajasthan. Individual plant on unprotected area portrayed far lower average height (0.95 m) and canopy area (1.75 m^2) than protected area (2.63 m and 13.89 m^2) signifying level of browsing pressure on this species in Jaisalmer. Soil samples belonging to Pali region have high organic carbon and low electrical conductivity content than Jaisalmer and Jodhpur. The statistical analysis of seed characters revealed the presence of high coefficient of variation (%) in 100-seed weight (HSW; 27.36) followed by seed length (SL; 8.06) and least in seed breadth (SB; 5.85). The range and mean values of HSW, SL, SB and length:breadth ratio (LBR) were (2.02–7.00 and 3.34 g), (4.36–6.15 and 5.36 mm), (3.73–4.68 and 4.25 mm) and (1.11–1.44 and 1.27), respectively. Significantly positive correlation was observed between SL and LBR (0.73) followed by HSW and SL (0.66). Along with these findings, its economic importance, utilization and conservation are detailed in this paper as to hasten further research on its various aspects for its successful conservation and utilization.

Keywords: browsing pressure, Gangerun, iron supplement, rangeland, underutilized fruits

Introduction

India has around 31.7 million ha hot arid region of the total geographical area comprised with regions from Rajasthan, Gujarat, Punjab, Haryana, Maharashtra, Karnataka and Andhra Pradesh. About 62% of hot arid region lies in western Rajasthan carrying 107 humans and 137 livestock per km^2. Overexploitations of resources and frequent droughts of this region have degraded 75% areas which are also affected by wind and water erosion. Vegetation of the Thar Desert is a unique blend of perennial grasses, hardy shrubs and scattered trees. Shrubs comprise of 17% of the total floristic composition of arid zone of India and constitute of 26.7% of the total of 131 medicinally important plants in western Rajasthan (Kumar and Parveen, 2004).

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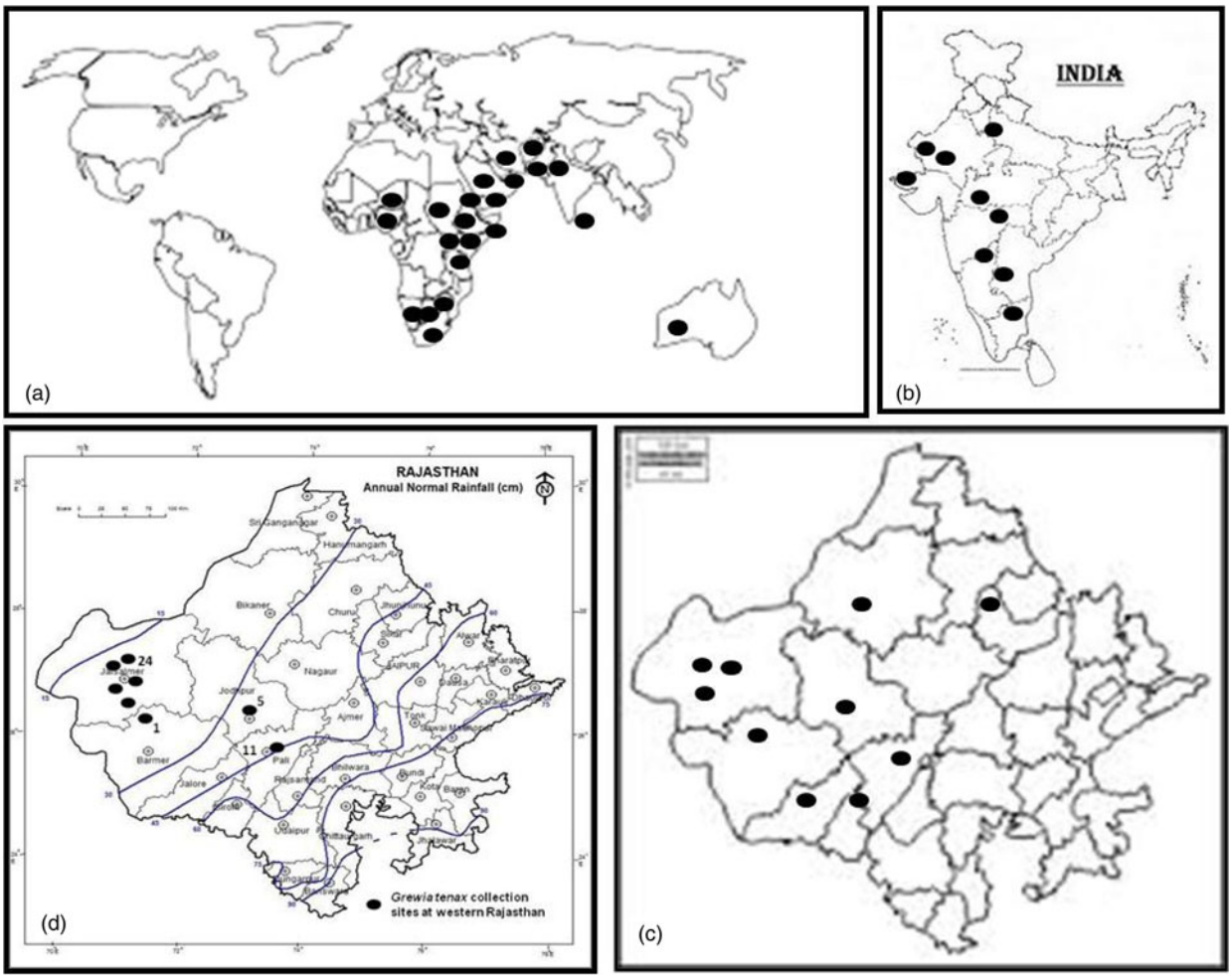

