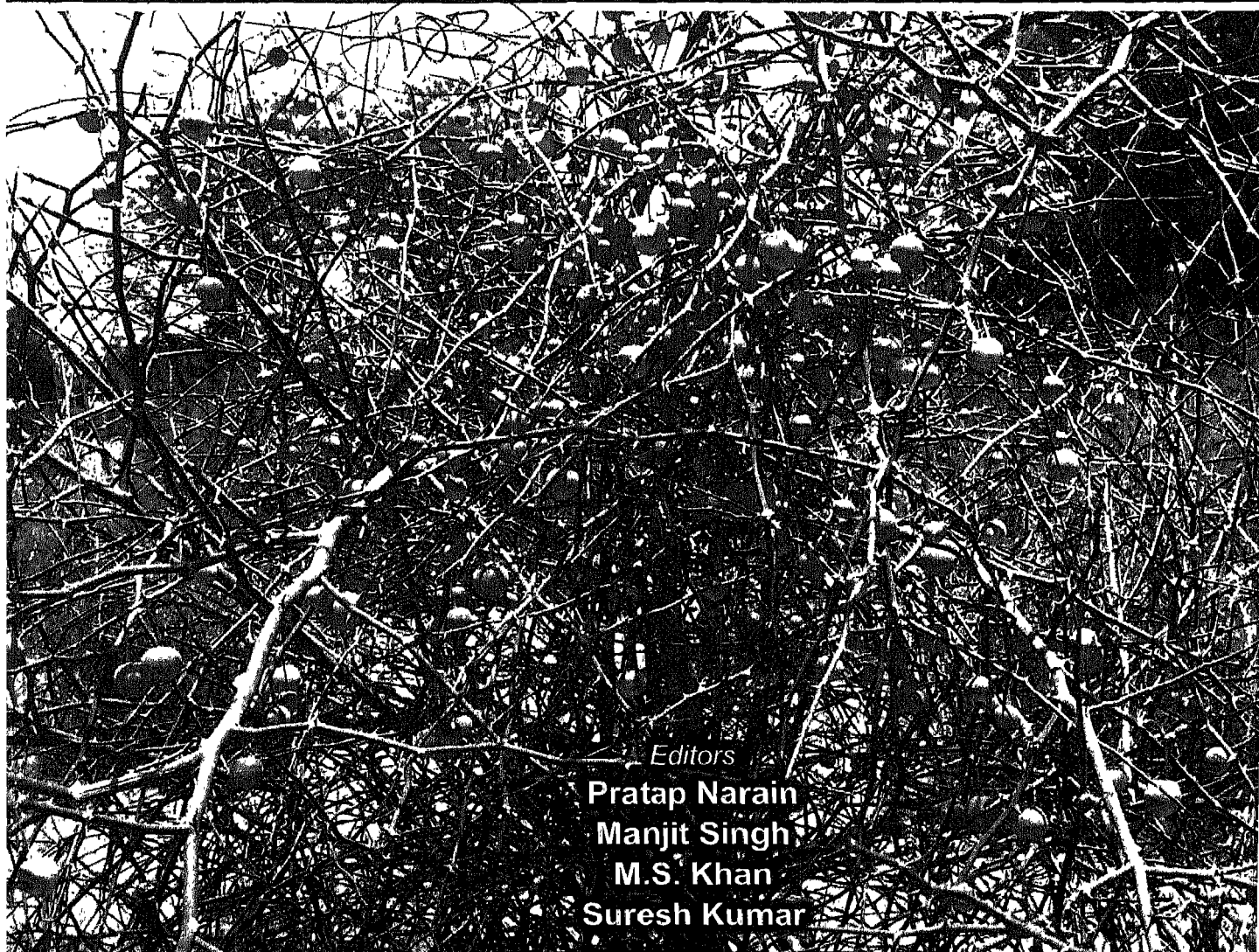




Shrubs of Indian Arid Zone



Editors
Pratap Narain
Manjit Singh
M.S. Khan
Suresh Kumar

**Arid Agro-ecosystem Directorate
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Front Cover : *Capparis decidua* (Kair) in fruiting

Back Cover (L to R) :

1. <i>Leptadenia pyrotechnica</i> (Kheep)	2. <i>Aloe vera</i> (Gwarpatha)
3. <i>Calligonum polygonoides</i> (Phog)	4. <i>Haloxylon recurvum</i> (Lana)
5. <i>Cassia angustifolia</i> (Sonamukhi)	6. <i>Commiphora wightii</i> (Guggal)
7. <i>Calotropis procera</i> (Aak)	8. <i>Opuntia ficus-indica</i> (Thor)

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Foreword

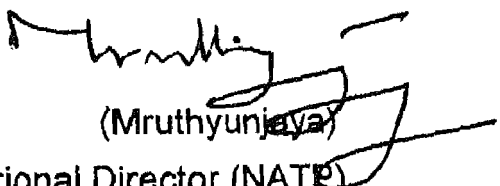
Shrubs are an integral component of any ecosystem and are important from both ecological and economical point of view. In arid regions shrubs have distinct significance, as these are hardy, have more adaptive power and are the source of food, fuel, fodder, fibre, gum, dye, and other products in these biomass deficient areas. That the shrub as a vegetation form is more hardy than the tree is proved beyond doubt by the presence of shrubs beyond the tree limit. Though shrubs are considered important, there is little scientific information available on this group of plants. Shrubs have been the lifeline for the survival of human and livestock in the region. Local inhabitants know it, but the role of shrubs in mitigating fuel wood problems, meeting fodder needs and as avenues for livelihood generation of the rural poor has not got the desired attention. Indian arid zone is endowed with unique resources of medicinal shrubs. These plants have been used over the millennia for human welfare in the promotion of health and as drugs. This close relationship between man and his environment continues even today as a large proportion of people still live in rural areas.

Even today fruits like kair and gums like that from guggal are collected from natural habitats and there have been hardly any efforts to cultivate these plants on commercial scale. The ever-increasing requirement of many dyes and medicinal products further highlights the need for a close look at the shrubs of the region.

Introduction of tractors and bringing more area under plough has damaged the shrubs of dry regions. Increasing browse pressure and cultivation of marginal lands has also led to decline in the population of many important shrubs. The ever increasing need for food, fuel, fodder and products of economic importance and trade necessitates concerted studies, especially in dry regions.

The efforts to document and compile information on all aspects of shrubs of arid zone through a National Symposium is a right and timely step. Various authorities have contributed articles about shrubs of cold as well as hot arid zone of the country. The deliberations during the workshop will help in identifying the research needs, prioritise the shrubs for research and development and integration of shrubs in the farming systems for enhancing productivity and livelihood of the inhabitants of the region. I hope that the outcome of this important symposium will help in planning the research, development including marketing and trade activities in future.

I wish the symposium a success.


(Mruthyunjaya)
National Director (NATR)

PREFACE

Shrubs are of great significance for sustainability of arid ecosystem because of their ecological significance in soil and water conservation and economic value as source of food, fuel, fodder and medicines. About one-third projects of arid ecosystem under NATP addressed issues related to shrubs of arid zone. These projects dealt with improvement, production and utilisation of shrubs and their products, genetic improvement, natural variability, propagation, agro techniques, IPM-schedules and control of parasitic diseases of livestock. Shrubs like Senna, Henna, Guggal and Kair have been adequately dealt with, reached a take off stage and sizeable lateral spread has occurred in the states of Rajasthan and Gujarat. Of late there is a tremendous thrust on medicinal and aromatic shrubs of hot as well as cold deserts to sustaining livelihood and socio economics of people.

It has been realized through interaction with the scientists, farmers and traders in various meetings to lay greater focus on the native shrubs. An integrated and holistic approach is required to conserve their diversity, utilize and integrate them with farming system for sustainability and livelihood of people. While conserving natural resources, shrubs can contribute immensely through crop diversification, bio fence and pasture improvement thus benefiting economy of rural poor. Research and Development on shrubs will not only address the need of the poorest of the poor but will also help in improving sustainability. After having organized location specific interaction meetings on Heena and Senna at Pali and Bikaner, respectively, it was realized in a Scientific Advisory Panel to organise a comprehensive deliberation through a National Symposium on "Shrubs of Arid Zone" which would be of great significance and provide researchable issues and future research strategies in this sphere of work. With this objective in view this National Symposium on Shrubs of Arid Zone has been endeavoured. As shrubs play significant role in preventing land degradation and provide drought proofing in arid zone, therefore the symposium is being organized on 17-18 June, 2005 to commemorate World Day to Combat Desertification and Drought.

The present compilation is based on the contributions by various research workers in both hot and cold arid zone. We believe that there is need for better understanding of ecological as well as economic significance of shrubs and integrate these into farming systems. There is also a need of quantification of processes of degradation and conservation as well as economic valuation of shrubs. Rational understanding of excellent performance of a specific shrub is required e.g. Henna under given edapho climatic situation of Sojat in Pali district. This will help plan soil-site suitability for crop zoning to boost industry processing in the region. Emphasis on these hardy perennials of desert accompanied by innovative uses and value addition and required market infrastructure, processing and certification can help in enhancing livelihood of rural people and impart sustainability in dry regions.

We would like to thank all the contributors for agreeing to our request to provide articles promptly and participate in this symposium. The compilation of these articles required collective efforts and we thank Dr. M.P. Rajora (Sr. Scientist), Dr. J.P. Singh (Sr. Scientist) and Shri Rakesh Pathak T-4 for their consistent help in going through the manuscript and Shri Dhamendra Bohra for typing. Financial support provided by NATP for organising the symposium and publication is highly acknowledged. We hope that this compilation will help the researchers and policy planners in understanding and prioritising future research needs on shrubs in dry lands.

Editors

CONTENTS

- ✓ 1. **Shrubs- The Untapped Wealth of Desert** 1
Pratap Narain
- ✓ 2. **Shrubs - The Saviours of Desert Ecosystem** 5
M.M. Bhandari
- ✓ 3. **Ethnobotany of Shrubs of Arid Rajasthan** 15
Suresh Kumar, F. Parveen, S. Goyal and A. Chauhan
4. **Halophytic Chenopod Shrubs of Arid Zone** 27
J.P. Singh, M.L. Soni and V.S. Rathore
- ✓ 5. **Some Important Introduced Shrub Species and Their Production Potential in Hot Arid Regions of India** 33
J.C. Tewari, L.N. Harsh and A.K. Sharma
- ✓ 6. **Arid Shrubs for Human Health** 39
Ram Harsh Singh and Giridhar Gopal Sharma
- ✓ 7. **Under-Utilized Medicinal Shrubs Suitable for Alternate Land Use Systems in Western Rajasthan** 45
J. P. Singh and Suresh Kumar
- ✓ 8. **Senna (*Cassia angustifolia* Vahl) - A Medicinal Plant for Barren Lands** 51
P.R. Kothari, Manjit Singh, S.K. Jindal and S.N. Jaimini
9. **Guggul - A Therapeutic Shrub** 55
S.K. Jindal, Manjit Singh and Deepa Singh
10. **Prospects of Shrubs in Rainfed Regions of Southern Peninsular India** 61
G. Pratibha, G.R. Korwar, M.S. Rao and S.K. Yadav
11. **Henna (*Lawsonia inermis* L.) A Promising Dye Yielding Shrub** 66
Y. V. Singh, S. S. Rao, P. K. Roy, P. L. Regar, Khem Chand, B. L. Jangid and Manjit Singh
12. ***Aloe vera* in the Indian Arid Zone** 73
Suresh Kumar, M. Mohibbe Azam and Farzana Parveen
13. **Fibre Yielding Shrubs of Indian Arid Zone** 79
J.P. Singh, Suresh Kumar and Manjit Singh
14. ***Salvadora* in the Degraded Saline Habitat of Arid Region** 83
S.K. Jindal and Manjit Singh

✓ 15.	Arid Shrubs for Livestock <i>M.S. Khan</i>	87
✓ 16.	Phog (<i>Calligonum polygonoides</i> L.) - An Important Arid Shrub of Rainfed Farming System in Western Rajasthan <i>R. K. Beniwal, J. P. Singh and V.S. Rathore</i>	91
✓ 17.	<i>Capparis decidua</i> - A Multipurpose Shrub <i>Manjit Singh, S.K. Jindal and Rekha Sivadasan</i>	97
18.	<i>Acacia jacquemontii</i> Benth - A Potential Multipurpose Shrub <i>R. S. Mertia and Rajendra Prasad</i>	105
19.	<i>Opuntia ficus-indica</i>-A Multipurpose Underexploited Arid Shrub <i>Gurbachan Singh, Manjit Singh and Suresh Kumar</i>	111
✓ 20.	Shrubs for Arid Land Management <i>Pratap Narain, Suresh Kumar, R.K. Goyal and J.C. Tewari</i>	115
✓ 21.	Role of Shrubs in Wind Erosion Control <i>Amal Kar</i>	121
✓ 22.	Shrub based Agroforestry for Arid Regions of India <i>P. Rai, Ajit, A. K. Handa and Nighat Jabeen</i>	125
✓ 23.	Ornamental Shrubs in the Arid Zone <i>S. K. Saxena and Suresh Kumar</i>	127
✓ 24.	Few Economic Shrubs and Their Commercialization <i>B.S.Chundawat</i>	131
25.	Distribution and Ethnobotany of Shrubs of Arid Gujarat <i>S.B.S. Tikka and S.N. Jaimini</i>	137
26.	Economic Shrubs of Banni Region of Arid Gujarat <i>S. P. Vyas</i>	141
✓ 27.	Micropropagation of Shrubs of Arid Regions <i>N. S. Shekhawat, H.R. Dagla, J.S. Rathore, V. Kataria, D. Gupta, J.B. Vibha, M. Singh, M.S. Rathore, A. Paliwal, D. Panwar, M. Parihar, K. Ram, A. Kacker and H.S. Gehlot</i>	145
28.	Distribution, Propagation And Bioeconomic Importance of Shrubs in Cold Desert Regions of India <i>V. K. Mishra and R. Raina</i>	147
29.	Ethnobotany of Shrubs of Cold Arid Zone in Western Himalaya <i>N.S. Chauhan</i>	159
30.	Seabuckthorn (<i>Hippophae</i> L.) - A Multipurpose Shrub of Cold Desert of Himalayas <i>Virendra Singh</i>	169

Shrubs- The Untapped Wealth of Desert

Pratap Narain

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Arid areas, both hot and cold, are characterised by extremes of temperatures, high evapotranspiration, scarcity of precipitation, high wind velocity, high flux of radiation, sandy /fragile soils with low productivity and poor water holding capacity. These fragile low biomass producing ecosystems are overexploited by ever increasing human and livestock population, which leads to serious water deficiency and land degradation.

Arid zone in India is spread over 31.7 million ha hot and 7.0 million ha cold arid region(Fig. 1). About 62 percent of hot arid region lies in western Rajasthan carrying 107 human and 137 livestock per square kilometre. Overexploitation of resources and frequent droughts have degraded 75% area by wind and water erosion. Larger part cold deserts occur in Ladakh region of Jammu & Kashmir and Chamba, Lahul-Spiti and Kinnaur in Himachal Pradesh under severe desertic conditions.

The vegetation in deserts is a unique blend of perennial grasses, hardy shrubs and scattered small trees. These perennial systems are the lifeline of desert and sustains high human and livestock, even during drought or near famine situations.

Of these, shrubs are dominant in hot arid ecosystem and adapted in harsh climate of arid and hyper arid region. The shrubs have a resilient role in resisting erosion and desertification because of their ability to withstand biotic pressure, conserve soil, moisture and improve soil productivity. These are primary source of fuel and fodder for the rural masses in the areas with low tree cover and have the potential to provide products useful to the local people as well as industry.

Masses in these areas depend on shrubs for fuel, food, fodder and various other economic products like gum, dyes, medicines, etc. There is wealth of ethnic

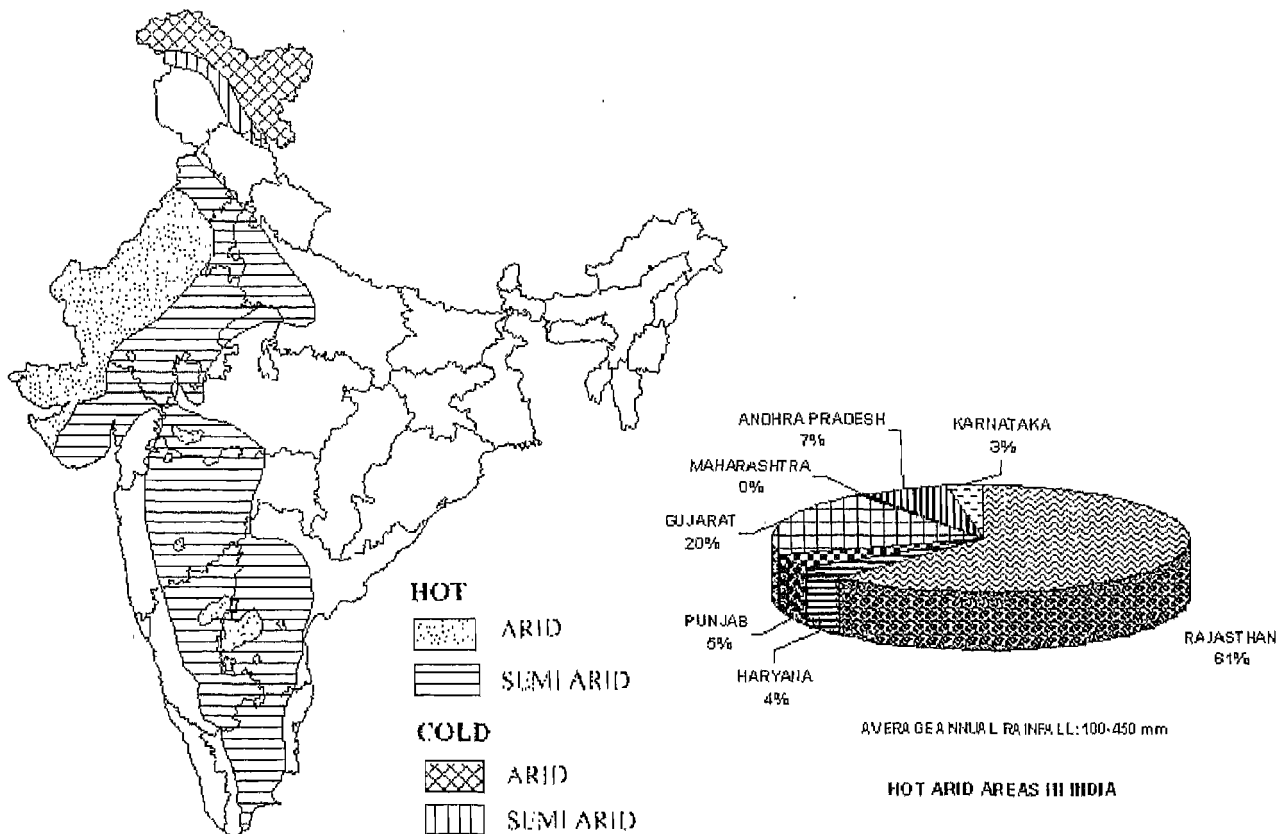


Fig. 1 Arid and semi-arid zones of India

knowledge on medicinal uses of these shrubs with local people, who have been practising to cure both human and livestock diseases. Many shrubs products are procured at very low prices by the middle men from natives. Hence there is great potential of value addition and developing market chain for shrub products.

Indian arid zone is endowed with unique resources of medicinal and aromatic plants used over the millennia for human health and cosmetics, which continues even today in rural areas. These people are precluded from the luxury of access to modern therapy, mainly for economic reasons. Despite their ecological and economic significance little planned research has been done on the shrubs of Indian arid zone.

There is vast wealth of shrubs but only a few have been commercially exploited in past. Now there is growing awareness about Aloe, senna, guggal, safed musali (Table 1) among the farmers of the region, however their marketing is still obscure.

Intensive cultivation, tractorization, irrigation through canal or tubewells and cropping adversely affected the shrub population and their regeneration. Even under afforestation programmes native shrubs are removed as weeds and only secondary growth becomes association.

It is only recently that focus has shifted towards shrubs on account of some indispensable uses. Emerging need for crop diversification, demand for medicinal and other products as source of fodder, and their value for conservation under drylands and industrial value of shrubs has attracted the attention of many farmers, scientists and industrilists towards this hitherto neglected group of plants.

Majority of the shrubs yield products of economic value like gums, dyes, tannins and medicines. Industry needs standard product of uniform quality throughout the year. The ground reality is that every collection from nature is different in quality and regular supply cannot be assured. Further, such type of collections are done using non-scientific methods that result in death of shrubs like guggal endangering its exitiction. Once we were meeting almost all our guggal requirements, and today almost all of it is imported. Commerciilasation of shrubs will require development of agrotechniques, scientific utilization, proceesing and value addition, while maintaining natural equilibrium.

Marketing of shrubs and their products is most important issue. In the absence of organised trade and awareness at the grassroot level, not only tapping of the wealth that is hidden in these shrubs is difficult, but poor farmer is deprived off the actual gains.