Fig. 1. Distribution of *Grewia tenax* at (a) global, (b) national, (c) regional level and (d) germplasm collection sites at western Rajasthan on the basis of rainfall gradients.

Important underutilized arid shrubs are: Bawli (*Acacia jacquemonti* Benth.), Phog (*Calligonum polygonoides* L.), Kair [*Capparis decidua* (Forsk.) Edgew.], Guggal [*Commiphora wightii* (Arnott) Bhandari], Gangerun [*Grewia tenax* (Forsk.) Fiori], Lana [*Haloxylon salicornicum* (Moq.) Bunge ex Boiss.], Jhil [*Indigofera oblongifolia* Forsk.], Khimp [*Leptadenia pyrotechnica* (Forsk.) Decne.], Morali [*Lycium barbarum* L.] and Jharber [*Ziziphus nummularia* (Burm. f.) Wt.]. Among these, *G. tenax* is one of the important multipurpose underutilized shrub of the arid zone which has much potential as food, fodder/browse, medicine, fibre and fuel wood. It belongs to family 'Tiliaceae' and is locally known as 'Gangerun'. It is a multi-stemmed shrub that grows up to 3 m in height. It has an ash-grey coloured stem, creamy-white coloured flowers and orange-yellow coloured drupe. Flowering and fruiting is common in months of August to November.

The genus *Grewia* is native to Africa, Asia and Australia and consists of 150 species of old world climbers, shrubs or trees. About 40 species occur in India. *Grewia tenax* is a tropical deciduous shrub with wide distribution in semi-arid and arid regions of the world (Fig. 1). Its presence is noticed as irregular, patchy population on rocky/gravelly habitats in different states of India, especially in western Rajasthan.

Although it has seed dormancy, normally it is propagated through seed. Its leaves and fruits are browsed by goat and the fruits are used to cure anaemia in children owing to its palatability and high iron content, respectively. It is not only adapted to high temperature and dry conditions, but has deep roots which stabilize sand dunes (Gebauer *et al.*, 2007a). Further, it plays vital role in rehabilitation of wastelands if grown along with trees (Singh and Kumar, 2003). The gathering and marketing of this indigenous fruits can significantly improve the livelihoods of the predominantly subsistence-orientated rural population in many parts of western Rajasthan. Therefore, the present investigation have been made to describe the details on associated vegetation, propagation, effect of rainfall and existing browsing pressure by small ruminants on distribution and

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growth pattern, variation on seeds and fruits, economic importance and its utilization, potential threats, conservation and future prospects of *G. tenax*, a well-adapted shrub species to harsh environmental conditions of Thar Desert of India, so as to hasten further research on its various aspects for its successful conservation and utilization.