Shrubs are emerging avenues for ethical or humanitarian reasons, self sufficiency to poors, economic gains, resource management, agricultural diversification, germplasm consertvation, nutrition and energy security. With the ever increasing population pressure and fast depletion of natural resources it has now become necessary that desired attention given on existing resources and explore the possibilites of exploiting new plant resources in order to meet the growing needs of human society. There are number of potential plant species which support life in extreme environmental situaions. These are required to be thouroughly prioritised and commercialised saving interest of farmers. Potential of growing them as biofence, as strips with crops or

Table 1 Multiple uses of few arid zone shrubs

S. No	Uses	Species
1	Fuel	Phog (<i>Calligonum polygonoides</i>), Angreji babool (<i>Prosopis juliflora</i>)
2	Fodder	Bordi (<i>Ziziphus nummularia</i>), Lana (<i>Haloxylon salicornicum</i>)
3	Gums & Resins	Bawli (<i>Acacia jacquemontii</i>), Gugal (<i>Commiphora wightii</i>)
4	Dyes & Tannins	Henna (<i>Lawsonia inermis</i>), Anwal (<i>Cassia auriculata</i>)
5	Food & Fruits	Kair (<i>Capparis decidua</i>), Ber (<i>Ziziphus mauritiana</i>), Anar (<i>Punica granatum</i>)
6	Fibres	Kheep (<i>Leptadenia pyrotechnica</i>), Aak (<i>Calotropis procera</i>)
7	Medicines	Gugal (<i>C. wightii</i>), Senna (<i>Cassia angustifolia</i>), Aak (<i>Calotropis procera</i>)
8	Ornamentals	Bougainvilleas, Kaner (<i>Nerium spp.</i>)

grasses, as a part of silvipastoral systems or even as sole crops should be explored. Future research agenda on shrubs calls for followings:

- Germplasm collection, conservation and evaluation from indigenous as well as exotic sources for the prioritised species for food, fodder, energy, dyes, gum or other medicinal or economic products.
- Adequate research and development on selected species, which are lesser known yet economically important.
- Standardisation of package of practices, the tools and techniques for harvesting of economic products and its processing for commercialisation of shrubs species.
- Evaluation for their suitability as fence, intercrop and integration in the farming system. Introduction of shrubs into existing systems would help in promoting these species as supplementary crops and not only as substitute crops. The effort should be to explore ecological advantage like checking of erosion and also harnessing of economic products.
- Post harvest technology, developing of marketing infrastructure, their certification with respect to chemical constituents and being growing organic is also relevant.
- Systematic efforts are required to develop superior and economically viable strains.
- Shrubs offer an upcoming field for research and development. Many unknown products and processes may fall under intellectual property rights and can be patented with moderate efforts and validation of indigenous practices.

Shrubs - The Saviours of Desert Ecosystem

M.M. Bhandari

Former Professor, Department of Botany, JNV University, Jodhpur

Arid zone of Rajasthan, mainly the Thar Desert, is unique both from the point of view of floristic and climate. It assumes special significance since the biodiversity in this zone survives in a very fragile ecosystem, under a highly hostile environment. Most of the area of this desert consists of dry undulating mass of loose sand, forming shifting sand-dunes. The sandy plain is full of sand-hills with several low depressions where salt and soda are deposited on drying. The rocks in western Rajasthan are largely covered by wind blown sand but at few places these rocks are exposed at the surface. The whole area is inhospitable and sterile. Trees are rather few and far between.

Major part of the desert is scrub thorny jungle with stunted and half-nibbled shrubs. Like all deserts of the world, the Thar Desert is sparsely vegetated and has a limited number of trees and shrub species. Xerophytic annuals constitute about 60 per cent of the Flora. True forest cover constitutes only 0.69 per cent of the area. A close relationship has been noticed between the habitat and the vegetation. The plant life varies in its magnitude from the 100 mm rainfall zone in the west to wetter eastern part. The bulk of the vegetation consists of a kind of scrub made up of shrubs and perennial herbs, capable of great drought resistance and of a period of comparative rest, extending throughout the greater part of the year. There are few trees to be seen, and these are stunted and generally thorny or prickly, thus protecting themselves against plant-feeding animals. Of the later, there are vast herds of camels, cattle, sheep and goats, forming the chief wealth of the rural population, and appearing to thrive in spite of the arid nature of the country. The presence of these herds is a factor of some importance in the economy of the region, certain plants being kept down, while others remain untouched. Thus it is sometimes impossible to find a fairly complete specimen of many plants over large areas, the branches being eaten, and only the woody base left. The struggle for existence between the plants, of the same or of different species, in practically non-existent, there being plenty of vacant spaces, and the formations being generally of the open type. Some plants which conserve water in this way, appearing almost dead for months or even years include the *Capparis*, the *Calligonum* and the *Euphorbias* etc.

A shrub is a low woody or semi-woody perennial plant with a little or no trunk. It has numerous branches from the base, may be from the ground or just near the ground. Shrubs are invaluable in a desert. In singles the shrubs become a focus of attention and in clusters they create a mass effect. The shrubs offer, in a very limited space, a wide choice of colours, shapes and sizes of flowers, leaves, and fragrance too.

It is extremely important to generate information on the origin, distribution, habitat, agro-climatic requirements and scientific utilization of important species of such adverse habitats, having economic potential for use as food, forage, fuel, energy, medicine, industrial or other uses based on folk-lore and experience gained from native communities need to be recorded on a priority basis. The local rural population in various extreme environment have identified large number of plants since time immemorial. Yet unfortunately the biological diversity in such areas has many neglected plants, which are assumed to be 'poor people's plants' since these provide food, fiber, medicine, materials, energy etc. to man and his animals and also have ability to grow and reproduce in extreme environment stress conditions. Diminishing in the face of environmental degradation of human and live-stock population pressures and requirements. Life support species in these emergency areas have enough to offer for the betterment of mankind provided we pay required attention to these valuable resources and do not let them continue in the category of unknown plants of economic importance.

Indian arid zone consists of both hot and cold desert. I will first speak about hot desert.

Hot Desert

Being involved in plant exploration in main arid zone of India, difficult terrain, of the Indian hot desert for over fifty years now, I have witnessed a great change in species distribution and floristic physiognomic patterns in that region. Quite a bit of habitats in the Indian Desert have either been already destroyed or have been badly mutilated over the years. Moreover, the whole range of such complex ecosystems is rapidly changing due to human activities. Great loss has, therefore, already been caused since many plant species of such harsh

environmentally adverse habitats have become extinct before they have even been properly recorded. The arid ecosystem is a distinct ecosystem, within which there exist different landforms, which constitute this ecosystem. These landforms are important sources of biodiversity in this zone, particularly because they have a long history of exogenic and endogenic activities. The formation of hilly or rocky and gravely pediment, flat buried pediment, older and younger alluvial plains, riverbed etc. are the products of fluvial processes. On the other hand, the formation of sand dunes, sandy undulating plains and interdunal plains are the result of aeolian activity. All these different landforms support varied and specific vegetation.

'Pag Pungal, sir Merta, udraj Bikaner

Bhulo chooko Barmer, thavo Jaisalmer'

There are some five important stresses in the hot desert :

1. Extremes of temperature and dryness of the atmosphere
2. Scanty rainfall
3. Low relative humidity
4. Severe droughts.
5. Excessive grazing
6. Increasing human interference
7. Degraded soil condition

No programme on biodiversity conservation, particularly in the arid zone where people have to depend on what ever meager resources available to them, can be successful without people's participation. Knowledge and utilization of local shrubs which is an outcome of the experience passed on to the successive generation, makes the poor desert dwellers to survive not only in the harsh desert environment but also in the prolonged droughts and famines. In order to bring more and more land under green cover, the thrust is given to the active participation of the people at all stages in the development and production of their own resources. A massive untapped potential of species exists in such habitats. Native plants which have adopted themselves to the harsh specific environmental and degraded soil conditions, should be immediately inventorised. This potential is however, a diminishing resource.

There is a great variation in the habitats in the desert and each one of these habitats support distinctive shrubs. Desert shrubs have a wide range of adaptability.

The present paper contains a variety of

indigenous shrubby plants, from which useful products like tannins , dyes, gums, resins, mucilage, detergents, soap substitutes, non-edible oils, spirit, county liquor and other beverages, timber and fire wood, fiber, materials for paper, food and many other miscellaneous products can be obtained.

Because of the various limitations only a few shrubs could be included in this lecture. These observations are based mainly on my experience of the desert for more than fifty years now.

In the sandy habitat of the lowest rainfall zone (100-150 mm), where shrubs and under-shrubs predominate *Calligonum - Haloxylon* type of associations prevail:

Calligonum polygonoides (Phog) is the major shrub and is associated with *Haloxylon* species . On the lower dune slopes in the Jaisalmer and Bikaner regions. *Leptadenia pyrotechnica* forms the main associate *Calerodendrum phlomoides* and *Acacia jacquemontii* are its associates in the Barmer sector.

***Calligonum polygonoides* L. (POLYGONACEAE)**

Local name : Phog

It is one of the most noteworthy shrubs of the desert which abounds almost throughout the desert, chiefly growing on sand, It being an excellent sand-dune stabilizer. *Calligonum polygonoides* has a wonderful ability of adaptation to diverse circumstances. When growing on sand dune, it prefers the very crest which it may entirely monopolize in short duration of time due to its suckers. Its grayish red bushes cling closely to the sand dunes, helping to stabilize the sand. The roots of this stunted *Calligonum* were considerably exposed, the finest ramifications, tracing the fine circles in the sand. Its bark is thick and corky, to insulate the sap bearing layers in the trunk from the searing heat of the sun. Removing *Calligonum* from its natural habitat is of great concern to those who work in the desert for the desert. *Calligonum* forms one of the traditional fuel-wood resources along with *Calotropis procera* and *Prosopis juliflora*.

The aerial part of Phog is not of much value but it is the underground wood bowls which are of commercial value. Its wood has a unique power of burning instantaneously after it is up rooted. Not only it burns so quickly, it also provides intense heat for which reason it is an excellent commodity of local iron and gold smiths. Phog- wood is also used in gypsum factories and brick kilns in their furnaces. Despite the fact that coal making

from phog wood is banned by the Government, numerous illegal Phog coal making units are in existence particularly in Bikaner district. Removal of Phog wood is a regular business and now with the introduction of tractors and bulldozers the plant is removed along with its root-bowl more easily. Phog has played an important part in politics of this region.

The wood is used in building field fences and huts. The young branches are eaten by camels. Flowers have cooling effect and used in treating sunstroke. The buds called 'Lasson' are eaten by poor in times of scarcity with whey and salt. Decoction of the plant is used as a gargle for the sore gums. Leaf juice is used for washing eyes as a cure against latex of *Calotropis procera*.

Main associate of *Calligonum* on the sand dunes and sandy undulations of Churu - Nagaur- Bikaner tract (250-350 mm rainfall zone) in Bikaner region is *Leptadenia pyrotechnica*. The density varies from 150 to 300/ha.

***Leptadenia pyrotechnica* (Forsk.) Decne. (ASCLEPIDACEAE)**

Local Name : 'Khimp', Khimparo'.

A much branched, often leafless, erect bushy shrub 8-10 dm high. Leaves are caducous, but when present are linear-lanceolate. Stem slender, green, straight, the branches divaricating opposing the leaf axils. Flowers yellow, small, Follicles terete, lanceolate, tapering into slender, apical beak. Seeds have 2-5 mm long comma.

Leaf paste is effective against thorn scratches. Juice of the plant is mixed with sugar and wheat which is then tied on the affected body part to take out the thorns. Paste of the plant is applied over the paralyzed portion of the body for relief. Stem decoction is given to cattle after delivery to facilitate the 'Jair' (a membrane in which the fetus develops. It is also given to cattle for removing fatigue.

Leptadenia is a traditionally used plant along with *Crotalaria burhia* for making ropes and cordages from the whole plant by twisting them for fences on the bullock carts or for fastening the fire-wood bundles or grasses. Ropes for charpoys are also prepared from them, particularly because the green watery latex (juice) present in the stem prevents it fiber from decomposing.

***Cassia auriculata* L. (CAESALPINIACEAE)**

Local name : Tervad, Anwal

Bushy shrubs. stipules large, foliaceous, reflexed, reniform. Leaves 8 cm long; leaflets 8-12 pairs, elliptic-

oblong, obtuse and minutely apiculate, 2x1 cm, with subulate glands in between. Corymb axillary and terminal, often panicked; bracts ovate, acuminate. Stamens 6-7 antheriferous, 2 larger. Pod flat, dehiscent, 10x1.5 cm, obtuse at apex with age. Leaves-are anthelmintic; used in ulcer, leprosy, skin diseases and nocturnal mission. Root- Urinary discharge, skin diseases, asthma.

On the deep sandy plains and low dunes *Prosopis-Tecomella* type is prevalent. Realizing the commercial value of these species, the farmers maintain these plants in their fields. At places 25-50 plants/ha could be seen. *Clerodendrum phlomoides* along with *Balanites aegyptiaca*, *Lycium barbarum*, *Ziziphus nummularia*, *Calotropis procera*, *Aerva pseudotomentosa*, *Mimosa hamata* and *Leptadenia pyrotechnica* are the major associates. *Clerodendrum phlomoides* is also the main associate of *Calligonum*.

In the Barmer sector along with *Clerodendrum phlomoides* there is a peculiar *Acacia*, in Indian desert - *A. jacquemontii* (एकेसिया जेकमोन्साइए, बूबावली) which grows as a spiny bushy shrub with zig-zag branches. Stipular spines connate at the base on the sand dunes. During rainy season when abundant water is available, this plant appears as dry leafless bush, but during summers when water is scarce, it sends a flush of minute feathery leaves. It flowers during winter when the entire bush is laden with pale yellow puffy heads. Widely used as fire-wood by iron smiths and Gadlia Lohars for preparing local iron implements. The root bark of *Acacia jacquemontii* is used to flavor local spirits. Despite the fact that the alcoholic distillation is prohibited in the area, the spirituous liquors are the distilled products of fermented sugars.

As mentioned earlier the Indian Desert is characterized by high percentage area under moving sand shifting between sand- dunes, shifting sand spreading into croplands. New sand dune formation is one of the biggest problem facing the arid zone. Shelterbelts around dune areas and sand dune stabilization effectively work as wind breaks and greatly reduce the menace of soil erosion. Plants like *Calligonum polygonoides*, *Calotropis procera* and *Citrullus colocynthis*, etc., have a remarkable sand binding capacity.

***Citrullus colocynthis* (Linn.) Schrad. (CUCURBITACEAE)**

Local name : Indrayan, Tumba, Blitter apple

It is a large prostrate scab rid perennial plant of the desert with its branches radiating in all directions with long tap root. The plant is very much effective in fixing

and establishing the sand dunes. It grows extensively on sandy habitats and sand-dunes of Western Rajasthan. It flowers and fruits during August- October. Plant dies back in winter but the root stock sprouts back in spring. Large number of strains of this species have been observed in the desert which vary in a number of morphological features as well as in per cent of oil contents of their seeds.

Its seeds of the plant contain 21 per cent non-edible oil which is largely used in soap industry these days. The pulp of the fruit is anti pyretic - reduces fever and is also given in jaundice and colic pains, leucoderma.. Root paste is applied in painful joints.

Root are eaten to nullify the poisonous effect of snake bite and scorpion stings. Crushed leaves are tied on the affected body part by guinea-worm (Bala, Naru).

Fruits are roasted with wooden ash and is given to camel for vigor and energy. Fruits are also given to animals to stop the sand eating habits. The dried pulp of unripe but fully grown fruits freed from the rind contains the dry colocynth of commerce. The pulp constitutes roughly 15% of the fruit, the seeds and the rind. The pulp of colocynth is a drastic hydrogogue cathartic producing large watery evacuations within 2-3 hours. In large doses it causes violent gripping The active principle of colocynth include bitter amorphous alkaloid and a resin both of which have a violent purgative action

Natural hybrid between *Citrullus colocynthis* and cultivated *Citrullus lanatus* (water melon) has been observed. This is a potential feature of great commercial value since if the disease resistant and perennial natured genes of *Citrullus colocynthis* can be combined with the gene responsible for sweetness of water melon.

Fruits and seed are purgative. Roots are also purgative, used in jaundice and rheumatism Bitter substance colocynthin. Seeds contain fixed oil, a phytosterolin and a mixture of fatty acids. Fruits-dried pulp of ripe fruit forms commercial drug colocynth, freed from rind, drastic hydrogogue, cathartic. and providing large watery evacuation; in large doses, causes violent gripping, prostration and sometimes bloody discharge. Small fruits taken out during rainy season and stuffed with common salt and Ajwain, a cure for acute stomach-ache in Unani medicine., used in kala-azar.

***Calotropis procera* (Ait.) R.Br. (ASCLEPIADACEAE)**

Local name : 'Aak', 'Aakro'

This species grows commonly and abundantly in waste

places on sandy stretches, particularly in ruderal formations i.e., in the immediate vicinity of the dwellings of man. The akra, or swallowwort, is to all appearances a humble wayside plant, a gray-leaved fleshy weed encountered on any walk in the desert, so the casual observer might be surprised by the plant's reputation, and the manner in which its mythological, ritual, and medical uses overlap.

The plant grows profusely and survives well under harsh conditions. Named akra after the sun, the swallowwort is noted for its heating properties, and for the milky latex that flows easily from its leaves.

It is an expectorant- promotes bronchial secretions and facilitates its removal. It is anthelmintic, destroys intestinal worms. Roots are purgative. Dried juice is antispasmodic and a nervine tonic. Dried leaves smoked in a pipe is a cure for asthma and cough. Fresh leaves are used as a bandage for rheumatic joints and swellings. Flowers are recommended as tonic and are digestive. Also recommended in small doses for cold. The fibers obtained from stem are fine silky, but are usually difficult to prepare profitably. Ash of the plant is boiled in water till whole water gets evaporated, then remaining mass is used in tuberculosis. Latex is applied on the inflamed skin. Latex and 'Ghee' mixed together is applied on the stomach to relieve pain on the upper part of the stomach. Slightly warm leaves tied over infected body part results in easy ejection of 'Bala' (Guinea worm). Latex is applied as an antidote to scorpion sting.

All parts of the plant are useful. Twigs and branches of Aak are used for beams and thatching. Floss from the seeds is soft and is utilized in stuffing the pillows. Cords and ropes are prepared from the fiber extracted from the stem. Raikas weave their coarse rugs from the rugged akara plants and also for making ropes and cordages. The seed comas or floss fiber are used for stuffing the pillows and the highly toxic sap is used for a variety of medicinal purposes.

Recently it has been suggested to use this plant as a source of photo- synthetically produced hydrocarbons as a substitute for conventional petroleum resource. The hexane extract of the whole plant yields a high density brownish fluid rich in hydrocarbons. The ratio of carbon and hydrogen in hexane extract is similar to the crude oil, fuel and gasoline.

Akara, the Shiva's plant is known so because the flowers of Akra are offered to Lord Shiva and is held in high religious esteem by local people. There is a white

akara temple at Barmer and also at other places.. In Ladnu and Sujangarh, in most of the houses as one enter them, one can notice Akara roots on the inside of the entrance of the first door. Roots are regarded as symbol of Ganeshji. Perhaps the plant's reputation for sternness in Hindu myth comes from an ancient tribal caution about the poison contained in its milky latex, but offering the leaves of the swallowwort in Hindu religious rituals is believed to enhance the good health of the sacrificer. The devout use them to pour ritual oblations to the sun, after which the leaves are burned.

Ordinary Indians of all faiths know the swallowwort's anti-rheumatic powers. They bind its leaves on their joints during the "seventh day celebrations of the swallowwort," which mark the last month of cold weather in the Indian calendar. The leaves of the swallowwort are also analgesic and anti-inflammatory when applied externally, while the dry powder derived from its burnt leaves and flowers is used orally with black pepper is a effective medicine for cough,, cold, asthma and gastric problems.

The simplest people in the desert are the nomadic hunters and food gatherers. Such people are living at a level no more advanced than that of the stone age. They plant no crops, have no permanent homes, and keep no domesticated animals except dogs. Their huts or `Jonparas` are made of Akara branches along with *Capparis* stem beams and fences of Phog. Local saying is aptly suitable here.

*Aak ro Jompro ne phog ri Bar,
Bajri ro Sogro ne monta ri Dal,
Dekhi Raja Mansing thari Marwar*

On the plains of Western Rajasthan, the most common plant community is *Salvadora oleoides* - *Prosopis cineraria*. This is the climax community of. and due to continuous biotic influences the vegetation has greatly been reduced to various stages of degradation. *Ziziphus nummularia* - *Capparis decidua* are the chief associations.

***Capparis decidua* (Forsk.) Edgew. (CAPPARACEAE)**

Locally name : Ker

It is a common plant throughout the area and is found on rocks, gravel and sandy plains on exposed habitats. Some times it occurs on sand-dunes where it forms the chief feature of the landscape.

The plant flowers twice a year, but profusely so only in beginning of summers. A densely branched

spinous shrub or a small tree in dry arid region The unripe fruits are pickled and also cooked and eaten as vegetable. Immature fruits are stored after drying in the sun for their use and surplus marketed. These form an integral part of the diet of people in the semi desert areas of the country. The protein contents and the mineral constituents of the fruits are comparatively much higher and hence could be profitably utilized especially in the dry regions. However mature unripe fruits are after processing are unpalatable as these contain high concentration of glucocinolates eaten as vegetable. Ker is a boon for desert It is used for preparing vegetables and pickles. Ripe fruits are also freshly eaten. It is a rich source of carbohydrate. It is also used for fuel purpose as it achieves rapid growth even under adverse conditions.

The flower buds are cooked as pot herbs. The unripe fruits are kept in saline water for a few weeks, washed thoroughly and pickled. The tender shoots relieve toothache. Unripe fruits are consumed as vegetable and pickles. They are sold in the market. Wood is tough , light , bitter and not touched by white ants. The bark of the plant is laxative; anthelmintic- destroys intestinal worms and is recommended in asthma, cough and inflammation. It is also recommended for cardiac troubles. Fruit is astringents- contracts tissues and stops bleeding. Dried fruit powder is taken in cough. Powdered root bark is used in rheumatism and intermittent fever. Root paste is rubbed on head in migraine. The wood is light yellow to pale brown, moderately hard and heavy and resistant to termite attack. It is suitable for making tool handles, cart wheels axles in beams and rafters in roofs and also agricultural implements. An excellent fire wood, it burns quickly producing much ash. Wood is very strong and durable used to make pivots of the stone hand-mills with which flour is ground. In sandy places wood is used to make the foundation of well- walls, the first layer being formed with Kair, and masonry built on top of it. Branches are also used for field-fences. The wood is valuable since it is not attacked by white ants.

Flower buds and unripe fruits are pickled as a legacy of the rich cultural heritage. Unripe fruits are rich source of protein (18.6 %) and contain 8 mg/100g fruit pulp vitamin C. Its seeds are rich in oil (20.3 %) of which 68.6 % is unsaturated fatty acid. These dry vegetable fruits are being exported out of desert and their cost has also increased enormously due to paucity of their availability. The intensity with which these are collected and in particular the seeds of *Capparis* and Sangari fruits are collected, when they are not fully mature, has seriously

affected the natural process of regeneration of these desirable species in this difficult terrain. Proper and judicious uses of these foods, propagating them of their high yielding strains, and educating people for their proper utilization are some of the methods of improvement in this regards. They may be very helpful as an immediate resource in times of acute crises when there are deaths from starvation and when hunger and despair is lit large on the faces of famine hit people who in such times, out of sheer despair, wander the streets of cities in search of jobs and foods. Moreover with the economic development, alienation of humans from their natural surroundings has taken place due their movement from villages to towns and has led to breaking away from the traditional system of know-how. Export and price rise over last two decades of Sangari (young pods of *Prosopis cineraria*), Kair (young fruits of *Capparis decidua*), dried and ground with any available coarse grain to augment the meager meal contained in it and give it more substance. As a result on the one hand their market value has increased enormously, resulting in their over exploitation, and on the other hand has gradually resulted in the depletion of these resources. Export and price rise over last two decades has sky rocketed. Thus this diversity preserved and maintained by them has become a source of deprivation since the material they have preserved through centuries of sustenance, has gone in the hands of elite.

The vast rocky tract of Jaisalmer has scanty distribution of these species along the runnels or on shallow colluvium. The associate species are vanishing fast due to continuous human onslaught (e.g. *Commiphora wightii*), but *Acacia senegal*, *Euphorbia caducifolia*, *Maytenus emarginata* and *Grewia tenax* still exists.

***Commiphora wightii* (Arn.) Bhandari
(BURSERACEAE)**

Local name : Guggul; Syn. Indian Bdellium;
Sanskrit name : Guggulu.

Formerly this plant was known as *C. mukul* Engl; Balsmodendron mukul Hook. ex Stocks but according to International Code of Botanical Nomenclature, it was found that the earliest name of the plant is *Balsamea wightii* Arnt. After examining the type sheet at *Copenhagen Herbarium*, I changed the name of this important species to *Commiphora wightii* (Arnt.) Bhandari. Hence my name is permanently associated with this species.

This thorny plant Guggal, seldom grows higher than six feet. It is endemic to dry arid rocky areas and

piedmonts of Rajasthan and Gujarat which are the natural habitat of this species. It occurs in rock crevices on sandy-loam soils. Usually it prefers rocky slopes where rain water is quickly drained away. The plant is very common on rocky slopes N.E. of Jaisalmer. It is also common on the gravelly slopes ahead of Kailana at Jodhpur. It is less demanding in terms of soil quality as it survives in highly calcareous and thin stony soils. The plant needs much less water than many other arid zone plants. It is a venerable plant species according to IUCN Red data book. High demand and low production has led to its over exploitation as a result of ignorance and greed of the people particularly during famines. Moreover faulty techniques of gum tapping and over grazing has further affected its seed production. The gradual climatic changes, leading to almost no winter rains has enormously affected its seed production in nature. Attempts should be made to introduce it in identical habitats.

The value as an incense was known from India to Greece since the records of Periplus show that the resin was being traded between India and Greece in the first century A.D., the very time when Charaka was describing its medicinal actions in his treatise. Charaka also refers to the drug action of this resin in reducing obesity and its attendant perils. His observations have been repeatedly confirmed by Ayurvedic physicians through the centuries. Guggul (or Indian Bdellium) has been cited by Sushuruta 3000 years ago as being a valuable drug.

Guggul of commerce is pale yellow or brown aromatic oleo- gum resin obtained from the bark in form of opaque round masses of varying sizes available towards the end of winter. The oleoresin contains 0.37% essential oil containing mainly Myrecene, dimyrecene and polymyrecene. Alcohol extraction gives a soluble resin and an insoluble carbohydrate gum which has long been used in Ayurvedic medicines, has of late attracted the attention for its anti-inflammatory, anti-rheumatic and hypocholesterolemic/ hypolipaemic activity. A proper evaluation from point of view of productivity will enable to choose the best available strain for commercial cultivation. Gum-resin-Called guggul(u), one of the constituents of several indigenous drugs, has been extensively investigated. Highly rated in Ayurvedic medicine for treatment of rheumatoid arthritis, obesity and several other disorders. Pharmacological studies of crude drug as well as its fractions and revealed significant anti-inflammatory, anti-rheumatic. and hypocholesterimic

activity, leading credence to ancient claims. A gum exudes from the stem in the cold season. It is collected by making incisions with a knife in the tree, and letting the resin fall on the ground. It exudes in large tears soft and opaque, hardens, and turns brownish black very slowly. A single tree is said to yield from half to a whole seer. The gum is used medicinally. It also forms one of the ingredients of incense. It is used as a toothbrush and is said to strengthen the gums and to render loose teeth firmer. Indigenous compound 'Guggulipid', useful in heart diseases and gout. The gum of Guggul drug is bitter, pungent hot, acrid, laxative, stomachic and astringent. It is a tonic, rejuvenator and revitalizer. It is highly efficacious drug in rheumatoid arthritis, obesity and neurological disorders. It lowers blood cholesterol. It is light in digestion and effective in alleviating pain any where in the body and correcting iron deficiency. Wherever there is pain particularly in joints, back, spine or even in legs guggul gum is an efficacious remedy. The gum should be washed cleaned and purified with triphala. Guggulipid Purified Guggul can be taken by itself. It has excellent germicidal and bactericidal properties. Guggulip tablets, taken twice a day is highly efficacious in muscular rheumatic pains. Inhalation of fumes from burning gum is recommended in hay fever. During the winter months incisions are made in its greenish yellow outer bark, to release a fragrant golden resin known from ancient times as an important source of Indian medicine. Resin is useful in indolent ulcers and as gargle in pyorrhea alveolar, chronic tonsillitis and pharyngitis. Inhalation of fumes from burning gum recommended in hay- fever, chronic bronchitis, nasal catarrh, laryngitis and phthisis. Commercial product contains 1.45% of essential oil, besides gum and resin. Originally, the fragrant resin which burns in fire, melts in the sun, and forms a milky emulsion when stirred in hot water, was used for religious ritual. Mentioned in the earliest instructions for performing Hindu religious oblations. It was traditionally burned by Indian virgins in rituals designed to enamor potential bridegrooms.

The only part of the Indian bdellium used by Ayurvedic medicine is the fragrant oleoresin, from which are extracted drugs for the treatment of arthritis, water retention, rheumatism, and glandular and neurological disorders. Contemporary clinical tests have located a steroid fraction in the resin, which has proved as effective in the treatment of secondary arthritis problems as hydrocortisone, as well as a highly potent anti-inflammatory agent. The demand for the Guggul gum is estimated to be 300-500 tones per annum and in 1986 we had to import 50 tones of this gum from Pakistan.

Because of its demand, commercial cultivation of Guggul has been started at Mangaliavas in Ajmer District as also by a number of private organizations.

Vegetation on Hills and Rocky Out Crops

The hill ranges in the Indian Desert have quite sparse vegetation. The vegetation cover here depends much on soil cover. Plant communities in this ecosystem have been grouped as mixed xeromorphic thorn forests and consists mainly of *Salvadora oleoides* - *Euphorbia caducifolia* associations.

***Euphorbia caducifolia* Haines (EUPHORBIACEAE)**

Local name : 'Thor', 'Danda Thor'

One of the most characteristic rock plant is *Euphorbia caducifolia*. This shrub is very common in Jodhpur area particularly near Kailana. In Barmer region it covers almost the entire hill side.

A fleshy, much branched thorny dendroid dense, fleshy shrub, 1.5 to 2 m high. Armed with stipular spines on the upper part, unarmed below.; bark smooth, green; spines in pairs from large conical tubercles., sharp, red when young, at length black. Leaves 8-12 mm long, sub orbicular, acute at apex., undulate along the margins, thick, fleshy, glabrous., crowded at the ends of branches, early deciduous involucre solitary, red or yellowish green, in axils of fallen leaves towards the apex. Capsules 8 mm in diameter, red, acutely trigonus. Seeds spherical, glabrous, brownish. Flowers; orange-red. Fruit a capsule, sharply 3 lobed. *Euphorbia caducifolia* store large amount of water in their cavernous leaves and specially stems. These remains green all over, and even after severe desiccation, can wonderfully respond to moisture. Leaves, and stem store large amount of water in their cavernous leaves and specially stems which remain green all over, and even after severe desiccation can wonderfully respond to moisture.

Plants are used to protect the fields from grazing animals. *Euphorbia caducifolia* bushes grow and they are also utilized as fuel wood in the face of droughts when all other available material has been utilized, even as feed for goats when nothing else is available during droughts, the degradation is on its extreme. Latex of the plant is a rubefacient to prevent the inflection of eczema and ring worm. Latex is also a health tonic. It is applied to the skin on blisters and wounds and is also applied on burnt and paining parts of the body. 2-3 drops of the latex is added into goat milk along with sugar and is taken in dysentery. Latex is also applied on body for

body pain and is also used as an antidote to snake-bite. Fresh stem pasted with 'Ajwayan (*Carum copiticum*) is roasted on fire, then powdered and mixed with 'Desi Khand' (Local Sugar) and taken against asthmatic complaint. (Latex and leaves are taken as such to prevent the 'Jalindar' (Dropsy) and other stomach disorders.

***Withania somnifera* (L.) Dunal (SOLANACEAE)**

Local name : Ashwagandha

A much branched erect leafy perennial unarmed under shrub found through out drier parts of India. With thin woody stems and leaves. Flowers small greenish or yellow. Calyx persistent in fruits, papery, larger than the berries which are orange-red.

It is a reputed medicinal plant, very much useful in Indian System of medicines for the cure of various diseases such as rheumatism, as also a tonic. The leaves are applied locally to tumors and tubercular glands. But it is the roots of this plant that are of great medicinal value. 1-3 gms of fine powder of roots with milk twice a day is efficacious in general debility and neurological disorders. They are used in dyspepsia, rheumatism, lumber pains and for producing abortion. Ground leaves and powdered roots are applied to carbuncles, ulcers and painful swellings. Withaferin A, one of the constituents of Ashwagandha has been reported to show marked tumor inhibitory. The fruit is considered as diuretic and in old age debility. To those who suffer from anxiety, neurosis, it acts as calming and soothing sedative. It is a best vitalizer and rejuvenator and virilific. Its oil, known as ashwagandha oil should be massaged all over the body. It strengthens the nerves and induces sound sleep. Oil also cures fatigue, exhaustions and insomnia. It is highly beneficial since it prevents premature aging.

The drug consists of dried roots of the plant. Ashwagandha is useful in consumption, sexual and general weakness and rheumatism. It is diuretic, i.e. it promotes urination, acts as a narcotic, and removes functional obstructions of body. The root powder is applied locally on ulcers and inflammations. The antibiotic and antibacterial activity of the roots as well as leaves has been demonstrated (Jain, 1994).

The plant is nervine sedative. Leaves and root have narcotic poisons. The root is an aphrodisiac. Used also in consumptions, emaciation and debility. The drug is reputed as improving vitality and preventing premature decay. Used to overcome sterility in women

Withania somnifera although has a number of active principles, but it is somniferine which is most important of them all. There are at least two distinct varieties - Nagori Ashgand and Dakashnui Ashgandh. The roots of the latter become fibrous and hence not very useful in comparison to Nagori Ashgandh which when broken emit white powder. Nagori Ashgandh is now not available in Nagore but is now cultivated in Southern Rajasthan and Madhya Pradesh. Nagori Ashgandh (*Withania somnifera*) roots have been mentioned to be of high value in comparison of other samples. The WS?20 of this species, released for commercial cultivation, is probably from this biodiversity region.

Although not so much familiar with the cold desert, as with the hot desert, but since I have been asked to include cold desert in this lecture, I propose to show some important modifications of plants of cold desert with respect to their habitat.

Cold Desert

The Himalayas are the store house of plant diversity. The rugged topography and enormous variation in climate and soils in Himalayas have added towards the diversification of plant genetic resources. With the increasing altitude, combined with low rainfall and high temperature, the cold arid climate of Ladak, Lahul, Spiti and Kinnaur, forms the stress area of cold climate. The cold desert comprises the Ladak district of Jammu and Kashmir and the Lahul Spiti district of Himachal Pradesh. The total area of cold arid zone of India consists of nearly, 1,10,000 sq. km. The region is characterized by stunted desert vegetation of tufted plants. The area of Ladak desert from Drass onward receive very little precipitation. The environment in the cold desert is incredibly harsh. The plants are generally stunted, tufted with reduced vegetative parts, having massive root stocks capable of penetrating deeper layers of soil. These help the plants to perenate deeper layers of soil through long spells of low temperature, often falling to 35°C as there is no insulating humus layer or snow cover to protect the perenating organs. Many plants survive extreme ecological conditions by adopting strange appearances or interesting modes of perenation. They are generally restricted to sheltered slopes, rock crevices and rock ledges. The commonest adaptation seen is cushion habit, development of wool and small size of leaves with thick and hairy texture.

There are some five important stresses in the cold desert :

1. Dryness of the atmosphere
2. Low precipitation
3. Low capacity of substratum to retain moisture
4. Frequent winds, snow and frost
5. Excessive grazing by sheep.

Since I am not much familiar with the cold desert, I will only highlight some of the important shrubs or say undershrubs of that region, habitat wise:

1. Rocky Slopes : *Maconopsis aculeata*, *Rosa webbiana*, *Saxifraga stenophylla*, *Eremurus himalaicus*, *Potentilla curvisetta*, *Rheum webbianum*, *Arenaria polytrichoides*,
2. Dry stony slopes : *Thermopsis inflata*, *Verbascum thapus*, *Echinops cornigerus*
3. Open slopes : *Anemone obtusifolia*, *Astragalus grahamianus*, *Drabasetosa*, *Herallium lallii*, *Decopetalum heterophyllum*.
4. Alpine steep slopes : *Androsacae sempervoides* , *Pedicularis biocornuata*
5. Over hanging rock faces : *Arenaria bryophylla* (hard mats-tight round cushions), *Arenaria densissima* (forming large compact tufts).
Thylocospermum caespitosum (hard compact cushions).
6. Forming forests in upper limits of tree growth : *Betula utilis*.

7. Sandy scree (small open rocks on the side of the mountain): *Arenaria edgiworthii* large green dense mats).
8. Whitewooly: *Tanacetum tibeticum*, *Sassurea simpsoniana*, *S.graminifolia*, *S.gossipiphora* (snow ball-like).
9. Robust shrubby perennials : *Paeonia emodi*, *Epilobium latifolium* (erect leafy perennial on damp places).
10. Damp slopes (recently cleared of snow): *Adonis chrysocyathus*

To me personally my innumerable visits to the desert have filled me with joy and zeal. Not only I began liking and loving the desert plants, I began to be more and more drawn to the desert itself. No commentary could be more relevant and eloquent on the desert of Thar than these noble words contained in this Sanskrit Couplet : -

पातुं वाञ्छति चाकस्य कदतो नेत्राम्बु यत्राम्बुदः
छायामिच्छति विच्छदक्षितिरूहः प्रत्याशया धावताम् ॥
अन्तर्गूढजला जनश्रमजलं नेतुं नदी कांक्षति
प्राप्तास्तं मरुनीवृतं वयमितो दूरं तु गंगा नदी ॥

Oh ! the beautiful desert with your ocean of sand and scorching sun, the clouds search for a drop of water from the tears of Chatak bird's eyes; where leafless trees wish to get shadow of a man who himself is running to get their shadow from the scorching heat of the sun, where dry rivers hope to get water even from the perspiration of the sweating man. Oh ! the river Ganges, you are far far away to flow in the desert.

Ethnobotany of Shrubs of Arid Rajasthan

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Knowledge about uses of plant resources for survival and livelihood among indigenous and local communities has been perfected over centuries of experience and has passed on orally, from one generation to another. Understanding this plant - human relationship and documenting this information comes under the realm of ethnobotany. Ethnobotanical studies in Indian Desert began as far back as in 1862 when King (1869, 1870) listed wild plants used as food and vegetables during famine. This was followed by Chopra (1960) listing 56 medicinally important plants, which was extended by Gupta *et al.* (1966) to 108 species. Bhandari (1974) listed 25 species as famine foods. Shekhawat and Anand (1984) listed 78 medicinal species used by Bhils, Nuts, Kalbeliyas and Raikas. Saxena (1979 & 1981) and Saxena & Shankarnarayan, (1985) summarized 60 species as food and economic plants. Shekhawat (1986) gave an account of Ethnobotanical survey while Pandey *et al.*, (1989) listed 170 useful species in Jodhpur district. Medicinal value of 116 species was listed by Kumar and Parveen (2000). In an excellent treatise, Singh and Pandey (1998) described 610 species in 'Ethnobotany of Rajasthan'. In a DST sponsored project Kumar and Parveen (2004) have listed 131 ethnomedicinal plants besides their distribution and threat status.

However, these works deal with all types of plants including herbs, shrubs, climbers, trees, grasses and sedges. A focused review on ethnobotany of arid shrubs is lacking. An attempt has therefore been made to present the ethnobotanical uses of arid shrubs in this paper.

Floristic and Ecological Status of Shrubs

Indian arid zone has 682 species (Bhandari, 1990), of which only 48 species are shrubs, 14 are shrub-cum-trees, 40 are undershrubs and 14 are climbing shrubs. All these put together make up 116 species, which is 17% of the total floristic composition. For the purpose of this paper, we have included shrubs (48), undershrubs (40) and shrub-cum-trees totaling 102 taxa of which 34 or 33.3% are of medicinal values. Although these constitute 17% of total flora in the Indian Desert, yet they cover over 70-80 % of the desert landscape from Aravallis to the International border. In the extreme arid zone, nearly 100% woody perennials are shrubs as trees are practically absent (Shankar and Kumar, 1987). It can be therefore said that though shrubs are less in 'variety',

they are ecologically most successful biotypes in the desert environs. Since they are most abundantly available, desert dwellers have found a large variety of their uses. But their uses in traditional healthcare have been staggeringly enormous. These and other uses were documented in four districts; Jaisalmer, Barmer, Bikaner and Jodhpur by visiting 6-8 villages in each Tehsil of each district. Individuals and group interviews were conducted to document the uses and identify the plants correctly. The data was synthesized and discussed below.

Ethnomedicinal Shrubs

Of the 102 species of arid shrubs in Western Rajasthan, 34 have been found to have medicinal value. These belong to 33 genera and 24 families. The maximum shrub species, three each belonged to Asclepiadaceae and Solanaceae, followed by two species each in Malvaceae, Acanthaceae, Fabaceae, Euphorbiaceae, Mimosaceae and Lamiaceae. Remaining 16 families have one shrub species each of medicinal value. A perusal of medicinal uses of these shrubs (Table 1) indicates that leaf was most used plant part in as many as 77 prescriptions, followed by roots (27 uses), stem (22 uses), latex (16 uses), bark (9 uses), seed (10 uses), whole plant and gynostegium (9 uses each), flower (11 uses), fruit (9 uses), inflorescence (5 uses) and remaining two or one uses in respect of resin, rind and galls.

Though shrubs constitute nearly 17% of the desert flora, they constitute a bigger proportion of 26.7% of a total of 131 medicinally important plants in the Rajasthan desert (Kumar and Parveen, 2004). Hence shrubs as a biotype are medicinally more in number than other woody perennials like trees and climbers which have nearly 20% and 8.39% medicinal taxa, respectively.