Materials and methods

Field survey and collection

Field surveys were conducted in Barmer, Jaisalmer, Jodhpur and Pali districts of western Rajasthan for the occurrence of species *G. tenax* in three consecutive years (2013, 2014 and 2015) during the fruiting stage in the months of August to November. While conducting field survey, the passport information of collection site, associated vegetation and conservation status of species were noted. Besides this, primary information on the ethnobotanical uses of species was also collected from the local people using a semi-structured questionnaire, house hold survey and interviews of the elder people of the family. The information on economic importance and ethnobotanical/medicinal uses were also added through scrutiny of available literature on this species. Soil samples were taken from collection sites and analysed for pH, electrical conductivity (EC), organic carbon (OC), available phosphorus and available potassium at ICAR-Central Arid Zone Research Institute, Jodhpur. Soil pH and EC (dS/m) were determined in the supernatant solution of 1:2 soil/water ratio (w/v) using a pH meter and conductivity meter (Jackson, 1973), respectively. OC (%), available phosphorus (kg/ha) and available potassium (kg/ha) in soil were determined by Walkley and Black's rapid titration method (Walkley and Black, 1934), Olsen's method (Olsen *et al*., 1954) and flame photometer methods (Jackson, 1973), respectively. Germplasm of *G. tenax* as fruit samples collected from different sites across rainfall gradients and GPS coordinates of these sites were also noted using GARMIN-etrex. These sites include both protected and unprotected (open) areas. The mother plant (from which seeds were collected) characters such as plant height and canopy areas were also observed.

Seed extraction, germination and seed characterization

The extraction of seeds from collected fruits involves soaking in water for overnight, removal of fibrous pulp with running water and drying at room temperature. Initially, seeds were sown in poly-bags prepared with soil mixture of sand, silt and FYM (1:1:1) at nursery in ICAR-Central Arid Zone Research Institute, Regional Research Station, Jaisalmer (India) for germination study. For seed characterization [seed length (SL), seed breadth (SB), length:breadth ratio (LBR) and 100-seed weight (HSW)], 50 seeds per accession were used except HSW. Data recorded were subjected to statistical analysis such as descriptive statistics and Pearson's correlation analysis by using the software package 'PAST3' (Hammer *et al*., 2001a).

Results and discussion

Field survey, collection and distribution pattern

During field survey, its distribution was found in different natural habitats of districts located in western Rajasthan such as Barmer, Jaisalmer, Jodhpur and Pali. Whereas, literature and herbarium specimens indicated its occurrence on Bikaner, Ganganagar, Jalore, Jhunjhunu, Sikar and Sirohi districts of Rajasthan also. The passport data of collected *G. tenax* fruit samples were presented in online Supplementary Table S1. During the field survey, its occurrence was observed at the following range of latitude, longitude and altitude (25.70174–27.07518N°, 70.80644–73.56725E° and 490–1310 ft, respectively). The distribution pattern of collected samples of *G. tenax* on the basis of habitat, district, altitude and rainfall gradient was presented in Fig. 2. With respect to habitat (%), majority of collection belongs to wasteland (44) followed by scrubland (34) and arable (22). Around 59% of collection belongs to the district Jaisalmer with altitude ranged from 751 to 1000 ft having rainfall gradient of <200 mm.

Basic analysis of soil samples

The basic analysis of 35 soil samples collected from different collection sites representing diverse habitats and rainfall gradient (ranging from 100 to 450 mm) of *G. tenax* germplasm revealed significant variation for pH, EC, available phosphorus, OC and available potassium (Table 1). The range and mean values of pH, EC, available phosphorus, OC and available potassium were (7.03–8.76 and 8.19), (0.09–1.01 and 0.19 dS/m), (1.12–31.36 and 8.40 kg/ha), (0.03–0.97 and 0.31%) and (67.5–798.75 and 304.98 kg/ha), respectively. Soil samples belonging to Pali region have high OC and low EC content than Jaisalmer and Jodhpur regions. Further, 71% (27) and 55% (21) of soil samples of *G. tenax* have <10.0 kg/ha of available phosphorus and 8.0–8.5 of pH, respectively.