Ethnoveterinary Shrubs

Shrubs provide health aids not only for human but also their livestock. As many as 13 shrubs of ethnoveterinary importance (Table 2) have been identified (Kumar *et al.*, 2004). These belong to 10 families. Asclepiadaceae, Ceasalpinaceae and Fabaceae, each have two shrub species of veterinary importance while remaining seven families have one species each of ethnoveterinary value. *Calotropis procera* has been reported to cure maximum number of ailments, i.e. 8 followed by 3 each of *Capparis decidua*, *Leptadenia pyrotechnica*, *Ziziphus nummularia*,

Tephrosia purpurea, 2 uses each of *Lycium barbarum* and *Ricinus communis*. Remaining species each has single medicinal use. Amongst the plant parts, stem has been the most used part i.e., in 6 ailments, followed by roots and leaves (5 ailments), and two uses each of inflorescence, gynostegium, bark, fruit, seeds, whole plant and one use of latex.

Miscellaneous Uses

Our studies have revealed that 18 taxa have a large number of uses (Table 3) for overall survival and sustenance. Of these maximum species (3) belong to Asclepiadaceae, followed by Fabaceae and Euphorbiaceae (2 each) and remaining 11 families had single species. Interestingly maximum uses were found in respect of stem (63 uses) followed by leaves (9), whole plant (7), inflorescence (4), roots (4) gum (2) and latex, oil and fruit, one each. Stem of *Capparis decidua* has maximum uses (14) followed by *Calotropis procera* (11), *Ziziphus nummularia* (10), *Prosopis juliflora* and *Calligonum polygonoides* (7 uses each), *Leptadenia pyrotechnica* and *Crotalaria burhia* (5 uses each) and remaining species one or two uses each. Stem was being used as furniture, cart wheels, tools, stilts, windows, doors, toys, utensils, fencing, thatching, ropes, brooms, matchstick, musical implements, incense, deodorant, tooth brushes, dying leather, worshipping, in magico-religious beliefs and explosives. Detail of other uses is given in Table 3.

Trading

While trading of plants of miscellaneous uses is abundant in rural markets, estimates are not available on their volume and amount. However, a survey of ethno-medicinal plants trading in the four districts viz, Jaisalmer, Barmer,

Bikaner and Jodhpur revealed that there was a difference in procurement and sale price of herbals to the tune of 15-25 per cent (Kumar *et al.*, 2005). Their sale price also varied within and between different districts; the variation being as high as 400 per cent. From the 41 plants procured from within Rajasthan markets, 13 are shrubs. Of these, six are amongst the first 20 most traded and exported herbals. In addition, there are three other shrubs of which exact trade data though not available, are substantially traded (Table 4).

Thus on the basis of ethnobotany, distribution and trade potential, the above shrubs need to be given research and extension priority for large scale cultivation so as to generate additional income for the farmers.

Conclusion

It is evident from above account that shrubs are vital for ecological and economic sustenance of people in the desert. Some most used species as medicine or otherwise are *Calotropis procera*, *Capparis decidua*, *Ziziphus nummularia*, *Calligonum polygonoides*, *Prosopis juliflora* and *Leptadenia pyrotechnica*. Incidentally, these very species are also widespread as dominant formation on almost all desertic habitats (Kumar, 1997). However, as many of such habitats are now threatened due to pressure of cultivation, irrigation, industrialization, urbanization, mining and over-utilization, populations of many of these shrubs are dwindling in extent and density. Future reboisement programmes should therefore utilize these shrubs for plantations. Concurrently, adequate research emphasis needs to be given for understanding their biology, value addition and product processing besides chemical and clinical validation of the medicinal claims.

Table 4. Trading of some selected medicinal plants

Name	Quantity in trade (tons/yr)	Abundance in nature in arid zone			Being cultivated	Needs cultivation
		Abundant	Adequate	Insufficient		
<i>Withania somnifera</i>	5702.4	-	-	Y	Y	Y
<i>Cassia angustifolia</i>	4206.7	-	Y	-	Y	Y
<i>Adhatoda vasica</i>	4067.3	-	-	Y	-	Y
<i>Sida cordifolia</i>	2585.9	-	Y	-	-	Y
<i>Ocimum sanctum</i>	2290.3	-	-	Y	-	Y
<i>Tinospora cordifolia</i>	1832.2	-	-	Y	Y	Y
<i>Aloe vera</i>	?	-	Y	-	Y	Y
<i>Commiphora wightii</i>	?	-	-	Y	-	Y
<i>Lawsonia inermis</i>	?	-	-	Y	Y	Y

Y=Yes ; ?= Exact data not available.

Table 1. Medicinal uses of shrubs

Ailment	Part Used	Mode of Administration
<i>Abutilon indicum</i>		
Kidney pain	Root	One teaspoon powdered root is taken orally with water, it acts as diuretic
<i>Adhatoda vasica</i> (Acanthaceae)		
Cough	Leaves	Decoction is prepared from fresh leaves of this plant, dried or fresh ginger pieces and a pinch of black pepper. It is taken orally thrice a day till the cough is cured.
<i>Aerva pseudotomentosa</i> (Amaranthaceae)		
Antidote	Inflorescence	Slightly warmed inflorescence tied on the affected portion to reduce the pain
	do	Inflorescence boiled in water, cool it to lukewarm. Scorpion bite portion kept in this water for 1/2 an hour. It neutralises the poisonous effect
Eye pain	do	Aqueous paste of inflorescence applied over eyelids and tied with cloth to get relief in eye pain
Flatulence	do	Pillows and mattresses stuffed with inflorescence. Patient suffering from flatulence allowed to sleep over it for 15- days
Kidney pain	Root	Crushed roots boiled in water and its filtrate is taken orally to get relief in kidney pain
Refrigerant	Seed	Aqueous paste of seeds applied on affected portion and tied with the cloth, gives cooling effect
Skin	Root	Roots boiled in water and its filtrate is taken orally to cure skin irritation
Stomachache	Root	Roots boiled in water and its filtrate is given orally in stomachache
	Root	Fresh roots chewed to cure stomachache
	Inflorescence	Inflorescence boiled in water and its filtrate is taken orally to cure dysentery
<i>Aloe vera</i> (Liliaceae)		
Antifever	Leaves	Leaves cooked as vegetable and eaten as such for few days
Asthma		Leaves fried in ghee and eaten as such to get relief in asthma
Boils		Extract of leaves mixed with alum and applied on boils to hasten suppuration
		Paste of leaves applied on boils to hasten suppuration
Constipation		Leaves cooked as vegetable and eaten as such for few days. It cures fever caused by heat stroke
Flatulence	Leaves	Leaves cooked as vegetable and eaten as such for few days
		Juice of leaves mixed with wheat flour to make chapati and eaten with butter oil
		Halwa is prepared by adding fresh leaves of this plant with ghee, wheat flour and sugar. It is eaten for few days
Fracture	Leaves	Halwa is prepared by adding leaves of this plant with sugar and ghee. It is eaten as such. It is also tied on fractured bone for early healing.
Inflammation	Leaves	A longitudinal cut is made in central portion of leaves and turmeric powder is filled in it. It is tied on inflamed portion
Pain killer	Leaves	A longitudinal cut is made in central portion of leaves and turmeric powder is filled in it. It is tied on affected portion
Piles	Leaves	A longitudinal cut is made in central portion of leaves and turmeric powder is filled in it. It is tied on affected portion
Rheumatism	Leaves	Upper layer of leaf peeled off and roots of Aak kept on leaf. Both heated for some time. Tablet of 10 g is prepared from above material. One tablet is taken twice a day for one month
		Leaves cooked as vegetable and eaten as such for few months
Ring worm	Leaves	A longitudinal cut is made in central portion of leaves and turmeric powder is filled in it. It is tied on affected portion
Tumour	Leaves	A longitudinal cut is made in central portion of leaves and turmeric powder is filled in it. It is tied on affected portion
<i>Barleria acanthoides</i> (Acanthaceae)		
Toothache	Stem	Branches were used as tooth brush to cure toothache and pyorrhoea.
	Whole plant	Whole plant boiled in water & its filtrate is used for gargle. It gives relief in toothache
<i>Calligonum polygonoides</i> (Polygonaceae)		
Antiemetic	Leaves	Few fresh leaves chewed to get relief in vomiting.
Coolent	Whole plant	Aqueous paste of whole plant is given orally to the person who took heavy dose of opium. It act as coolent for body
Dental problem	Leaves	Young leaves chewed once a day to cure sour teeth
Eczema	Root	Roots dried in shade and made into powder form, mixed with own's urine and applied on eczema
Eye problem	Whole plant	If aak's latex get into eyes than immediately wash the eyes with juice of plant. It neutralises the poisonous effect of latex
Gynaecological	Whole plant	Whole plant except roots is ground into a paste and taken orally. It is used to clean the uterus
	Stem	Coal of stem is taken orally with water to reduce heavy bleeding during menstruation
Pregnancy	Leaves	Leaves boiled in water and its filtrate is given to mother if she gets sick before delivery

Tumour	Leaves	Leaves soaked in water for few hours. Extract is taken out from soaked leaves and applied on tumours. Remaining water is used to wash the tumour
Typhoid	Flower	Flowers boiled in water and its filtrate is taken orally
<i>Calotropis gigantea</i> (Asclepiadaceae)		
Antidote	Latex	Paste is made by adding latex of this plant with sesamum oil and little amount of salt and applied on scorpion bit portion to remove poisonous effect
Antifever	Gynostegium	1-2 flowers taken orally with water to cure fever. It should not be taken during the month of Chaitra and Vaishak
Cough	Root	Slightly warmed roots ground to make powder. 1/2 g powder taken orally with water once a day for a week
Tuberculosis	Gynostegium	One piece of gynostegium is boiled in water and its filtrate is taken orally twice a day for few days till the patient is cured
<i>Calotropis procera</i> (Asclepiadaceae)		
Antimalaria	Latex	Latex mixed with sand and made into tablet form. One tablet taken orally with water twice a day for 2 days to cure malaria and fever
	Gynostegium	100g gynostegium mixed with 25g black pepper and consumed orally with water. 3 tablets should be taken in 7 days to cure malaria
	Root + Stem	Both dried in shade and ground into powder form and mixed with jaggery and given orally to the patient to cure malaria
Cuts	Latex	Latex is applied on cut region for early healing
Antidote	Latex	One drop of latex allowed to fall on the sand and made into tablet form. One tablet is given orally to the affected person in snake bite. The poison comes out through vomiting
	Gynostegium	If mad dog's bite, one piece of gynostegium is given orally with water to the affected person. The poison comes out through vomiting
Antifever	Flower	1-2 flowers taken orally with water to cure fever. It should not be taken during the month of Chaitra and Vaishak
	Leaves	Powdered leaves mixed with sugar and it is taken orally with water to cure fever
Arthritis	Latex	Latex applied on joints region with the help of camel's pellets. It reduces the swelling on joints and pain
Asthma	Flower	5-6 flowers soaked in buttermilk for 2-3 hours and cooked as vegetable and eaten as such
	Leaves	Dried leaves crushed into powder form and filled in 'chilam'. The smoke is inhaled to get relief in asthma
	Gynostegium	1 gynostegium is given to the patient for 1st day, two for 2nd day, three for 3rd day and so on upto seven days and again a number of gynostegium is given in decreasing order like seven for 8th day, 6 for 9th day and so on to cure asthma
	Latex Stem	Latex mixed with jaggery and consumed as such A hollow is made into stem of this plant. Mixture of 50g coriander seeds, 50g sugar candy and some dry chestnuts kept in the hollow and close it for 8 days. On 9th day this mixture is taken out and taken orally in the morning
Boils	Bark	Bark is heated on a pan and then put in water. This water is applied on boils
	Flower	Dried flowers crushed into powder form and apply on boils only once
Cancer	Gynostegium	1-2 pieces of gynostegium is taken orally with water daily in the morning to cure any type of cancer
Constipation	Leaves	Leaves smeared with mustard oil, slightly warmed and tied on stomach portion to get relief from constipation
Cough	Gynostegium	Heat on pan till it turn into ash. Add common salt to it and taken orally twice a day for 4 days to cure cough problem
Cuts	Bark	Inner bark is tied as a herbal bandage on cut region to stop bleeding and for early healing
Dental problem	Latex	Mustard oil is applied in the cavity of tooth. Latex of plant soaked in piece of cotton and put in the cavity. Repeat this procedure next day also. The germs will come out and gives relief in pain
Dislocation of naval	Latex	Latex apply on naval region to cure dislocation of naval
Dysentary	Gynostegium	Ash of gynostegium is given orally with water to the patient suffering from blood dysentary
Earache	Leaves	Yellow mature leaves is slightly warmed and its juice is taken out. 1-2 drops of this juice poured into ears to cure earache
Epilepsy	Flower	Paste is made by adding 25 flowers of this plant with 12 pieces of black pepper and 1g jaggery. It is taken orally with water twice a day
Eye problem	Latex	Few drops of latex mixed with ghee and apply on eye lids to get relief in eye irritation and to reduce redness of eyes
	Leaves	Aqueous paste of leaves tied in a cloth and kept on fresh earthen pot for half an hour. Then keep this cloth on eye lids for relief in eye pain
Jaundice	Latex	Apply any edible oil over hands and feet. Latex applied over it for 3 days. Water should not come in contact with hands and feet during treatment

Pain killer	-	Sand near the roots of 3-4 year old plant is taken out and warm it. Patient having backache problem is allowed to sleep over it for few hours for 10-15 days
Pain killer	Leaves	Leaves smeared with mustard oil ,slightly warmed.Tied on affected portion for relief in chest pain, headache and knee pain
Refrigerant	Latex	Apply any edible oil on burnt portion. Latex applied over it so that no blisters would formed
Rheumatism	Leaves	Mixture prepared by adding 30 yellow mature leaves with 500g wheat and 500g cane sugar. It is heated in 500g cow's ghee on a pan and ground into powder form. 'Halwa' a sweet dish is prepared by adding this powder and wheat flour
Skin irritation	Leaves	Leaves warmed in sesamum oil . Cool it and then the extract is taken out and applied an affected portion to cure skin irritation
Sprain	Latex	First any edible oil is applied on affected portion and than the latex is applied over it
Stomachache	Gynostegium	1 piece of gynostegium is given orally with water to the patient suffering from stomachache
Throat problem	Latex	Latex applied on central portion of head to cure lowering of uvula locally called as 'gala upadna'
Tuberculosis	Latex	1-2 drops of latex given orally to the patient for 15-days
	Flower	1-2 flowers heated in ghee and this ghee is consumed as such
Tumour	Leaves	Warmed leaves tied on small tumours for early suppuration
Wounds and injuries	Latex	Any edible oil is applied on injured portion and than latex applied over it . It cures the old injury
	Bark	Fresh inner bark is tied as a herbal bandage on wounds for early healing
Xiphoid process	Latex	Any edible oil is applied over the xiphoid process and latex applied over it to cures Xiphoid problem locally called as "Koopli galna"

***Capparis decidua* (Capparaceae)**

Arthritis	Bark	Ash of bark is applied on knee joints
Asthma	Fruit	Powdered mixture is prepared by adding, 100g capparid fruit, 10g heera heeng, 5g pipli (small), 10g joharad and 200g sugar candy, 10g of mixture taken twice a day in morning before meal and in evening after meal
Boils	Bark	Aqueous paste of bark applied on boils
Constipation	Fruit	Mixture is prepared from powdered dry fruit of this plant, rock salt, powdered leaves of <i>Cassia angustifolia</i> and small harad. It is taken orally with water in night
Cough	Flower	Aqueous paste of fresh flowers is mixed with sugar and taken orally with water
	Stem	Powdered coal of stem is made in which cane sugar is added. 10g is taken orally with water once a day for 5 days
Cuts	Stem	Wet stem heated on fire and the juice that comes out is applied on cut region to stop bleeding and for early healing
Dental problem	Stem	Extract of fresh branch is applied on teeth to cure toothache
	Leaves	Spinous tipped part of young leaves is put in between two teeth to relieve in pain
	Leaves	Ash of leaves used as toothpowder to cure toothache
Eczema	Stem	Wet stem smeared with oil and burnt on fire. The extract which comes out during burning is applied over affected portion
	Leaves	Aqueous paste of young leaves applied on eczema
Eye problem	Stem	Extract of fresh stem applied on eyelids to cure cataract
Fracture	Stem	Powdered coal of stem mixed in 1/2 cup of sesamum oil and given orally to the affected person
Gastritis	Stem	Extract of wood taken orally with water in gaseous problem
	Fruit	Powdered fruit is taken orally with water
Gynaecological	Stem	Powdered coal of stem mixed with sugar candy and taken orally with water. It reduces heavy flow of blood during menstruation
Injury	Stem	Powdered coal of stem mixed with vegetable oil and given orally to cure old injury.
Jaundice	Flower	Powdered flower taken orally with water
Pain killer	-	Sand near the roots of 2-3 year old plant is taken and warmed. The pregnant women having backache is allowed to sleep over it for few hours
	Root	Coal prepared from roots taken orally with ghee and milk for 3-4 days to cure body pain
		Equal amount of fresh roots of <i>Capparis</i> and <i>Prosopis cineraria</i> taken and the upper layer is peeled off. Now slightly saute in mustard oil and then spread on floor. Person having backache is allowed to sleep over it for few days
Skin problem	Root	Roots cut into small pieces and boiled in water. Its filtrate is used for bathing to cure urticaria
Tuberculosis	Leaves	Aqueous paste of young leaves is made and sieved through a muslin cloth. Some water is added to filtrate and taken orally twice a day for five days
	Fruit	Mixture is prepared by mixing fruit of this plant with 100g amla fruit, 10g alum (white), 10g big harad, 10g turmeric powder, 10g dried ginger powder, 10g big pipli and 200g sugar candy. 10g (each dose) mixture taken twice a day in morning before meal

		Fruits cooked as vegetable in pure ghee in which red chilly, turmeric powder and corander powder is added. This is eaten twice a day for 90 days
Typhoid	Flower	Powdered flower taken orally with water
<i>Cassia angustifolia</i> (Caesalpinaceae)		
Asthma	Leaves	Powdered leaves mixed with desi sugar and taken orally with water daily once a day before going to bed for one month for relief
Constipation	Leaves	1 teaspoon powdered leaves is taken orally with water in night
Flatulence	Leaves	1 teaspoon powdered leaves is taken orally with water in night
Piles	Leaves	Mash the fresh leaves and its extract is taken orally with water
Stomachache	Leaves	Mixture is prepared by adding powdered leaves of this plant and ajwain seed powder and taken orally with water
<i>Citrus lemon</i> (Rutaceae)		
Gastritis	Fruit	Ajwain seeds mixed in lemon juice and dried. Than ground into powder and taken orally after meal
<i>Clerodendrum phlomidis</i> (Verbenaceae)		
Arthritis	Leaves	Fresh leaves slightly warmed and tied on joint portion
Boils	Leaves	Aqueous paste of leaves applied on boils
Flatulence	Leaves	Extract of leaves mixed with sugar and ghee and taken orally with milk
Pain killer	Seed	1 teaspoon powdered seeds mixed with halwa and eaten as such to get relieve in backache
Rheumatism	Leaves	Few leaves boiled in water. Some rice in a cloth bag kept in boiling water. After some time rice bag is taken out and 250g ghee and 100g sugar candy is mixed and eaten in the morning for 7 days
Ring worm	Leaves	Warmed leaves tied on affected portion
Sciatica	Leaves	Fresh leaves boiled in water and its filtrate is taken orally at time of severe pain
Stomachache	Leaves	Aqueous paste is made into a tablet. One tablet is taken once a day for 3 days
Wounds	Leaves	Aqueous paste applied on wounds to repel insects and flies
<i>Commiphora wightii</i> (Burseraceae)		
Toothache	Stem	It is used as tooth brush in toothache
	Resin	Oleo gum resin applied on teeth to get relief in toothache
Skin problem	Bark	Aqueous paste of bark applied on affected portion to cure eczema
<i>Crotalaria burhia</i> (Fabaceae)		
Boils	Root	Aqueous paste of fresh root applied on boils
Cold and Cough	Root	Roots boiled in water and its filtrate is taken orally
Constipation	Root	Crushed roots boiled in water and filtrate is taken orally in constipation
Coolent	Root	Roots boiled in water and its filtrate is taken orally. It acts as coolent
Diuretic	Root	Decoction prepared from crushed roots and sugar candy. It is filtered and than taken orally
Earache	Root	Few drops of extract of fresh roots is poured into ears to get relieve in ear pain
Flatulence	Root	Root powder boiled in water and some sugar candy added and taken orally
Nasal bleeding	Root	Crushed roots boiled in water and its filtrate is taken orally to stop nasal bleeding
Stomachache	Root	Crushed roots boiled in water and filtered. It is taken orally in stomachache
Stone problem	Root	1 teaspoon powdered root is taken orally with water to cure stone problem in kidney
<i>Datura stramonium</i> (Solanaceae)		
Asthma	Leaves	Powdered leaves filed into traditional cigar locally called as 'hukka'. It is burnt and its smoke is inhaled to get relief in asthma
Flatulence	Leaves	Leaves slightly boiled in water & its residue is tied on affected portion with the help of cotton cloth
Rheumatism	Root	Aqueous paste of roots mixed with desi sugar and eaten for 10 days with water once a day
Ring worm	Leaves	Leaves slightly smeared with mustard oil and warmed. It is tied on affected portion
<i>Euphorbia caducifolia</i> (Euphorbiaceae)		
Purgative	Latex	Latex applied on one side of roasted 'papad' (made up of moong and urad flour) and eaten. It is used as purgative
Stomach disorder	Leaves	Leaves cooked as vegetable and eaten to cure stomach disorders
<i>Grewia tenax</i> (Tiliaceae)		
Fracture	Root	1 teaspoon powdered root taken orally twice a day with fresh milk. It helps in joining the bones
Stone problem	Leaves	1 glass of juice of leaves is taken orally in kidney stone problem
Urticaria	Leaves	Aquous paste of leaves taken orally with milk

***Jasminum grandiflorum* (Oleaceae)**

Blisters Leaves Young leaves chewed but don't swallow the juice of leaves. Repeat it twice or thrice a day

***Lawsonia inermis* (Lythraceae)**

Refrigerant Leaves Aquous paste of leaves applied on burnt surface

Sterility Leaves Aquous paste of leaves given orally with water to woman. It induces sterility

Refrigerant Leaves Aquous paste of leaves applied on burnt surface

***Leptadenia pyrotechnica* (Asclepiadaceae)**

Antibortion Whole plant Whole plant boiled in water and its filtrate is taken orally thrice a day for 7 days to stop abortion

Antidote Stem Juice of stem applied on snake bite portion to remove the poisonous effects

Stem If aak's latex get into eyes than immediately wash the eyes with juice of stem of this plant. It neutralise the poisonous effect of aak's latex

Antifever Fruit + flowers Both were boiled in water & its filtrate is taken orally to cure high fever

Arthritis Stem Extract taken out from fresh stem and 4 kg extract mixed with 1 lit. til oil Add 1/2 kg pulp (remained after extract is taken out) to it. Heat all these three ingrediants till it shows redness in color. Now sieve it and this oil is used for massage

Flatulence Stem Stem boiled in water and its filtrate is given orally to the patient for one week

Rheumatism Stem Stem juice taken orally 2-3 times a day. After that ghee should be given orally to rheumatic patient for relief in pain

Skin irritation Whole plant Juice of stem applied on affected portion of skin. It is a remedial treatment for eczema, white spots and skin irritation

Tumour Stem The extracted juice of crushed stem mixed with 'bajra' flour and applied on small tumour for fast healing

Typhoid Fruit + flowers Both were boiled in water & its filtrate is taken orally to cure typhoid

***Lycium barbarum* (Solanaceae)**

Cold Leaves Aqueous paste of leaves made and its extract is taken out. Now the smell of this extract is inhaled to get relieve in cold

Skin irritation Whole plant Whole plant boiled in water and its filtrate is used for bathing. It removes the skin irritation

***Majorana hortensis* (Lamiaceae)**

Earache Leaves Few drops of juice of leaves poured into ears to get relief in ear pain.

Inflammation Leaves Ash of leaves mixed with ghee & applied on the swollen portion caused due to hitting by a solid object

Refrigerant Bark Bark rubbed on hard surface with cold water and paste of bark applied on burnt surface

Skin irritation Leaves Leaves smeared with ghee & warmed. It is tied on affected portion to cure skin irritation

Sprain Leaves Paste of leaves is slightly warmed & applied on affected portion

Wounds Leaves Ash of leaves applied on wounds for early healing

***Mimosa hamata* (Mimosaceae)**

Asthma Stem Stem boiled in water and its filtrate is given orally to asthmatic patient

***Ocimum sanctum* (Lamiaceae)**

Cold & cough Leaves Decoction of fresh leaves prepared with dried powder of ginger and a pinch of black pepper prepared and taken for 3 day

Blood pressure Leaves Paste of fresh leaves and black pepper prepared and one tea spoon butter is mixed and eaten for once a day for few days

***Peganum harmala* (Zygophyllaceae)**

Ear problem Whole plant Whole plant is burnt and its smoke is passed into ear to kill bacteria present in it

***Prosopis juliflora* (Mimosaceae)**

Asthma Leaves Powdered leaves filled in 'chilams' on burning coal. Its smoke is inhaled to get relief in asthma

Boils Leaves Paste of leaves applied on boils to hasten suppuration

When boil is formed by uprooting of hair (folliculitis), leaves paste is applied on the boils

Eye problem Leaves Juice of leaves added with sugar candy and taken orally to cure cataract

Paste of leaves applied over the eyelids. It gives relief in eye irritation

Paste of leaves applied on abdomen to cure stomachache

***Psidium guajava* (Myrtaceae)**

Dental problem Fruit Fruit boiled in water and its filtrate is used for gargle. It gives relief in toothache

***Punica granatum* (Punicaceae)**

Cough Rind Rind rubbed on bronze utensil surface. Its extract is taken orally to cure cough

Throat problem Fruit Dried powder rind mixed with honey and applied on uvula portion

***Ricinus communis* (Euphorbiaceae)**

Arthritis	Leaves	Upper surface of leaves smeared with mustard oil or any other edible oil and warmed. It is tied on stomach region to get relief from stomachache. It is tied on affected portion to get relief from joints pain also
Constipation	Seed	Seed oil is given to the person having constipation
Flatulence	Seed	1/4 teaspoon full seed oil is taken orally to cure flatulence
	Leaves	Leaves smeared with edible oil on upper surface & warmed. It is tied on the affected part of the body. Leaves are boiled in water. Its filtrate is used to cook the rice kept in a small musline bag. This cooked rice is given to the patient suffering from flatulence
Stomachache	Leaves	Upper surface of leaves smeared with mustard oil or any other edible oil and warmed. It is tied on stomach region to get relief from stomachache
Pain killer	Leaves	Upper surface of leaves smeared with mustard oil or any other edible oil and warmed. It is tied on knee to get relief from knee pain
Stomachache	Seed	3 drops of seed oil mixed with sugar balls locally called as 'patasha' and given to children to cure stomach disorders
	Leaves	Upper surface of leaves smeared with mustard oil or any other edible oil and warmed. It is tied on stomach region to get relief from stomachache

***Sida cordifolia* (Malvaceae)**

Arthritis	Seed	Halwa prepared by adding powdered seeds, wheat flour, ghee & sugar. At least 1 kg halwa should be eaten daily to get relief in joints pain
Pain killer	Seed	Halwa prepared by adding powdered seeds of this plant, wheat flour, ghee and jaggery. It is eaten as such to get relief in backache

***Tamarix aphylla* (Tamaraceae)**

Refrigerant	Bark	Powdered bark applied on burnt surface
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***Tephrosia purpurea* (Fabaceae)**

Flatulence	Seed	Powder of 2-4 seeds mixed with butter and eaten for few days
Boils	Leaves	Aqueous paste of leaves applied on boils to hasten suppuration
Stomachache	Root	Root boiled in water and filtrate is taken orally for 3-4 days

***Withania somnifera* (Solanaceae)**

Arthritis	Stem	2 teaspoon powdered stem is taken orally with 50 ml fresh milk. It gives relief in joints pain.
	Root	Halwa prepared by adding powdered roots of this plant, ghee, sugar & wheat flour. Eat 2-3 teaspoon daily in morning before meal for 5 days. It gives relief in joints pain
Asthma	Stem	Stem used in herbal preparation with other ingredients to cure asthma
Eye problem	Root	Halwa is prepared by adding roots of this plant with wheat flour, sugar and ghee. It is given to the person suffering from eyes problem
Flatulence	Whole plant	Whole plant crushed into powder form. One teaspoon powder is taken orally with water to cure flatulence
Pain killer	Stem	2 teaspoon powdered stem is taken orally with milk twice a day to get relief in backache

***Ziziphus nummularia* (Rhamnaceae)**

Abortion	Galls	Mash the fresh galls in water and take out its extract. The extract is given orally to abort 2-3 months foetus
Antidote	Leaves	In dog's bite, paste of leaves applied & tied with a cloth to get relief in pain
Antifever	Seed	Seeds boiled in water and its filtrate is taken orally to cure fever
Antiseptic	Fruit	Fruits boiled in water and its filtrate is used to wash wounds, cuts etc. It is a good antiseptic liquid
Blisters	Root	Crushed roots boiled in water & its filtrate used for gargle to cure blisters in mouth
Boils	Leaves	Paste of leaves applied on boils to hasten suppuration
Cough	Seed	Powdered seeds taken orally with water for relief cough
Toothache	Root	Crushed roots boiled in water & its filtrate is used for gargle to cure toothache
Toothache	Bark	Powdered bark mixed with 'white alum' and boiled in water. Its filtrate is used to gargle to cure toothache
Eye problem	Leaves	Paste of leaves mixed with sand of wasp's house. It is applied on eyes & tied with cloth to get relief in burning of eyes, removes blood clouds in eyes
Refrigerant	Bark	Aqueous paste of bark applied on burnt surface for a cooling effect
Rheumatism	Gum	Laddu's prepared by adding gums of this plant with sugar, ghee and wheat flour. It is eaten as such
Stomachache	Leaves	Aqueous paste of leaves taken orally twice a day to stop bleeding during dysentery
Tumour	Leaves	Paste of leaves mixed with wheat flour and applied on tumour twice a day for early healing

Table 2. Plants of veterinary importance in western Rajasthan

Botanical name, family	Local name	Part used	Prescription
<i>Aerva pseudotomentosa</i> Blatt. & Hall. (Amaranthaceae)	Safed bui	Inflorescence	Warmed inflorescence is smeared on affected part of camel's body to cure swelling and inflammation*
<i>Calligonum polygonoides</i> L. (Polygonaceae)	Phog	Leaves	Fresh leaves are soaked in water for one hour and ground to paste. Few drops of this paste are poured into nose of camel to initiate curding process*
<i>Calotropis procera</i> (Ait.) R. Br. (Asclepiadaceae)	Aak	Latex	Latex is applied on cyst to hasten suppuration and on affected portion to cure cracking of teats
		Twig	Fresh green twig is heated and used as toothbrush to cure gingivitis*
		Gynostegium	Gynostegium is boiled in water and its filtrate is fed orally to kill bacteria in the stomach*
		Gynostegium	Gynostegium mixed with butter milk is given to animals to reduce the infestation of worms in the stomach*
		Bark	Fresh bark is tied as a bandage on udder to cure cracking of teats
		Stem	Stem ash mixed with 'ghee' is applied on wounds for early healing
<i>Capparis decidua</i> (Forsk.) Edgew (Capparaceae)	Keir	Flowers	100-150 g flowers are boiled in water and filtrate is administered orally to camel and goats once a day for three days to cure gastro-intestinal parasitic lobe of worms
		Roots	Charcoal of roots mixed with sesamum oil is given orally to animals for quicker healing of fractured bones*
		Stem	Extract of fresh stem is applied on wounds for early healing*
<i>Cassia angustifolia</i> Vahl (Caesalpiaceae)	Sonamukhi	Fruit	Fruit fed to goats to cure gastric problem*
			Pods and leaves are fed to camels to cure gastric problem*
<i>Crotalaria burhia</i> Buch-Ham. (Fabaceae)	Sinio	Roots	Oral feeding of aqueous filtrate of boiled roots expels placenta*
<i>Leptadenia pyrotechnica</i> Forsk. Decne (Asclepiadaceae)	Kheemp	Stem	Decoction of stem with few seeds of 'ajwain' and sesamum oil is administered orally to expel placenta*
		Stem	Stem decoction is given orally to sheep as it is believed to help in movement of joints i.e. perhaps antiarthritic*
		Stem	Filtrate of stem in water is administered orally to camels to cure flatulence.*
<i>Lycium barbarum</i> L. (Solanaceae)	Murali	Roots	Roots are boiled in water and its filtrate is given orally for expulsion of placenta*
		Roots	Powdered roots put into nose of horse to get relief in respiratory problem*
<i>Parkinsonia aculeata</i> L. (Caesalpiaceae)	Vilayti kikar	Leaves	Aqueous paste of leaves is fed orally to goats to cure constipation*
<i>Prosopis juliflora</i> (Swartz) DC (Mimosaceae)	Vilayati babool	Leaves	Aqueous paste of leaves is applied on affected portion to cure affection of the foot pad of animals*
<i>Ricinus communis</i> L. (Euphorbiaceae)	Arandi	Seeds	1/2 teaspoon seed oil cures stomach disorders, gastric problem and acts as a purgative in animals
		Seeds	Seed oil is given to sheep to cure throat problem*
<i>Tephrosia purpurea</i> (L) Pers. (Fabaceae)	Biyani	Whole plant	Aqueous extract of the whole plant applied on entire body to cure skin diseases in camels*
		Whole plant	Filtrate of whole plant boiled in water is given orally to cure haematuria*
<i>Ziziphus nummularia</i> (Burm. f.) Wt & Arn. (Rhamnaceae)	Bordi	Bark	Inflamed part is applied with ash of bark mixed in 'ghee'*
		Leaves	Aqueous paste of leaves applied on wounds
		Roots	Roots along with <i>Crotalaria burhia</i> with jaggery and alum in water is kept in a utensil whose lid is air tight and kept under ground for few days. The resultant liquid serves as a tonic for goat (1 teaspoon) and camel (1 glassful)*

* New uses that are not matched with published literature by Jain (1991)

Table 3. Miscellaneous ethnic uses of plants in the arid zone of western Rajasthan

Botanical name, family	Local name	Part used	Uses	
<i>Aerva pseudotomentosa</i> Blatt. & Halb. (Amaranthaceae)	Bui	Whole plant	It is used as fuel Used as fodder	
		Inflorescence	Inflorescences are used for stuffing the pillows	
<i>Aloe vera</i> (L.) Webb & Benth. (Liliaceae)	Guarpatha	Stem	Used as fuel (by goldsmiths especially)	
		Leaves	Leaves cooked as vegetable	
<i>Calligonum polygonoides</i> L. (Polygonaceae)	Phog	Flowers	Buds are used to make 'raitā' a preparation made by mixing buds in curds	
		Root	Used for dyeing leather	
		Stem	Used in fencing field Stem fibres used to make ropes Used as fuel Charcoal is made Used in house building Net of coolers made from it	
			During summer the stem wood is very light and harmless to the body so the villagers made 'nakel' for camels	
<i>Calotropis gigantea</i> (L.) R. Br. (Asclepiadaceae)	Safed aak	Flowers	Used for worship Lord Shiva	
		Root	Statue of Lord Ganesha is made from it	
<i>Calotropis procera</i> (Ait.) R. Br. (Asclepiadaceae)	Aak	Stem	Stem fibre used in making ropes Used as fuel Used in roof thatchings Used as fodder Agricultural tools and serving dishes are prepared Used during cremation Stem is used as fire wood in religious rituals like 'Hawan' Dried powdered stem is used in making an explosive, 'Barood' Stem wood is used in making furniture A spoon shape utensil is made which is used in hawan	
		Leaves	Leaves are used as "Toran" on the doors	
		Latex	Used for dyeing leather	
		Roots	Spoon is made from the wood which is used in 'hawan'	
		Stem	Dried branches are used for fencing around their fields and houses	
			Agriculture tools are made from it	
			Inhabitants make doors and windows of their houses.	
			Used as fuel	
			Charcoal is made	
			Used as 'Toran' in marriage ceremony	
	Serving dishes are made for keeping cooked food, Utensils for keeping water and milk			
<i>Capparis decidua</i> (Forsk.) Edgew (Capparaceae)	Keir		In making spoon and ghatti, and spoon shaped utensils, like Dohi's	
			For roof thatching	
			Furniture is made	
			Used in cart building	
			It is used as fire wood during 'hawan'	
			Cooked as vegetable and pickles are also made	
			Gums	Exudation of the stem is used as food
			Leaves	Used as fodder
			Stem	Used in house building
				Rai' a type of stirrer is made from the wood
<i>Euphorbia caducifolia</i> Haines (Euphorbiaceae)	Dandathor	Whole plant	Used in fencing houses and fields	
		Leaves	Young leaves cooked as vegetable	

Botanical name, family	Local name	Part used	Uses
<i>Haloxylon salicornicum</i> (Moq.) Bunge ex Boiss. (Chenopodiaceae)	Khari	Whole plant	Used as fodder
<i>Leptadenia pyrotechnica</i> (Forsk.) Decne. (Asclepiadaceae)	Kheemp	Stem	For roof thatchings and for making side walls of their huts. Stem fibers are used to make ropes Fencing around huts is also made from stem Serving dishes are made for keeping cooked vegetable and o things Brooms are made from stems
		Juice(stem sap)	Sap of the stem is dropped on the skin having plant's thorn. W juice action, the skin becomes soft , the thorn comes out from deeper layer of the skin
		Flower buds	Cooked as vegetable
<i>Lycium barbarum</i> L. (Solanaceae)	Murali	Whole plant	It is kept in salt water to make salt
<i>Ocimum sanctum</i> L. (Lamiaceae)	Tulsi	Whole plant	Worship the plant and called as "Tulsa ji" It is very pious plan
		Leaves	Leaves used in making tea during winter
<i>Prosopis juliflora</i> D. C. (Swartz) (Mimosaceae)	Bilayti babul	Stem	Used for fencing Used as fuel Used in roof thatching and making side walls of their hut Used in cart building and agricultural tools"Doors , Windoes a other furnitures also made
		Leaves	Used as fodder
<i>Ricinus communis</i> L. (Euphorbiaceae)	Arandi	Seed	Seed oil is used in making detergents and lubricants
<i>Sida cordifolia</i> L. (Malvaceae)	Bal	Stem	Used in making brooms
<i>Tephrosia purpurea</i> (L.) Pers. (Fabaceae)	Biyani	Leaves	Used as fodder
<i>Ziziphus nummularia</i> (Burm.f.) Wt. (Rhamnaceae)	Ber	Stem	Used as fuel Used in house building, in roof thatching Used in agriculture tools and cart building Charcoal is made Toys are made Torans are made from leaves and stem at the time of marriag cremony Dried branches are used for fencing around their fields and hc Evil-spirits rests at the time of 12.0' a.m. and p.m. so the peop believe that no body should go there
		Root	Desi liquor is prepared from roots
		Leaves	Used as fodder
		Fruit	Edible
		Gum	Used as food

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Halophytic Chenopod Shrubs of Arid Zone

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The fragile ecosystem of western Rajasthan is characterized by harsh environment, and limited water resources. The area is endowed with a wide range of biodiversity due to varied landforms and climatic conditions. These native plant species have peculiar structural, functional and biological characteristics, which allow them to survive in harsh climatic conditions of arid zone. Well-developed root system of arid plants shows specific ways of adaptations for their successful growth. The family Chenopodiaceae has important place in natural vegetation of Thar Desert. This family includes genera consisting of more or less halophytic xerophytes: *Haloxylon*, *Salsola* and *Suaeda*.

An overview of the potential of chenopod shrubs of the western Rajasthan for economic uses, fodder production and rehabilitation of degraded lands is presented below.

Distribution and Morphology

In the salt ranges of Punjab and Rajasthan, most of the Chenopod halophytes have the folk generic name 'Lana' that simply means the plants growing in the saline or salty environment. The local names of these chenopod shrubs reflect the morphological appearance and also the use of these shrubs (Table 1). Distribution and botanical description of these shrubs is described in the following text.

Lana (*Haloxylon salicornicum* (Moq.) Bunge ex Boiss.)

This species is commonly found in sandy tract but also in mild saline areas. It grows naturally in sandy undulating hummocky plains, dunes, interdunes and in the former river courses of the ancient river Saraswati (Shankar and Kumar, 1984). It is distributed in patches in Bikaner, Jaisalmer and Sriganganagar districts of western Rajasthan.

It is erect, about 60 to 90 cm tall, much branched leafless shrub and woody at base. Branches arise from the basal woody part, which is often partly covered with sandy hummocks (Agnew, 1961). It has jointed, pale-yellow stem with leaves reduced to triangular scales. Flowers appear in dense lateral erect spikes at the end of the terminal and lateral shoots. The fruit is disc shaped and winged. Seeds are horizontal, flattened and orbicular.

It flowers during October-November. Fruiting starts from last week of October and continues up to December.

During the survey for germplasm collection of Lana, it was observed that natural cover of Lana has declined to a great extent. However, some of its natural stands especially in Nachna tehsil in Jaisalmer and Pugal tehsil in Bikaner district are still having considerable plant density and diverse germplasm. Study of different morphological characters viz., dehusked seed and husked seed weight, and perianth size and colour showed significant variations. The 100-seed weight (with perianth) ranged from 0.10-0.22g while fruits were white, pinkish white, cream and pink colour with large, medium and small type perianth.

Khara Lana (*Haloxylon recurvum* (Moq.) Bunge ex Boiss.)

This stem succulent halophyte shrub is native to salt deserts. It is found mainly in saline habitats of Anupgarh and Suratgarh in Sriganganagar and other parts in western Rajasthan.

It has divaricately spreading straight or recurved glabrous branches. Leaves are variable in size, 3-8 mm or more in length, trigonous or half-terete, ovate-subulate or ellipsoid, obtuse or acute at the apex, spreading or recurved. Flowers appear on axillary strict spikes. The perianth segments are fleshy, ovate, subobtuse, closing over the utricle; wing membranous, finely veined, orbicular. Seeds are orbicular, flattened. Flowering and fruiting occur from October to January. Plants turn blackish grey on drying. Large, medium and small size with light to dark pink colour perianth were observed in Khara Lana. The 100-seed weight of dehusked seed (without perianth) ranged from 0.240-0.256 g.

Lani (*Salsola baryosma* (Roem. & Schult.) Dandy)

This pale halophytic shrub is commonly found in sandy-saline habitats in Bikaner, Jaisalmer, Jodhpur and Sriganganagar districts of western Rajasthan.