Associated vegetation, survival and existing browsing pressure

Its association found with other species (online Supplementary Fig. S1) also noticed during field survey

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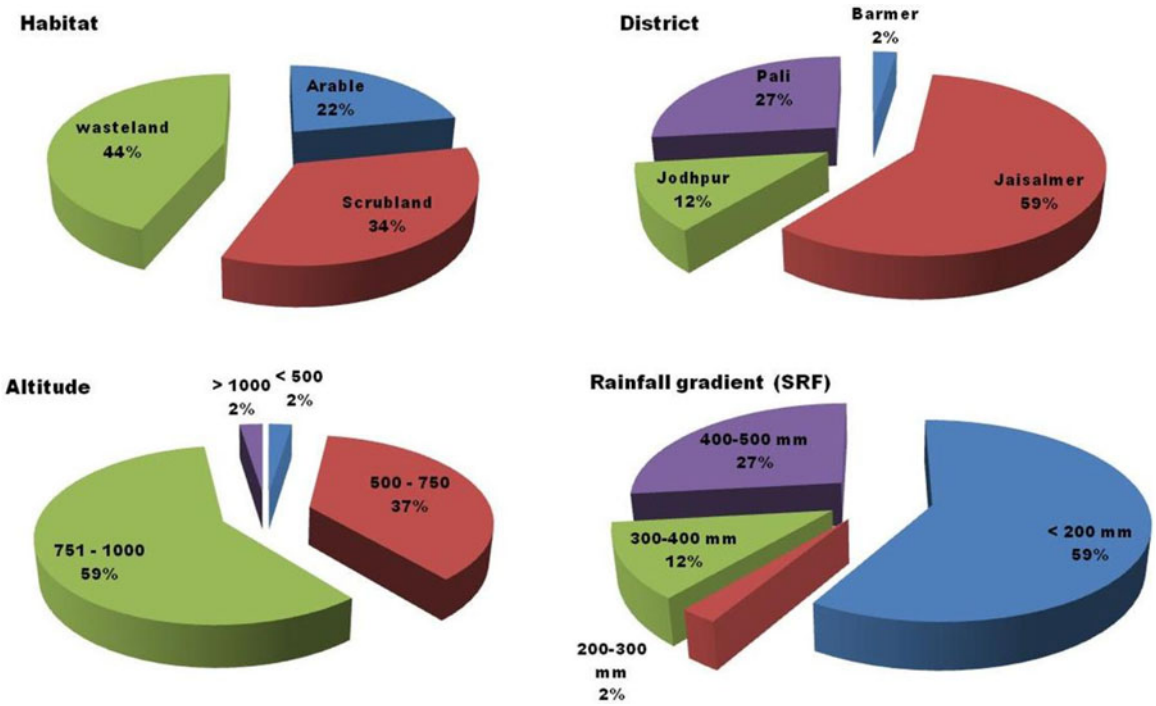

Fig. 2. Distribution pattern of collected germplasm of *Grewia tenax* on the basis of habitat, district, altitude and rainfall gradient.

Table 1. Range of variation on soil parameters of soil samples collected from different collection sites of *Grewia tenax*

	pH	EC (dS/m)	Av. P (kg/ha)	OC (%)	Av. K (kg/ha)
Average	8.19	0.19	8.40	0.31	304.98
Minimum	7.03	0.09	1.12	0.03	67.50
Maximum	8.76	1.01	31.36	0.97	798.75

in western Rajasthan are: Pilu (*Salvadora oleoides*), Aak (*Calotropis procera*), Lana (*H. salicornicum*), Danda-thor (*Euphorbia caducifolia*), Jhil (*I. oblongifolia*), Guggal (*C. wightii*), Jharber (*Z. nummularia*), Kair (*C. decidua*), Khejri (*Prosopis cineraria*), Kumat (*Acacia senegal*) and Khimp (*L. pyrotechnica*). The species such as *S. oleoides* and *C. decidua* were commonly present in collection sites of *G. tenax* followed by *A. senegal* and *Z. nummularia* at Jaisalmer district. This analysis of associated vegetation of *G. tenax* provides the clue on what kinds of protection could be possible for its better survival in natural habitats especially in open area like Jaisalmer region of the Thar Desert of India. The kind of protection provided by *E. caducifolia* (owing to its thorny/bushy nature) to *G. tenax* from existing browsing pressure from livestock in Jaisalmer area played an important role in conservation of *G. tenax* (Venkatesan *et al.*, 2014). Other alternative way of protection available to *G. tenax* in open area is live fence of cultivated field.