It is low to high growing, much branched, spreading shrub. The stem is slender and twiggy; new shoots are bright and reddish in colour. The leaves appear in clusters of small balls that are triangular and scale-like. They are minute, alternate, sub-orbicular and fleshy.

Table 1. Old and recent local names of Chenopod shrubs in salt ranges in Punjab and Rajasthan

Species	Old local names	Present prevalent local names
<i>Haloxylon recurvum</i> (Moq.) Bunge ex Boiss.	Kari lana	Khara lana, Saji lana, Kangan saji
<i>H. salicornicum</i> Bunge ex Boiss.	Metra lana, Sheri lana	Lana
<i>Salsola baryosma</i> (Roem. & Schult.) Dandy	Meti lana, Gora lana	Lani
<i>Suaeda fruticosa</i> (L.) Forsk.	Bagg lana , Chati lana	Luni, Lunaki, Pichki lana
<i>S. nudiflora</i> (Willd.) Moq.	Khari lana	Lunaki

The flowers form dense cylindrical spikes, solitary in the axil of leaves. The flowers are tiny, and are followed by the appearance of conspicuous winged fruit. The plant flowers between August and September. Significant variations in seed weight were observed in the sample mean of various accessions. The 100-seed weight of husked seed (with perianth) ranged from 0.038 - 0.057g. This shrub gives peculiar unpleasant odour of rotting fish when crushed particularly when in flowering stage. Two plant types of *S. baryosma*, i.e. tall and short were noticed during the germplasm survey. Most of the collections from the Lunkaransar (Bikaner) and Suratgarh (Sriganganagar) were tall type while from Phalodi (Jodhpur) was the short type. The short forms of most *Salsola* are said to be more browsed by camel and goats.

Luni (*Suaeda fruticosa* (L.) Forsk.)

This is a glabrous halophyte shrub naturally found in saline areas near Suratgarh (Sriganganagar), Tal Chhaper (Churu) and Pachpadra in western Rajasthan.

It is silvery green, erect, much-branched shrub that turns black when dried. It is divaricately branched with glaucous stems. The leaves are blue-green, short petioled, glaucous, variable in size and shape, 5-15 mm long and 2-6 mm wide, linear-oblong or obovate, spatulate elliptic-oblong, flattened above. The flowers are axillary, solitary or 2 to 5 together and with 2-3 bracteoles arranged in, loose, leafy spike inflorescence. The perianth is parted into five equal green sepals united at the base, with 3 yellow stigmas. The seeds are obliquely ovoid, smooth and shiny black.

Phenological Progression

Time and amount of rainfall profoundly influence phenology of chenopod shrubs. These species bear flowers and fruits profusely in the nature. Most of these shrubs flower after post-monsoon (September-October) and fruiting occurs in the early winter months (November-December) and continues up to January. Phenological stages of various chenopod shrubs as observed during the survey and collection are presented in Table 2.

Reproduction Biology & Natural Regeneration

Chenopod shrubs set lot of seeds that fall off after maturity. In Lana (*H. salicornicum*), husked seeds (with perianth) show higher rate of germination as compared to the dehusked seeds (Kaul, 1986), as wing like perianth protects the embryo and gives it mechanical resistance. Smaller seeds loose their viability earlier than larger seeds. Dispersal of seeds of *H. recurvum*, *H. salicornicum*, *S. baryosma* takes place by wind, ants, and rats and also by runoff water. Winter rainfall is of paramount importance in natural regeneration of chenopod shrubs in the hot arid region. The seeds of arid plants have developed mechanisms that work to hold back the onset of germination until certain conditions, such as optimum moisture and right temperature, have been met (Omar, 2000). During germplasm evaluation of arid shrubs good germination of *H. recurvum*, *H. salicornicum* and *S. baryosma* was observed after winter rains in the first week of February 2005. Thus January-February may prove the optimum time for sowing of these species under large-scale rehabilitation programme.

Table 2. Phenological stages of Chenopod shrubs

Stages	Plant species			
	<i>H. salicornicum</i>	<i>H. recurvum</i>	<i>S. baryosma</i>	<i>S. fruticosa</i>
Floral bud stage	August	August-September	August	August-September
Blooming	October-November	October-November	September-November	October
Milk stage (soft seeds)	November	October-November	October-November	November
Dough stage (well-formed seed yet soft)	November	November-December	November-December	November
Ripe seed	November last-January	December-January	November last-January	November-December

Uses of Chenopod Shrubs

These shrubs have been employed for various ethnic uses such as fodder, fuel wood, detergent for cleaning cloth and utensils, medicines, rehabilitation of degraded wastelands and other economic products (Table 3). The detail description of their main uses have been described in the following text.

Fodder

Lana (*H. salicornicum*) is well known camel fodder shrub in the Thar desert. Its importance is chiefly due to its browse value. Farmers generally harvest the fruiting tops of *H. salicornicum* in November-December and preserve for future use as fodder. It is generally mixed with guar phalgati (cluster bean straw) and *Lasu* (dried phyllodes of *Calligonum polygonoides* L.). Taste of fresh Lana is salty due to high concentration of salts and minerals. Farmers in the area believe that during mineral deficiency, the animals selectively browse this shrub to meet the mineral requirement. The succulent twigs of *H. salicornicum* provide not only fodder but also water to the browsing animals. The analysis of green twigs and fruiting tops of *H. salicornicum* revealed that fruiting tops contain higher protein (14-19 %) and minerals (21-24 %) as compared to green twigs. Shankar and Kumar (1984) mentioned that Lana (*H. salicornicum*) alongwith Sewan (*Lasiurus sindicus* Henr.) and Murath grass (*Panicum*

turgidum Forsk.) forms a very productive natural grazing land ecosystem. Phenology of these two plants appears to complement each other with respect to the livestock production. Whereas the forage from *L. sindicus* is available to the animals during the monsoon, the browse from *H. salicornicum* is available during the lean period (December-March).

The utilization of halophytic chenopod shrubs for reclamation of saline soils also make available fodder from these shrubs. Some species, especially obligate halophytes not only tolerate high level of salinity but require salts for their optimal growth. This makes them ideally suited for salt land reclamation. They survive by developing leaf succulence, which is more prominent in *Salsola* and *Suaeda* species. *S. fruticosa* on saline conditions showed better growth as compared to non-saline soils. Khara lana (*H. recurvum*) is also a potential fodder during the summer period under rainfed conditions. Its green foliage during summer months was found rich in crude proteins (13.3 %), total carbohydrates (62.9 %), crude fiber (20.7 %), neutral detergent fiber (58.2 %) and acid detergent fiber (25.2 %). The high salt contents of halophytes offer some constraints in utilization of these materials but there are ways to over come those problems such as blending with other components in prepared feed mixtures or washing with water. Preliminary study of the feeding trial conducted at CAZRI, RRS, Bikaner showed that though

Table 3. Ethnic uses of chenopod shrubs in arid region

Uses	Species	How used
Food	<i>H. salicornicum</i>	Seeds along with pearl millet are used for making bread at the time of scarcity
	<i>S. fruticosa</i>	Leaves with young shoots used as vegetable in August-September
Fodder	<i>H. salicornicum</i>	Flowering tops are cut in November-December and stored to feed animals. Also browsed by camel, goat, donkey and sheep
	<i>H. recurvum</i>	Browsed in scarcity period by camel and goats
	<i>S. baryosma</i>	Browsed by camel and goats
	<i>S. fruticosa</i>	Browsed by camel, goat and sheep and acts as appetizer
Fuel wood	<i>H. salicornicum</i>	Used as good fuel wood by inhabitants
	<i>S. baryosma</i>	Used in scarcity period
Medicine	<i>H. salicornicum</i>	Plant ash is applied to cure skin diseases
	<i>H. recurvum</i>	Plant ash given in water against internal ulcers (Bhandari, 1990)
	<i>S. fruticosa</i>	Leaf vegetable is eaten to cure flatulence
Detergent	<i>H. salicornicum</i>	Plant ash is used as soap substitute
	<i>H. recurvum</i>	Plant ash is used as soap substitute
Saji *	<i>H. recurvum</i>	Used to improve the quality of Papad (said to be of best quality)
	<i>S. fruticosa</i>	Used to improve the quality of Papad (said to be of medium quality)
	<i>S. baryosma</i>	Used to improve the quality of Papad (said to be of medium quality)

* Obtained after burning the dried branches along with seeds

green Khara lana is normally not preferred by goats, however, can be fed to goats by mixing @ 25% in the feed with other palatable roughage such as groundnut haulm without any harmful effect. The Lani (*Salsola baryosma*) and Luni (*Suaeda fruticosa*) are particularly valued as camel fodder.

Saji

Halophyte shrubs like *Haloxylon recurvum*, *Salsola baryosma*, *Suaeda fruticosa* absorb high amounts of sodium and chloride, accumulate these ions, and store them in leaf vacuoles. When dried and burnt, these plants yield saji (a mixture of sodium and potassium bicarbonate, which is of industrial importance). It presently costs Rs. 150-200/kg. Harsh *et al.*, (1991) mentioned that if systematically grown, Kala lana could raise Rs. 10000 per hectare of saline wastelands. During the germplasm survey in 2003 in Ganganagar district, it was noticed that some of the farmers in Anupgarh and Vijainagar Tehsil of Sriganganagar district are cultivating *H. recurvum* as a rainfed crop under saline environment with no fertilizer and irrigation and earning Rs. 8-10 thousands per hectare by selling the standing crop to local traders.

Other uses

The litter fall from natural stands of Lana (*H. salicornicum*) act as a medium for the growth of edible mushroom (*Phellorina* sp.). The villagers of Nachna Tehsil in Jaisalmer and Pugal Tehsil in Bikaner informed the importance of natural cover of Lana for potential of mushroom growth. In the rainy season, the mushrooms grow naturally under the canopy of Lana and collected by local inhabitants for their own consumption and also for sale in the local market. In the local market it is sold at the rate of Rs. 25 to 35/ per kg. Farmers also claim more yield of pearl millet (*Pennisetum americanum* (L.) Leeke) moth bean (*Vigna aconitifolia* (Jacq.) Marechal), and cluster bean (*Cyamopsis tetragonoloba* (L.) Taub.) crops from the land bearing natural stands of Lana (*H. salicornicum*). Similarly more yield of watermelon (*Citrullus lanatus* (Thunb.) Matsuman & Nakai) locally known as Matira may be obtained from Lana field. However, there is need for detailed systematic study in this direction.

Biochemical Aspect

Chenopod shrubs contain a number of chemical compounds. New piperidine alkaloids, aldoltripiperidine, halosaline, haloxine and anabasine were isolated from *H. salicornicum* (Donovan and Creedon, 1971). A new

pyranone, 5-hydroxy-3 methoxy-4H-pyran-4-one was also isolated from the aerial parts of *H. salicornicum* (Gibbons *et al.*, 2000).

Rehabilitation of Degraded Rangelands

Halophyte shrubs have a prime place in rehabilitation and reclamation of saline lands. These species grow naturally on wide range of saline soils and are adapted to extreme conditions. They can also be established on salt affected lands through either direct seeding or transplanting of seedlings depending on their sensitivity to salt stress at germination. Ecologically C₄ Chenopod species are very important in saline areas and in cold arid deserts (Pyankov *et al.*, 2000). These saline plants are important to recycle the salts through the soil-plant system and provide nutrients for animals. They can complete their life cycle and produce biomass despite the presence of large amount of salts in the root zone. It has been found that these arid plants tend to accumulate the salts in epidermal and sub-epidermal tissues including various glandular structures on leaves, bracts/bracteoles and perianth segments. In these plants the concentration of sodium in leaves is many folds as compared to potassium.

The preliminary evaluation of diverse germplasm of Lana (*H. salicornicum*) at CAZRI, RRS, Bikaner revealed that planting of shelterbelts with shrubs like *H. salicornicum* may markedly reduce wind speed in the rangelands/rainfed agricultural lands and can provide fodder for livestock grazing. Its wide-spread and deep tap root system (Shankar and Kumar, 1984) extends beyond 5 m and it is estimated to go 8 to 10 m deep. Brown and Porembski (1998) reported that in the desert and semi deserts of Kuwait, the miniature dunes are formed around the base of *H. salicornicum* shrubs, which represent distinct habitat patches. The formation of miniature dunes is due to the accumulation of wind-blown sand, particularly on the leeward side of the shrubs. The leeward side of these dunes offers the most favorable growth conditions of most of the species. These micro dunes could represent important centers of vegetation regeneration and play an integral part in combating desertification caused by anthropogenic actions such as grazing (Brown and Porembski, 1997).

Salt affected soils cover a large area in western Rajasthan. Besides the naturally occurring salt affected soils, the extent of man made salinized soil is also significant. This is mainly a consequence of improper

irrigation management. In the last 15-20 years, intensive irrigation in arid and semi-arid region has led to salinization of thousands of hectares of arable lands. In some cases, this increase is due to forcible use of brackish ground water as irrigation due to water shortage in canal system. These chemically degraded soils can be rehabilitated through plantation of suitable tolerant species. Halophytic chenopods are most appropriate for such purpose. The study conducted in the deserts and semi deserts of Uzbekistan showed that the species of *Haloxylon* and *Salsola* are suitable for establishing new pastures or for improving degenerated pastures (Khasanov, *et al.* 1994).

Some of the halophytes need saline condition for their growth; others need no salt concentration but do develop better with it. Therefore, in view of the collection of information regarding their natural site characteristics, surface soil samples were collected from their natural habitats and analyzed for pH, electrical conductivity of saturation extract (EC_e) and texture. The *H. salicornicum* was mostly found on sandy to loamy sand, deep to very deep soils with hummocks. These soils were loose and highly prone to wind erosion. They were alkaline in reaction (8.2 to 8.6), non-saline (EC_e < 2.0 dS m⁻¹) and low in organic carbon (0.8-0.18). They have very high infiltration rate. So, for the growth of *H. salicornicum*, loose sandy soils with no salt concentration is needed but it can perform in mild salinity.

The *H. recurvum* is a highly salt tolerant stem succulent shrub, which accumulates high quantity of salt and makes it suitable for phytoremediation of highly saline areas (Ajmal Khan, 2000). Our study also indicated that the natural sites of *H. recurvum* were saline with EC_e > 5.0 dS m⁻¹ but it can also be grown on medium to low salinity soils. In addition to salinity it can withstand high alkaline conditions (pH = 8.9-9.1). The site characteristics of *Suaeda fruticosa* were also highly saline. Both of these species prefer loam to clay soils in contrast to *H. salicornicum*, which prefer sandy soils.

Conclusion

Chenopod shrubs, *H. salicornicum*, *H. recurvum*, *S. baryosma* and *S. fruticosa* are highly drought-resistant and can grow vigorously during hot summers. Primary evaluation of diverse germplasm of *H. salicornicum* revealed its great potential for development of sandy mildly saline wastelands. The species viz., *H. recurvum*, *S. baryosma* and *S. fruticosa* are naturally adapted to salt affected soils. They provide browse for the animals. Though

some of these species also contain some bitter substances, salts and unpleasant smell (like *Salsola baryosma*), these can be fed to animals after mixing suitably with other feeds. For this we have to screen the available germplasm from various habitats, for absence of bitter taste, less amount of salt, odourless and provide more leaf fodder. While selecting the species, emphasis should be also given to dual-purpose species viz., fodder-cum-soil conservation, fodder-cum-fuel wood, fodder-cum saji, fodder-cum-medicinal types. So far, salt depressions in the desert of western Rajasthan have not received due attention for fodder production or utilization for other economic products such as Saji, which has great demand by the local Papad industry. Following research needs are therefore identified.

Future Research Needs

- Survey, collection and screening of PGR of chenopod shrubs
- Standardization of propagation techniques for large scale plantation programme
- Evaluation of chenopod shrubs with focus on
 - Suitability for specific habitats and soil types
 - Suitability for shelterbelts, silvi-pasture and other alternate land use systems
 - Palatability and quality as livestock feeds
- Systematic studies on growth, regrowth and also frequency and intensity of defoliation under cut and carry system
- Studies on ecological interaction competition/interference and nutrient cycling between chenopod shrubs and grasses/crops in silvi-pasture, Agri-silviculture and other alternate land use systems
- Standardization and improvement in traditional technique for saji making for its best quality
- Important areas of halophyte vegetation for *in situ* conservation should be identified in western Rajasthan and concerned agencies/departments, may be convinced about their need for conservation
- There is need for National and International Network Programme on Halophytes in hot deserts for collection, evaluation and exchange of diverse germplasm from the range of natural distribution in arid zone.

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Some Important Introduced Shrub Species and Their Production Potential in Hot Arid Regions of India

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The number of tree/shrub species is very limited in arid zones, and in general, they are very slow growing due to limitations of environmental conditions, but nowhere in the world are they so intricately associated with the life of human beings as in arid areas. To evade or minimize the adverse effects of frequent droughts, the native peoples in arid zones have often developed production systems in which woody perennials have a very important role, both from productivity as well as a resource conservation point of view. Their centuries-old experiences, under diverse socioeconomic and cultural conditions, were passed from generation to generation and have established well-contained systems of production (silvipastoral/ agrisilvicultural/ agrisilvipastoral/ livestock husbandry) which accrue maximum benefits from their woody component(s). If arid zones are looked at from the angle of forestry development, it appears that this is basically concerned with the management of trees and shrubs which are either native to a particular arid zone, or have been introduced, especially for conservation purposes Sharma and Tewari (2004). However, concern for trees and shrubs has increased in arid zones as it has for any other region in recent years. This concern has been fuelled mostly by the disappearance of large quantities of woodlands and trees/shrubs from such fragile ecosystems in many countries of world.

As indigenous shrub species in arid tract are very few in number and that too are very slow growing. Therefore, it is very essential to identify fast growing and adaptable shrub species from iso-climatic regions of the world for plantation in different landforms of India arid zone. Since last more than 30 years, Central Arid Zone Research Institute, Jodhpur is actively engaged in this direction through long-term evaluation and screening trails of various exotic shrub species.

Humans and Trees/Shrubs in the Hot Arid Zone

To evade or minimize the adverse effects of frequent droughts, rural folk in the hot arid zone of India have evolved some combined protective-productive systems. Their centuries-old experiences, under diverse socioeconomic and cultural conditions, were passed from generation to generation and have established well-contained systems, which accrue maximum benefit by integration of woody perennials into the farming systems Tewari *et al.* (1999).

According to the climatic, edaphic and socioeconomic characteristics, various suitable drought-hardy and multiple-use tree and shrub species have been selected to grow in crop fields for sustainable production. These are in fact true extensive agroforestry systems. Thus agroforestry is a way of life in the hot Indian arid zone.

These extensive agroforestry systems are living systems, evolved through the interaction of many environmental, biological, social, economic and cultural factors, and have adapted to specific sites and climates, as are the plants, animals and humans functioning as elements within them. Agrisilvicultural, silvipastoral, hortipastoral and agrisilvipastoral systems are the most common forms of agroforestry of the hot Indian arid zone. Woody components (i.e., trees or shrubs) in these agroforestry systems supply a considerable amount of subsidy for sustainable operation of specific systems in the form of fuel wood, fodder, minor timber, fruits, and many other edibles. In fact, the production of arable crops in the hot arid zone is a gamble, if not impossible. When arable crops fail because of failure of the monsoon—a common phenomenon in the hot arid zone of India—even then trees and shrubs are able to provide many essential products and services.

Introduced Shrub Species Profiles

A large number of shrub species have been successfully introduced in Indian hot arid zone. There are many nitrogen fixing species that can tolerate infertile sites, and some others are fast growing and have the ability to coppice, thus helping to avoid costly replanting. Many shrub species, which have been introduced from isoclimatic regions of the world, have also been introduced into other hot arid zones of the world. *Acacia bivenosa*, *Colophospermum mopane*, *Dichrostachys nutans*, *Parkinsonia aculeate*, *Simmondsia chinensis*, *Prosopis juliflora* and other *Prosopis* species, and *Opuntia* and many other cacti are found to be highly adaptable in hot Indian arid environs.

Acacia bivenosa

Introduced first in the year 1980 at CAZRI, Jodhpur from western Australia has now proved its potential as a fast growing multipurpose shrub for Indian arid zone.

Natural habitat and botanical features: The species is widespread and abundant in the Pilbara/Hamersley ranges extends along a near coastal belt to the southern edge of Kimberleys (Derby-Fitzroy crossing) in northern part of western Australia. The climate of the area is typically hot arid with maximum summer temperature touches a mark of 42°C. Plant is multistemmed dense, bushy shrub. The stem is smooth barked. Rich golden, globular flower head are produced on long peduncles (20-25mm) between January and February at Jodhpur condition. However, in its native place they appear between June and September. The pods are woody and somewhat constricted between seeds. The seeds are brown, shiny, ellipsoid to broadly ovoid, 4-6mm x 3-4.5mm and flattened, with central portion often depressed. In its native place, fruit maturation occurs during October and November, while at Jodhpur it occur during April and May.