The status of existence and survival of *G. tenax* in western Rajasthan was assessed during the survey and collection of germplasm by measuring plant height and canopy area. The nature of occurrence of population of *G. tenax* is varied from occasional to frequent. Browsing pressure existing in rangeland by goat made its survival under questionable by leaving only stem at ground level (online Supplementary Fig. S2). It was evident by comparing the data obtained on individual plants of *G. tenax* from protected area with unprotected one (Table 2). Average height (m) and canopy area (m^2) of individual plant on unprotected area were far lower (0.95 and 1.75) than protected area (2.63 and 13.89), which indicated the level of browsing pressure existing on species in Jaisalmer area (Venkatesan *et al.*, 2014). Among protected area, they were comparatively higher in Jodhpur (3.35 and 6.08) and Pali regions (3.62 and 9.10) which might be owing to higher annual rainfall gradient from below 150 mm (Jaisalmer) to 400 mm (Pali) along with high OC content of Pali region than Jodhpur and Jaisalmer.

Propagation

Two eco-physiological phenomena of arid climate such as drought and salinity stress are inter-related and it causes many problems for seed germination and plant growth inducing physiological and biochemical disorders in metabolic processes. Despite its great ability to withstand

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Table 2. Variation on plant height and canopy area of *Grewia tenax* under protected and unprotected area

	Plant height (m)			Canopy area (m^2)		
Area/characters	Min.	Max.	Ave.	Min.	Max.	Ave.
Jaisalmer (unprotected)	0.55	1.59	0.95	0.85	2.69	1.75
Jaisalmer (protected)	2.10	3.20	2.63	5.72	24.6	13.89
Jodhpur (protected)	2.75	3.75	3.35	2.83	9.92	6.08
Pali (protected)	1.84	5.75	3.62	4.15	17.71	9.10

drought and high temperature, the wild stands of the species are sparse. Seed dormancy is a typical feature of dry land tropical woody species for seed survival under unfavourable climatic conditions for a number of years in the soil seed bank. On view of this, no and poor germination of seed were observed among *G. tenax* germplasm collection over 2 years period with different seed treatments under study might be owing to its prolonged physiological dormancy [the most common form of dormancy found in seeds (Baskin and Baskin, 1998; 2003)]. But little is known about how to increase its propagation and early seedling establishment under the harsh conditions (Saied *et al.*, 2007). Another study on *G. tenax* indicates that seeds of it possess non-deep physiological dormancy, which can be overcome by heat stratification (Sohail *et al.*, 2009). The importance of age of collection (1-year-old seeds showed higher germination than 2, 4 and 7 months old seeds of collection) was also reported (Saleem *et al.*, 2012b). It was reported that the germination of *G. tenax* is very difficult and older seeds germinate better (Vogt, 1995). The delay of germination can be attributed to seed dormancy, which might be a result of immaturity of the seeds or the unfavourable environmental conditions for germination. On the other hand, the 4-year-old seeds (collected in the year 2011 from farm area of Jaisalmer station) showed 33–77% germination under different seed treatments (Kumawat *et al.*, 2017).

Grewia tenax is traditionally grown from seeds and information on the vegetative propagation is currently unavailable. Vegetative propagation plays a key role in domestication and improvement programmes of any tree species as a means of a large-scale multiplication of superior genotypes owing to the disadvantage of genetic variability of seedlings raised through seed propagation. Although, significant stimulation of rooting reported with the concentration of 1000 or 1500 ppm of IAA or IBA in promoting root formation in stem cuttings of *G. tenax* (El-Siddig *et al.*, 2005), only initial sprouting (60–70%) observed in stem cuttings of our collections treated with IBA (500 ppm) under semi-shade nursery showed no further establishment of plants after sprouting. The cause behind this poor establishment might be due to low relative humidity and hot-dry windy conditions of arid region.