Silvicultural attributes : The species is propagated from seeds. In Jodhpur, under 366 cm rainfall regime, plants gained on an average 1.8 m in height in first three years. Maximum height attained by the plants after 10 years of initial field establishment was an order of 3.1 m. It appears that height growth is slowed with age. But the spread of species on the ground was so vigorous that average crown diameter per plant after three years has become 1.50 m to 1.75 m and after ten years it attained an average diameter of 5 m. In another experiment, the growth behaviour of plants of *A. bevinosa* was studied under different spacing (viz. 2 x 2 m, 2 x 3 m and 2 x 4 m) at CAZRI, Jodhpur. The two year growth performance data shows that the plant respond best to wider spacing, i.e. 2x 4m. Owing to its multi-stemmed habit plant spread vigorously on the ground and therefore, it require enough space for its crown expansion.

Utilization : *A. bivenosa* excels as a species for sand dune stabilization, soil protection and shelter. More than 50% part of arid western Rajasthan is sandy and intensities of dunes vary from place to place. These shifting sand dunes hold a good amount of moisture in deeper layers. Owing to its efficient moisture utilization ability, the species can be very useful in sand dune fixation programme. Under water technology mission, the species is being tried for sand dune stabilization in Barmer district of Rajasthan. Due to its capacity to spread vigorously on ground, the species is also suitable for outer or flank rows of shelterbelt. It has a soft wood, but some time a core of dark brown heartwood is also found to be present. The wood is absolutely dense and can be

used for fuel after drying. Average plant biomass after ten years of field establishment at Jodhpur condition was in order of 51.1kg/ plant of which 35.4% leaves, 35.6% branches and 29% twigs. If the species is planted in a spacing of 3x3m, to talk 39.5 tonnes/ha fuel wood can be harvested in a span of ten years (main branches are the source of fuel wood).

Colophospermum mopane

C. mopane (family Leguminosae) is indigenous to central and south Africa, where it grows well into the arid environment. It was introduced to the hot Indian arid zone in 1965, and spread rapidly in the arid and semiarid zones.

Natural habitat and botanical features : It is a small tree, rarely taller than 10 m under Indian hot arid conditions. The natural regeneration of the species is tremendous, and profuse when rainfall is <200 mm. The leaves are highly palatable and nutritious fodder, and they are found in pairs and appear almost like butterflies. Leaflets are kidney shaped and have seven veins. Flowers are slender racemes and pods are flat kidney shaped. Seed ripening occurs in September-October.

Silvicultural attributes : *C. mopane* has a remarkable ability for self-propagation by wind-dispersed seeds even in highly arid situation. Fallen seeds immediately start to germinate with onset of monsoon rains. Root suckers also come up around the base of established trees. Artificial propagation by planting of seeds in polythene bags is reliable and easy. More than 95% germination is obtained within five days of sowing in polythene bags. Four to five months old nursery raised seedlings are planted on field just before the onset of monsoon rains. Early growth of seedlings is moderate, however after 2 years age they grow with a fast speed attaining a height of 4-5 m in a span of 5-6 years in arid environment of India (Harsh and Tewari, 1993).

The leaf production from 7-year-old trees at Jodhpur (rainfall = 300 mm) recorded to be 7 kg per tree, if trees are planted at a spacing of 3m x 3 m. Thus, 7 ton /ha leaf fodder can be obtained. Leaf production is directly related to rainfall. In a rainfall zone of 150 mm the reported leaf production was only 1.5kg /tree, while in rainfall zone 200-250 mm the leaf fodder production was 2.5 kg /tree. The wood production from 7 year old trees recorded to be 38 kg /tree. For sustainable leaf fodder and fuel wood production 50% vertical lopping is recommend.

Utilization : Leaves of *C. mopane* are eaten fresh or dry by livestock and wild animals. They are highly palatable

and nutritious. Crude protein content in green leaves is around 15%. The wood is very hard and often used in hut construction in its natural domain in Africa. The wood is also an excellent fuel, burns slowly and gives off very good heat with little ash.

Dichrostachys nutans

D. nutans (family Leguminosae) is native to tropical Africa and widespread in Iran, Australia, and many countries of South Asia, including India. It was introduced into the hot arid zone of India during the early 1960s.

Natural Habitat and botanical features : The center of diversification of *D. nutans* is tropical Africa. It is found from sea level to an altitude of around 1700 m. It is a branched shrub. It naturally regenerates through root suckers, therefore, it thrives very well in the arid zone, and the hot arid areas of peninsular India. The specie is highly branched. The feathery bi-pinnate leaves are alternate or crowded on spurs and end in sharp points. The flower spikes are pink and yellow. The flowers are hermaphroditic, and appear during September-October. The number of pods in a spike is 25-50. Mature pods contain 1-9 small ovoid seeds. The number of seeds per kg is as high as 40,000.

Silvicultural attributes : Natural regeneration is strongest by root suckers. Within a period of 10 years, an individual of this species produced 130 new stems in a radius of 20 m by its root suckers. Self seeding is partially successful. Artificial propagation by transplanting natural root suckers is most successful . Species can also be propagated by raising seedlings in the nursery through seeds. For field plantation, root suckers or seedlings are planted out during the onset of monsoon. For fuel wood plantation and sand dune stabilization 3m x 3m or 3m x 5m spacing is recommended. To get maximum biomass in terms of fuel, *D. nutans* shrubs are harvested at the age of 8-10 years. If the production objective is only leaf fodder, then plants should be coppiced in every alternate year after reaching about 3-4 m height.

Utilization : The leaves and pods are highly palatable and nutritious fodder for livestock. The crude protein content in green leaves is about 11-15%. In arid condition the species produced dry leaf fodder to the tune of 2 kg/ tree after 8 years (Tewari and Harsh, 1993). Wood is used for fuel and also for fenced post. However, wood production after 8 years in very closed density plantation was reported to be less than 1t /ha /year. The wood also makes high quality charcoal. In Africa, various part of this shrub is used for medicinal purposes.

Parkinsonia aculeata

P. aculeata (family Leguminosae) is a native to tropical America, and has been introduced and almost naturalized in much of the hot arid and semiarid zones of Africa and Asia, including India.

Natural Habitat and botanical features : It is a shrub or small tree with stout thorns and tough pendulous branches. Leaves are bi-pinnate bearing 25-30 pairs of tiny leaflets. Flowers are bright yellow axillary racemes 12-15 cm long, and appear in April-May and then sporadically up to autumn. Pods are long and slender containing 4-12 hard brown seeds.

Silvicultural attributes : It grow quickly, is easy to propagate, and is nitrogen fixing plant. Though natural regeneration by self-seeding occurs but is scarce in arid regions. Artificial propagation is easily done by seed, seedlings and cuttings. It is a strong coppicer, re-growing vigorously after lopping. The early growth of plant is quite fast and within a span of 2-3 years, the plants attain a height of 3-4 m.

Utilization : It is useful for the reclamation of tough sites, gullied areas, and mine spoil. Its browse resistance and stout thorns make it valuable as a live fence. The wood is not very useful as fuel, however it is some time used for making charcoal.

Simmondsia chinensis

S. chinensis commonly known as Jojoba (pronounced as Ho-Ho-Ba) is native to the triangle of Sonoran desert of Mexico, California and Arizona. It is found growing naturally in sandy soils, and stony and gravel lands of these areas. The species can tolerate as high temperature as 54°C in summer and as low as -5°C in winter. In arid tracts of India, the species was first introduced in 1966 at CAZRI, Jodhpur, however, scientific trials for cultivation of this species initiated during second half 1970s (Harsh *et al.*, 1987).

Natural habitats and botanical features : In its native habitat i.e. sonoran desert plant grow as wild in variety of landforms. Plant expresses itself best in deep sandy and well drained soils, however, it grown well even in rocky and semi-rocky sites in its native habitat. It is both drought and frost hardy and thus has very wide ecological amplitude. The plant can survive even in 200 mm rainfall zone with well drained soil appears to be most suitable. (Anonymous, 1999). The plant can not tolerate water logging at all.

S. chinensis is a dioecious plant and thus bears male and female flowers in separate individuals. In the male plants flowers are borne in clusters and their number varies 7 to 36 per cluster. Female flowers normally bloom in the month of December- January and seeds mature by mid-May. Seeds of the plant differ in their shape, size, colour and weight and contain 45-55% oil with an average of 50%.

Silvicultural attributes : *S. chinensis* can be cultivated in well drained soils having pH from 5 to 8. In arid regions with rainfall >250 mm, plant can be cultivated successfully even in rainfed situation, however, for commercial seed production irrigation is essential. The life span of the plant is more than 150 years. The plants can be raised using seeds, seedlings and rooted cuttings. Best time of sowing seed for raising nursery is mid-October, so that more vigorous 8 months old seedlings could be obtained for out-planting. Nursery can also be raised in mid-February. The seedlings attain a height of 25-30 cm at age of 5 months and 35-45 cm at the age of 8 months. The propagation through rooted cuttings has been found most successful as seedlings of desired sex are obtained. However, for raising rooted cuttings appropriate mist chamber with provision of timely watering and humidity level maintenance is required.

For raising *S. chinensis* plantation through seedlings, plant to plant distance is kept 1 or 2 m and row to row 4 m, however for raising plantation through rooted cuttings the plant to plant distance is maintained at 2 m and row to row 4 or 5 m. Male plants started flowering only after one and half to two years, while female plants generally flowers after two years (in case of plantation are raised through seedlings). Plantations raised through rooted cuttings flowers early. Irrigations from flowering to seed setting stage i.e. from December to April are required for higher seed harvest. Drip irrigation has been found very cost effective for cultivation of the species in arid trees of India (Anonymous, 1999). *S. chinensis* starts producing seed from third year but consistent yield starts only after fourth year. On an average, the seed yield at 5 years age reported to be 400-500 g/plant which increased to 1.0 kg/plant (average) by 10th year and some times goes as high as 2.0 kg/plant by 13th-15th year. At the moment, in India, about 600 ha land is under commercial cultivation of *S. chinensis*, and more and more plantation are being raised especially in Gujarat and Rajasthan state.

Utilization : The oil obtained from *S. chinensis* seed is similar in properties to body fat of sperm whale and

therefore, its is very suitable for high presume engines. However, at the moment *S. chinensis* oil and its derivatives are being used in 300 products, most common are cosmetics, pharmaceuticals, lubricants, electrical insulators, foam control agents, heating oils, plasticizers, fire retardents, transformers, etc. The oil of *S. chinensis* is also good source of long chain alcohols and acids with double bounds in slightly different configuration from those natural fatty acids.

Although cultivation of *S. chinensis* in India has not reached in true commercial lines, even then income from average produce from one-hectare plantation can be assessed on broader basis. A yield of 125-200 g seeds/plant after 5th year of plantation (distance 4 x 1 m) can be obtained. This yield can be increased to about 1.5 kg by 12th-14th year of plantation. Thus, an income of Rs. 1.50 lacs can be taken from one-hectare plantation by selling seed even at as low price as Rs. 60/kg. The benefit cost ratio of Jojoba cultivation in suitable lands in India is reported to be 3.4 : 1.0 (Anonymous, 1999).

***Prosopis juliflora* and other *Prosopis* species**

Introduced *Prosopis* species which is extensively distributed in the Indian hot arid zone is *P. juliflora*. In the hot arid zone of India it was introduced during early 1930s by the ruler of the erstwhile princely state of Marwar, and at that time was given the status of a royal tree. It proved its potential soon after its introduction. It is commonly known as mesquite in its native ranges, and as vilayati babool in India.

Natural Habitat and botanical features : This species is native to the southern part of North America and South America, It was introduced only 130 years ago into the Indian subcontinent. Owing to its fast growth and drought hardiness the species has since been introduced in many part of India from North-west to extreme southern parts. Due to its wide ecological amplitude has spread over the entire arid and semiarid tropics of India. The most abundant distribution of *P. juliflora* is found in Kutchh region of Gujarat western part of Rajasthan, south-central parts of U.P. and in drier pockets in A.P. and Tamil Nadu.

It is a medium sized thorny tree or many time as a shrubby growth, generally evergreen, and distinguished by the wavy drooping and zigzag appearances of its new shoots, which extend above the crown. Due to its vigorous coppicing habit, new shoots regularly emerge from the old stumps, and in the process of repeated cutting and coppicing, the species often form shrubby thickets rather than woodlands. The stem height

of these shrubs varies but generally ranges between 1 and 3 m. Leaves cluster on short shoots along the branches. They are bi-pinnate with 13-25 pairs of dark green leaflets/pinna. Inflorescence is an axillary spike, 8-10 cm long which bears greenish-white flowers at 3-4 years age. The trees usually start flowering earlier in south than in north India. The plant flowers three times in a year i.e., August-September, November-December and February-April. The pods from August-September flowering mature by early November and those from Nov.-Dec. flowering ripen by Feb. to early March. The pods from Feb.-April flowering mature by early May. The pods are 6-30 cm long, 5-16 mm wide and 4-9 mm thick and contain 12-29 seeds.

Silvicultural attributes : *P. juliflora* is mostly propagated by seeds. Although it can also be propagated through cuttings, seed propagation is easier and more cost effective. Seeds of the species have hard impermeable coats which stop them from germinating because no water can reach the seed and therefore seed scarification through mechanical and chemical treatments is almost essential. After germination the seedlings start growing and 4-week old seedlings, on average, attain a height of 9 cm under nursery conditions. By the end of 19th-20th week under nursery condition, the seedlings are ready for out-planting.

P. juliflora plantation raised for fuel wood on degraded land at a spacing of 1.5x1.5 m attained an average height of 2.7 m and basal diameter of 3 cm/twig in three years. Generally one clump contains 15-30 twigs (Tewari et al., 2000). In better site conditions the species grows in tree form with an average growth rate of 2.5-4.0 cm/year/tree in girth and 30-60 cm/year/tree in height. In sandy loam soil of arid tract, 4.3 t/ha fuelwood production from three-year-old well-managed *P. juliflora* plantation with spacing 4m x 3m has been estimated. During the past few years, the species has been proclaimed as a disaster in many quarters. This prejudice is mainly due to the thorny nature of the species, and to its rapid expansion into bushy thickets.

Utilization : It produces an excellent timber if allowed to grow to arboreal form. In general, *P. juliflora* can be found everywhere in the hot arid zone of India, and it is an integral part of life support. It is a main source of fuel for more than 80% of the rural population in the hot arid and semi-arid zones of India. The wood, which has a calorific

value 6000 kcal/kg (air dried), also makes high quality charcoal. The pods provide nutritious fodder for livestock. They are highly palatable and provide good nutrition to cattle, sheep, goats, camels and horses. The ripened pods on average contain 8% digestible protein, 55% total soluble carbohydrates, 2% fat and 14% fiber. In its native range, the pods are widely used as human food and medicinal purposes.

Other *Prosopis* species, which are similar in habit and uses to *P. juliflora* and introduced in India are: *P. alba*, *P. chilensis*, *P. glandulosa*, *P. nigra* and *P. flexuosa*. *P. chilensis* is often found mixed with *P. juliflora* bushy thickets. Other species are still under research trials in various R&D organizations of the country.

Summing Up

Arid environments are extremely diverse in terms of their land forms, soils, fauna, flora, water balance, and human activities. The binding element of all arid environments is aridity. Of the total land area of the world, arid zones account for 18.8%. Water is a scarce commodity in arid zones, and much of the rainfall is lost by evapotranspiration. In arid zones, vegetation is typically sparse, and woody species richness is low. The vegetation of the hot Indian arid zone is broadly classified as tropical thorn forests. In general, vegetation is very sparse and hostile environmental conditions do not support the much required natural regeneration and subsequent growth of plants. Many peoples all over the world are now very concerned about woody perennials. People whose way of life depends on daily easy access to tree/shrub products are most directly affected by loss of trees, and this is particularly true in the complex environmental, socioeconomic and cultural conditions of hot arid zones of India. Perhaps trees and shrubs provide more fodder to livestock than the grasses in arid areas. The shrubs are also very important component of fragile ecosystems of the region. Due to very slow growth of native shrub species and moreover failure of much required natural regeneration, the above mentioned shrub species were introduced from iso-climatic regions of the world. With passage of time these species have proved their potential in arid land situation. The need of the hour is to have a balanced approach for introduction of exotic and native shrub species in any afforestation, reclamation, agroforestry programmes, etc.

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Arid Shrubs for Human Health

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Plants have been the eternal source of food and medicine since antiquity in all traditions and cultures. This green resource has been fast re-emerging in the field of health care with Green Pharmacy gradually occupying the central place in pharmaceutical industry. The increasing craze for use of green pharma products as medicine and food supplements has now revolutionised the global market which is claimed to have crossed 100 billion US Dollars with sustained further rise reflected to reach five trillions US Dollars by mid of the present century. This global scenario has warranted stock-taking at home to be able to profitably share the global demand. Besides enforcing GMP regulations and establishing good pharmacies, attempts are being made to regulate and to extend the raw material resources. Natural sources of green materials from forests and wastelands have to be now registered and regulated to avoid undue exploitation in addition to extended attempts of conservation and cultivation of medicinal plants with appropriate value addition technology utilising the Good Agricultural and Collection Practices (GACP) defined by WHO. (2003, 2004)

Ayurvedic Materia Medica has been using all range of plants viz., herbs, shrubs and trees. However, use of herbs and barks-roots-fruits of trees have been in more popular usage. Shrubs have been in vogue less commonly although in arid regions shrubs are the dominant vegetation. Hence this presentation is inclined to focus specially on Medicinal Shrubs of arid zone.

As rightly pointed out by Pratap Narain (personal communication), it cannot be over-emphasised that shrubs are important component of arid ecosystem offering ecological and economic sustainability under adverse climatic conditions. The shrub as a vegetative form is more hardy than the tree, is proved beyond doubt by the presence of shrubs beyond the tree limit. Though not much promoted in forest policy the shrubs continue to be the thrust area of horticultural activity. Shrubs were neglected in forest policy due to their low productivity of wood but realization of their conservation value and significance as fuel, fodder, food, medicine, fibre, dye etc. in arid regions have brought them in focus. If popularised and managed properly shrubs can contribute in crop diversification and impart sustainability as these can provide supplementary income for livelihood of rural masses while arresting wind and water erosion. The following are some of the important medicinal shrubs of arid zone warranting protection, plantation, planned industrial utilisation and evaluation of the market potential (Table 1).

The properties and pharmacodynamics of some of these shrubs as described in Ayurvedic texts, traditional claim and recent advances are reviewed in this communication.

Most of the above mentioned shrubs are used in herbal drug industry and as home-remedies from wild source except Guggulu, Ashwagandha and Karanja that are cultivated for medicinal purpose. Remaining shrubs are horticultural agents while some are cultivated for fruits

Table 1. Some important medicinal shrubs of arid zone and their main uses

S.No.	Name	Part Used	Main Use
1.	Arka - <i>Calotropis procera</i>	Latex, Root, Leaves, Flowers	Anticancer, Antimalarial
2.	Ashwagandha - <i>Withania somnifera</i>	Root	Antistress, Adaptogen
3.	Guggulu - <i>Commiphora wightii</i>	Gum	Hypolipidemic, Anti-arthritis
4.	Karanja - <i>Pongamia pinnata</i>	Seeds, Bark, Leaves	Anthelmintic
5.	Nirgundi - <i>Vitex negundo</i>	Leaves	Anti-inflammatory
6.	Japakusum - <i>Hibiscus rosasinensis</i>	Flowers	Antifertility
7.	Mehandi - <i>Lawsonia inermis</i>	Leaves	Cosmetic, Hair care
8.	Dadim/Anara - <i>Punica granatum</i>	Fruits, Tender Leaves	Antidiarrhoeal
9.	Nimbuka - <i>Citrus acida</i>	Fruit	Digestant
10.	Bougainvillea	Whole Plant	Antidiarrhoea

/ food viz., Anara, Karmarda and Nimbuka. Mehandi is a popular cosmetic shrub and is cultivated for use of its leaves for preparation of hair care and hair dyeing products. Three most popular medicinal shrubs of the arid region (Table 2) are being described in some greater detail below.

Aaka / Arka (*Calotropis procera*/*C. gigantea*)

Calotropis gigantea (Linn) R.Br. i.e. Alarka or Mador is an erect spreading perennial shrub with milky juice growing almost all over India, more over the dry waste land. This plant is profusely growing wild in western Rajasthan. The roots, flowers and the latex of this plant are used for medicinal purpose. The plant is categorised in Ayurved as *Upavisa* i.e. minor poison. In recent years the latex has been used extensively for processing the *Kshara Sutra* i.e. medicated thread applied in the re-innovated Ayurvedic Para-surgical technique of the treatment of Fistulla-in-ano and Piles. Because of its cytotoxic effect this drug has been tested for its anticancer activity with encouraging results (Smith, *et al.*, 1995; Kiuchi *et al.*, 1998). The chemistry of the medicinally useful parts of this plant has been extensively studied by different investigators in different years. The important chemical constituents of different parts of this plant are tabulated in Table 3.

Pharmacology and medicinal usage

Ethanollic extracts of the root of *Calotropis gigantea* and flowers of *Calotropis procera* revealed

Anticancer activity in studies reported by Smit *et al.*, (1995, 1997; Dhar *et al.*, 1968 and Kiuchi *et al.*, 1998). The plant is also reported as antipyretic, anti-asthmatic, purgative and emetic. The *in vitro* observations on cytostatic activity of this plant against COLO 320 tumor cells as reported by Smit *et al.* (1995) is reproduced below (Table 4).