Seed characterization

Characterization of collected germplasm of *G. tenax* revealed considerable variations in seed characteristics and correlation among them. The statistical analysis of seed characters (Table 3) revealed the presence of high coefficient of variation (CV in %) in HSW (27.36) followed by SL (8.06) and least in SB (5.85). The range and mean values of important seed characters of *G. tenax* such as HSW (g), SL (mm), SB (mm) and LBR were (2.02–7.00 and 3.34), (4.36–6.15 and 5.36), (3.73–4.68 and 4.25) and (1.11–1.44 and 1.27), respectively. The similar kind of results for HSW, SL and SB of the *G. tenax* collected from Jaisalmer region was reported by Kumawat *et al.* (2017) as 9.76 g, 5.66 ± 0.22 mm and 4.68 ± 0.13 mm, respectively. Further, it was also comparable with 1000-seed weight (g) of *G. tenax* collections from Kachch region, which ranged from 60.3 to 150.7 with an average of 113.8 (Dev *et al.*, 2017). This higher range and mean of *G. tenex* seeds of Kutch region might be owing to the effect of climatic factors of that region, where the annual rainfall (326 mm) is higher than the Jaisalmer (<165 mm). Pearson's correlation study (Table 4) revealed the significantly positive correlation between SL and LBR (0.73) followed by HSW and SL (0.66). HSW showed significantly less positive correlation with SB and LBR. Non-significant negative correlation was observed between LBR and SB.

Reproductive behaviour

Usually, the flowering and fruiting occur in *G. tenax* during the months of August to November and also depend on the occurrence of rainfall events of the region. The nature of flower is hermaphrodite and is pollinated through insects, especially by honey bees. Although, the pollen–ovule ratio of populations of *G. tenax* and *G. erythraea* in Pakistan is facultative xenogamous (Cruden, 1977), the study by

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Table 3. Variation among seed characteristics of collected germplasm of *Grewia tenax*

Seed characters (observed on 50 seeds except 100-seed weight)	Range		Mean	SE	Variance	SD	CV
	Min.	Max.					
Hundred-seed weight (g)	2.02	7.00	3.34	0.14	0.85	0.92	27.36
Seed length (mm)	4.36	6.15	5.36	0.07	0.19	0.43	8.06
Seed breadth (mm)	3.73	4.68	4.25	0.04	0.06	0.25	5.85
Length:breadth ratio	1.11	1.44	1.27	0.01	0.01	0.09	7.15

Table 4. Correlation among seed characteristics of collected germplasm of *Grewia tenax*

	HSW (g)	SL (mm)	SB (mm)	LBR
HSW	–	–	–	–
SL	0.66	–	–	–
SB	0.49	0.53	–	–
LBR	0.37	0.73	−0.19	–

HSW, 100-seed weight; SL, seed length; SB, seed breadth; LBR, length:breadth ratio.

Hashmi and Qaiser (1990) showed these populations breeding behaviour as amphimetric and inbreeders.

Economic importance and utilization

It is a multipurpose arid shrub which has much potential as food, fodder, medicine, fibre and fuel wood. It has vital role in livelihood and rehabilitation of rangelands of hot arid zone of India owing to its characteristic features such as: iron content of fruit, browse/fodder value of leaves, ethnomedicinal/botanical value, etc. Edible fruits of *G. tenax* are nutritionally balanced (fibre – 20.5%; protein – 7.7%; lipids – 1.7% and carbohydrate – 66%) and rich in iron and calcium. The drupes also contain amino acids, mineral elements (K, Ca, Mn, Fe, Cu and Zn), tannin and pectic substances. Because of its high iron content (7.4 mg/100 g), the fruits are used by local peoples as an iron supplement for anaemic children and its iron content is 20–30 times more than orange fruit (Freedman, 1998). In western Rajasthan, it is an important source of browse material for livestock especially small ruminants such as sheep and goat during the dry period and its high palatability to them also has been reported in Oman (Miller and Morris, 1988; Von Maydell, 1990). It is slightly palatable at the end of dry seasons owing to its hardy and dried twigs. The roots and leaves of *G. tenax* were used for treatment of fracture and stone problem/urticaria in the Thar Desert of India (Kumar and Parveen, 2004). The decoction of wood is given in cough and pains (Chopra *et al*., 1956; The wealth of India, 1956; Kirtikar and Basu, 1975; Badshah *et al*., 2006). It is also used to cure stomach upset, skin and intestinal infections, cough, fever, diarrhoea, dysentery, jaundice, rheumatism and have mild antibiotic properties. Leaves and twigs are an important component of folk medicine for the treatment of trachoma, tonsillitis and infections. Its bark is used to make ropes for binding purposes in house construction. The gathering of stem, making and marketing of implements made from them like chowkney/baskets (online Supplementary Fig. S2) significantly improve the livelihoods of the predominantly subsistence-orientated rural population in many parts of western Rajasthan. Its occurrence on rocky/gravelly areas and its ability to grow in various soil types made suitable to introduce it for rehabilitation of the degraded rangelands or to utilize in Alternate Land Use Systems (ALUS) such as agri-silvi-pasture, silvi-pasture, horti-pasture or even as sole plantation. Due to its deciduous nature, it could be able to tolerate seasonal drought and/or temperature up to 50°C. If it is grown along with the trees and grass, it plays effectively for rehabilitation of wastelands and rangelands of arid zone through improving the carrying capacity and productivity of these lands.

Threats and conservation

During field survey in western Rajasthan, it was found to be a heavily grazed condition by the high number of free roaming domestic animals, which indicates the high palatability of the species and the similar condition was previously reported by Gebauer *et al*. (2007b) in Oman also. Its very scarce occurrence in wild and natural condition at different habitats of western Rajasthan combined with high palatability could lead to the local extinction of the species and also to the loss of this valuable genetic resource of fruit species to the biodiversity of arid region. But due to overgrazing, debarking by animals, encroachments, unsustainable utilization and other developmental activities, this persistent medicinal plant species is on the verge of extinction. The existing livestock population per unit area in western Rajasthan and combination of non-availability of fodder and its sources in the region laid highest browsing

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pressure on this species which finally led to overgrazing. This species is also included in the list of important threatened medicinal plant species of Jharkhand. In Sudan, its fruits are identified in trade as wild species of medicinal and aromatic plants. These wild fruit tree species are often referred to as neglected or underutilized but their genetic resources contribute to the biodiversity of agroecosystem (Grivetti and Ogle, 2000; Hammer *et al.*, 2001b). Its fruits are intensively collected from the wild, which leads to overexploitation of natural stands and recently to losses of genetic resources. Owing to its medicinal values, it fetches high prices at local markets of Sudan (Gebauer *et al.*, 2007b) and is also overexploited by the tribal people of India for their fruits which are common household food and are direct or indirect sources of income. So, efforts must be taken to conserve this species and also for the conservation of traditional knowledge for sustainable management of biodiversity. Micro-propagation by tissue culture techniques may play an effective role for plant conservation. *In situ* conservation could be a suitable method for the protection of diverse germplasm of *G. tenax* in natural rangelands. Another aspect of conservation of this species is the introduction in ALUS, planting as hedge-row and creation of public awareness. The species of *G. tenax* also needs phytochemical, pharmacological and morphogenic investigations on a wider range, which may have great scope in near future.

Future prospects

Owing to its importance in medicinal and rural livelihood security, the priority should be given to the following research areas: (a) extensive field survey and exploration of this valuable indigenous fruit shrub throughout India, (b) collection of genetically variable individuals available in natural population, (c) characterization of these germplasm for outstanding elite genotype, (d) investigation on propagation techniques including micro-propagation for commercial utilization, (e) efforts to protect natural rangelands, (f) introduction of elite species in ALUS and (g) phytochemical, pharmacological and morphogenic investigations for proper utilization in future.

Conclusion

Grewia tenax is one of the important underutilized and potentially threatened shrub of the Thar Desert of India. The present study clearly indicates the distribution pattern, browsing pressure and survival of *G. tenax* under extreme hot arid conditions of western Rajasthan. During the field survey, its existence was mainly found in wastelands and low rainfall regions. The occurrence of population is varied from occasional to frequent in patches with dominant association of *S. oleoides*, *C. decidua*, *A. senegal* and *Z. nummularia*. The analysis of associated vegetation of *G. tenax* provided a clue on all kinds of protection (owing to thorny/bushy nature of *E. caducifolia*) available for its better survival and conservation in natural habitats, especially in open area like Jaisalmer region of the Thar Desert of India. The current overexploitation of natural population and the lack of regeneration are leading to the loss of fruit sources and also to the depletion and erosion of the natural gene pool of this species. Therefore, *in situ* conservation of natural stands as well as domestication and cultivation in ALUS of *G. tenax* is necessary for the protection of diverse germplasm in the region. Its suitability to adopt extreme conditions (both coldness in winter and hotness in summer) of the Thar region made this species useful for climate change scenario in the future.

Supplementary material

The supplementary material for this article can be found at https://doi.org/10.1017/S1479262118000370.

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