Calotropis procera has been studied for its antimalarial activity and as larvicidal. It has also been found effective against the malaria and dengue carrying mosquitoes. It is expected to be useful in the treatment of chloroquin-resistant malarial-fever. There is a need of further studies to isolate the larvicidal active principle of this plant and its clinical trial to establish it as an important drug of indigenous origin which could be patented. It is also anthelmintic, antiasthmatic, febrifuse, expectorant, laxative and emetic.

Ashwagandha (*Withania somnifera*)

Ashwagandha of Solanaceae family is one of the most popular medicinal plants of India with proven antistress, adaptogenic and general tonic effect. It grows well in light sandy soil with pH 6-8.5. There are several improved varieties of this plant available for cultivation viz., Jawahar Ashwagandha - 20 and JA 134. Ashwagandha grows wild on wasteland but is now being cultivated in Rajasthan, Gujarat, Madhya Pradesh, Punjab and Hariyana. This plant is propagated by seeds and its part of medicinal value is its roots. The chemical constituents

Table 2. Rasa, Guna, Virya, Vipaka and main uses of Arka, Ashwagandha and Guggulu

Shrub	Rasa	Guna	Virya / Vipaka	Main use
Arka / Aaka	Katu, Tikta	Tiksna	Usna / Katu	Anticancer, Antimalarial
Ashwagandha	Madhura, Kasaya, Tikta	Laghu Snigdha	Usna /Madhura	Antistress, Adaptogen
Guggulu	Kasaya	Laghu, Suksma, Sara	Usna/Katu	Hypolipidemic, Antiarthritic

Table 3. Chemical constituents of roots and flowers of Arka

Part of the Plant	Major Constituents	Minor Constituent
Root	Mudarol, Akundarol, Uscharidin, Calotropin, Calotoxin Frugoside, Calotropisides, Cardiac glycosides.	Alfa-Amyrin, Beta-Amyrin, Taraxasterol, Beta-sitosterol, Taraxasteryl - Bovalerate & Acetate, Lupeol acetate, Gigantursenyl Acetate
Flowers	Alfa Calotropeol, Beta Calotropeol, Rutin	Beta-Amyrin Hyperoside

Table 4. Cytostatic activity of Arka

Name (Botanic Name)	Part used	IC 50 µg / ml
Arka (<i>Calotropis procera</i> R.Br.)	Flowers	<10
Bhallataka (<i>Semecarpus anacardim</i> L.f.)	Fruits	<10
Cisplatin	Modern known control drug	<10
Placebo	Placebo	>100

and pharmacological attributes of this plant have been studied extensively and are all documented. The prabhava roots in Ayurveda in 'Vrisya' and chemical constituents of roots include several Pyrazole alkaloids, Withanine, Withasomnine, Steroidal Lactones, Withaferin A, Withanolides, Starch, Reducing sugars, Hentria contane, Glycosides, Withaniol Dulcitol and Iron.

Pharmacological attributes and clinical uses

Ashwagandha is an established general tonic, antistress agent and adaptogen. It is somniferous, thermogenic, stimulant and aphrodisiac. Withaferin is reported to be bacteriostatic and anti-tumor agent. Some observations on experimental and clinical studies conducted on *Withania somnifera* are reproduced in Table 5.

The above data indicates that Ashwagandha is twice more potent anti-stress agent as compared to popular Chinese herb *Panax ginseng* and hence Ashwagandha is called Indian Ginseng and hence there is a need to propagate it to replace Ginseng in the market as well as in the profession. Corroborating the above observation Archana and Namasivayam (1999) demonstrated stress indices before and after treatment with Ashwagandha suggesting anti-stress effect in this drug. The some observations of the latter authors is reproduced in Table 6.

Ashwagandha has also been used as a geriatric tonic and anti-aging remedy. The pilot studies conducted in clinical settings in an open clinical trial by Dwivedi and Singh (1997) reveal notable beneficial effect of Ashwagandha on physical and mental health of elderly volunteers. The sample observations made on a six months trial by Dwivedi and Singh (1997) is reproduced in Table 7 as measured through a Biological Age Scale (BAS) and Brief Psychiatric Rating Scale (BPRS).

Cultivation potential and economics

Ashwagandha is better cultivated in light sandy land, pH 7.5-8.0. It does not need much water. It is cultivated by seeds 2.0-2.5 kg per acre. The common sowing time is late rainy season, i.e. July-Sept. One irrigation 2-3 months after sowing and use of biological fertilisers help increase the yield. Harvesting is done 5-6 months after sowing preferably in Dec. to Feb. When the crop is ready for harvesting the fruits become red and the leaves start drying out. In harvesting whole plant alongwith roots is taken out. The roots are separated, washed thoroughly and cut into pieces of 3-7 cm and are left for drying in airy shade. When it is dry, it is ready for marketing and use. The approximate economics of this plant has been worked out by Medicinal Plants Board and certain other agencies claiming net income Rs. 20000 per acre.

Table 5. Antistress Activity of Ashwagandha in terms of Ed 50 in Stressed Rats : (Singh, 1987)

Drugs Tested	Swimming performance Adrenal wt.	Prevention of Increase of Ascorbic Acid	Prevention of rise in Adrenal cortisol	Prevention of induced ulcers under stress	Antistress unit / mg/ g
Ashwagandha	15.0 ± 1.3	13.0 ± 1.4	14.5 ± 1.5	16.0 ± 1.8	14.9 ± 1.5
Tulasi	13.3 ± 1.2	12.0 ± 1.6	13.0 ± 1.5	13.4 ± 2.0	13.7 ± 1.3
<i>P. ginseng</i>	44.0 ± 3.8	15.0 ± 1.8	24.1 ± 2.1	24.07 ± 2.2	25.2 ± 2.3

Table 6. Plasma Corticosterone, Phagocytic Index and Avidity Index under normal and stress conditions

Observation Mean ± SE	Control	Ashwagandha	Stress (Swimming)	Swimming Stress + Ashwagandha
Plasma Corticosterone µg/dl.	98.95 ± 0.51	98.95 ± 0.27	107.2 ± 0.38 p<0.05	99.77 ± 0.14
Phagocytic Index	68.50 ± 0.56	69.60 ± 0.70	78.0 ± 0.58 p<0.05	68.83 ± 1.20
Avidity Index	2.26 ± 60.10	2.51 ± 0.08	3.84 ± 0.13 p<0.05	2.39 ± 0.09
Total Swim Time			5.30 ± 0.24	8.90 ± 0.50 p<0.05

Table 7. BAS and BPRS before and after treatment

Observations	Before Treatment	After Treatment	t	p
Total BAS Scores	18.77 ± 4.55	14.20 ± 4.37	2.92	<0.01
Total BPRS Scores	32.40 ± 5.22	22.93 ± 2.86	6.12	<0.01

BAS = Biological Age Scale

BPRS = Brief Psychiatric Rating Scale

Guggul (*Commiphora wightii*)

Guggulu is one of the very prominent medicinal shrubs specially occurring in the arid land of Rajasthan preferably in acidic, alkaline and or salty soil. It can be cultivated in dry wasteland. The plant needs minimum quantity of water. However, it is advantageous to arrange regular irrigation during first 2-3 years in order to achieve good growth and better yield of gum. It also does not need any fertiliser. However, it is advisable to use Neem, Karanj, Erand or Ratanjot *khali* for manuring as well as pesticide to eradicate white ants, which are the only pests on this plant.

The germination rate of its seeds is very poor hence Guggulu is ordinarily propagated through sipping. Guggulu shrubs are exposed to yield of medicinal gum usually when they are 8 years old. The resin is delivered by incising deeply over the stem, which allows the *Guggulu* to ooze out getting exhausted by 15-20 days giving average yield of about 500-800 g. per plant. Usually the plant dies after this delivery. Guggulsterones are the important chemical constituents in the gum (Table 8).

Table 8. Chemical constituents of gum of guggulu

Part used	Chemical Constituents
Resinous gum	Guggulipid 24%
	Guggulsterone - I-IV
	Guggulsterone - E,
	ZCholesterol Seasamin,
	Camphorene, Cambrane - A
	Essential oils Gum 3.3 %
	Resin and Minerals 58%

Table 9. Parameters in patients treated with guggulu and placebo

Parameters	Placebo Control		Treated by Guggulu		P
	BT	AT	BT	AF	
Body wt. kg.	68.66 ±9.08	67.80 ±9.23	69.0 ± 7.01	67.20 ±6.25	p<0.02
Body wt. Index	1.127 ±0.074	1.113 ±0.072	1.043 ±0.107	1.014 ±0.100	p<0.01
Body Surface Area Sq. Mr.	1.757 ±0.160	1.747 ±0.169	1.741 ±0.829	1.722 ±0.076	p>0.05
Ponderal Index	39.40 ±1.04	39.51 ±1.91	40.61 ±1.77	41.00 ±1.70	p<0.01
Serum Cholesterol Mg / 100 Ml.	221.20 ±35.52	212.67 ±44.45	233.40 ±46.01	180.00 ±41.05	p<0.01
Serum Tri Glyceride Mg / 100 Ml.	120.70 ±25.75	112.37 ±23.30	86.00 ±39.24	60.70 ±37.88	p>0.05
Serum HDL Mg / 100 Mg.	31.20 ±10.35	37.60 ±10.11	35.00 ±8.66	50.00 ±9.25	p>0.05
Total Lipid Atherogenicity Index	7.780 ±2.75	6.199 ±2.64	6.94 ±3.01	3.60 ±1.45	p<0.05

Pharmacological attributes and uses

Guggulu has been classically used in Ayurved as a remedy for Vata-vyadhi and Arthritis. Classically it is claimed as Kapha-Vata Hara drug. It has anti-inflammatory and analgesic activity. The most prominent contemporary use of this drug is for treatment of obesity and hyperlipidemia. Its hypolipidemic effect is scientifically proved and it is claimed to be the best medication of herbal origin for treatment of obesity and increased blood cholesterol besides treatment of arthritis. A series of patients of IHD treated with *Guggulu* for 3 months reported by Mangain and Singh (2005) showed significant beneficial effects as tabulated below which suggest definite hypolipidemic and anti-obesity activity in this drug (Table 9).

Thus all the three arid shrubs described above possess significant medicinal value and appear to have notable economic impact. These are projected in the present paper to illustrate the scope of work in this sector. There is an urgent need to document the available information and to develop strategies and R & D Activities.

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Under-Utilized Medicinal Shrubs Suitable for Alternate Land Use Systems in Western Rajasthan

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Growing interest for cultivation of medicinal crops in arid zone has focused our attention to search newer woody perennials. Such woody perennials which have remained underutilized include promising medicinal shrubs which also provide browse, brush wood and rehabilitate degraded rangelands. Attempts had earlier been made to document the medicinal plants of arid zone of Rajasthan (Chopra and Abrol 1964, Gupta *et al.* 1966). Recently, Singh and Pandey (1998), Kasera *et al.* (2002), Sharma and Prajapati (2002), Singh *et al.* (2002), Chaudhari *et al.* (2005), Kumar *et al.* (2005) also made account of medicinal plants of arid region. The needed attention has, however, not been given to promote these shrubs.

In arid ecosystem native shrubs are adapted to soil moisture stress, desiccated winds and high ambient temperature due to morphological and physiological adaptations. In view of economic potential and ecological sustainability, shrubs can be useful in agro forestry system particularly with a view to diversify it to generate additional income.

In this paper, an attempt has been made to stress the importance of a few selected underutilized arid medicinal shrubs of potential as alternate to existing land use in arid region.

Shrub Diversity in Traditional Rainfed Farming System

Since ancient times woody perennials have been the integral part of the traditional agro forestry system in arid region. These systems were developed by farmers over years of experience to suit ecological and socio-economic conditions with a view to attain stability and diversification in production. These have been broadly categorized into nine agroforestry systems by Saxena (1994). The shrub component in these nine zones include distinct genetic stock of important indigenous shrubs like Bawli (*Acacia jacquemontii*), Phog (*Calligonum polygonoides*), Lana (*Haloxylon salicornicum*), Arni (*Clerodendrum phlomidis*), Jharberi (*Ziziphus nummularia*)

Kheep (*Leptadenia pyrotechnica*), Kair (*Capparis decidua*), Kankera (*Maytenus emarginatus*), Gondi (*Cordia gharaf*), Hingot (*Balanites aegyptiaca*) Murali (*Lycium barbarum*), Jinjwa (*Mimosa hamata*), Gangeran (*Grewia tenax*), Aak (*Calotropis procera*), Sinia (*Crotalaria burhia*), Kharsan (*Heliotropium rariflorum*) and Bui (*Aerva pseudotomentosa*). These species occur in both croplands and grazing lands. In croplands, these can either be found as mixed with crop (such as *Z. nummularia*) or on field fences (such as *Clerodendrum phlomidis*). In fact, through ages of experience, farmers have selected live hedges in traditional farming systems itself representing a subsystem of traditional agro forestry. A number of species are used as live fence along the border of agricultural fields to demarcate boundaries and to protect home yards, agricultural crops from livestock and wild animals. They are also used as wind breaks and create favorable microclimate for crops. Arid shrubs like Phog (*C. polygonoides*), Kheep (*L. pyrotechnica*), Hingot (*B. aegyptiaca*), Kankera (*M. emarginata*), Morali (*L. barbatum*), Arni (*C. phlomidis*), Bawli (*A. jacquemontii*), Gangeran (*G. tenax*), Jinjwa (*M. hamata*) etc are characteristic dominants on field boundaries. These drought-hardy species of shrubs representing population of variable and adapted types amongst live hedges have been selected by farmers as per the land and soil type. Traditional wisdom of inhabitants clearly indicates that they are not only familiar with the species of surroundings but they also understand the ecological interrelationship of various components of the shrub-crop interactions.

Therapeutic Uses of Shrubs

Most of the arid shrubs are used to cure many diseases and ailments, and some of them are also utilized by the pharmaceuticals. Some of the under-exploited arid shrubs are as follows:

Alhagi maurorum Medikus (Leguminosae)

(Syns. *A. pseudoalhagi* (M. Bieb) Fisch., *A. camelorum* Fisch.).

Local Names: Javasa, Oant-jhari, Unt kantalu

It is found in Ganges valley and in arid parts of Kashmir, Punjab, Gujarat, Rajasthan, Maharashtra and Bihar. In western Rajasthan it commonly occurs in low-lying saline and alkaline fields and riverbeds.

It is deep-rooted, erect, bushy spiny shrub, upto 1 m high. The axillary spines are sharp, straight and 2.5-6.0 cm long, which bear flowers. The leaves are simple, one-foliolate, obovate-oblong, mucronate or emarginated at the apex, entire, glabrous or pubescent. The flowers are red or pinkish violet in colour. The pods are 2.4 x 0.2 cm linear-cylindric, beaked with blackish-brown, polished and reniform seeds. Flowering and fruiting is from March to July. Leaves and roots are medicinally important.

Therapeutic uses : The plant is cooling and bitter, possesses anti-bilious and antiseptic properties. Its fresh juice is used as a laxative, diuretic and expectorant. The twigs/flowers are used as a poultice or fumigation for piles. The oil from leaves is applied to cure rheumatism (Kirtikar and Basu 1935). Plant is also used for asthma (Caius 1889). Singh and Pandey (1998) mentioned that its crushed flowers with sugar are taken orally to cure bleeding piles by Saharia and Damar tribes in Rajasthan. Leaf decoction is taken in hot weather as a cooling drink (Sen *et al.*, 1986).

Paris and Dillemann (1960) reported that Alhagi manna is some times considered to be the 'manna' of the Bible. But other authorities, however, are more inclined to favor lichen, i.e. *Leconora esculanta* or the excretions of *Tamarix mannifera* as 'Manna'. They also mentioned that to harvest the 'manna', the arial parts are cutoff and shaken over a cloth. Alhagi 'manna' is one of the principal laxatives and purgatives in the compendium of traditional Persian remedies. The secretion is not found on the Indian plant and is chiefly collected in parts of Turkey, Iraq and Iran (Anonymous, 1985).

Research Needs: No systematic work has been done on the production potential of this species. There is low demand of this species by the pharmaceutical industry. There is an urgent need to collect and understand its range of diversity from nature.

***Clerodendrum phlomidis* (Verbenaceae)**

Local Name : Arni; Trade Name : Arani, Agnimantha, Bharangi

In Rajasthan it is distributed in sandy hummocky habitats as a bio-fence along the boundaries of cultivated fields, as well as in wastelands:

It is a large, erect, more or less scandent shrub or a small tree. The stem and branches are pubescent and whitish-grey. The leaves 3-8 x 3-5 cm, ovate or subrhomboid, obtuse, subentire or coarsely crenate-dentate, glabrous above and gland-punctate beneath. The flowers are white or creamish, fragrant, in axillary and terminal spikes. Fruit is drupe 0.5 - 1.3 cm long, obovoid, 4-lobed, glabrous, blackish-brown with persistent calyx. Seeds are 5-7 mm long, oblong and dirty white. Flowering and fruiting is from October to March.

Therapeutic value : Root is bitter tonic and is an important ingredient of 'Dasamul', a famous Ayurvedic drug. It is given in convalescence of measles. Leaf juice is given in neglected syphilitic complaints. Extract of leaves cures flatulence and leaf paste heals wounds. Decoction of leaves and poultice is used to cure piles (Kumar *et al.*, 2005). Green branches are fed to cattle as a cure for diarrhoea and worms. The leaves are applied locally against guinea-worm (Kirtikar and Basu, 1935). The leaf is used in prolonged body ache, constipation and dropsy by Chenchus of Andhra Pradesh (Venkata Raju, 1996). Seed oil is used as hair tonic by Garasia tribals in Rajasthan (Singh and Pandey, 1988) while seed powder is useful in treatment of rheumatism.

Research needs : There is a good scope of this species in alternate land use systems as the species is traditionally grown on field boundaries in western Rajasthan. Considerable diversity exists in this species ranging from small under shrub to a tree type. This is also an emergency fodder for camel and goats during the drought.

***Cordia gharaf* (Forsk.) Ehrenb & Aschers. (Boraginaceae)**

Local names : Goondi, Guindhira

This species is distributed in Delhi, UP, Gujarat and Rajasthan. In western Rajasthan, it occurs in Bikaner, Barmer, Jaisalmer and Jodhpur districts often cultivated for its edible fruits.

It is a tall shrub or a small tree with deeply furrowed gray bark. Leaves are opposite or sub-opposite, 6-10 x 2.0-2.5 cm, oblanceolate-oblong, entire, rounded at apex, rough and glabrous above when mature and more or less pubescent beneath. The flowers are small and white in short, axillary or terminal corymbose cymes.

Fruits 9-12 cm long, ovoid glabrous, orange or reddish-brown when ripe. Flowering is in March-April followed by fruiting in May-June.

Therapeutic value : Bark decoction is used for gargles and has astringent properties (Kirtikar and Basu, 1935).

Research needs : This species needs greater attention for its utilization in Silviculture, Agrisilviculture and also in Agri-horti system. Being a multipurpose woody species viz., food, fodder and medicinal value there is a need to exploit its potential particularly in Bikaner, Barmer and Jaisalmer districts. It is also in demand by local Ayurvedic practitioners.

***Grewia tenax* (Forsk.) Fiori (Tiliaceae)**

Local names: Gangerun, Gangan

This shrub is distributed in Gujarat and Rajasthan. In western Rajasthan, this shrub is abundant on buried pediments and hill-slopes.

It is a winter deciduous shrub. It attains 0.5-1.0 m height under browsing condition, but can be as tall as 3 m in protected sites. Branches are stiff but slender, thinly pubescent with green and smooth bark when young but turns ashy gray and rigid when old. Leaves are variable 2-4 x 1-3 cm, broadly ovate, orbiculate at the base, acute, and coarsely dentate. Flowers are leaf opposed, white on simple pubescent peduncles. Fruits (drupe) are smooth, shining, yellow orange to red when mature. Fruit production in natural stands varies from 15 to 100 per plant. Flowering starts in August and continues up to October. Leaf fall occurs from November onwards and remains leafless from January-June.

Therapeutic value : The fruits are given for colds. The wood decoction is given as a cure for coughs and pains in the body (Caius, 1989). Fruits eaten by villagers to quench thirst. Decoction of fruit is used to cure asthma, cough and urinary problems.

Research needs : Little work has been done on this species for its fodder potential. Sharma (1997) reported that its efficient root system can penetrate into minute rock crevices for survival in quite extreme sites. It is extremely drought hardy and tolerates frost well but plant growth is slow in arid climate. It does best on deep sandy loam, but can grow in very shallow, skeletal, gravelly or clay soils. This species has medium demand by the

pharmaceuticals, however its biology needs to be understood.

***Indigofera oblongifolia* Forsk. (Leguminosae)**

Local names: Goilia, Jhil, Bekar; Trade name: Raktpala

This species is distributed in Upper Gangetic Plain and Rajasthan. In western Rajasthan it occurs in open mesophytic dry rocky habitats.

This is an erect, ashy-gray, much-branched shrub, up to 1 m high. The branches are slender, woody, divaricating, and terete. The leaves are simple or imparipinnate, both types on the same branches; leaflets 3-5, alternate, 10-25 x 6-8 mm, elliptic-oblong, more or less hairy above and silvery hairy beneath. The flowers are small, in many-flowered axillary racemes and scarlet in colour. The pods are borne along the whole length of the peduncle. Seeds are oblong, 4-gonous and yellow. Flowering and fruiting is from September to March.

Therapeutic value : Considered an antidote to all kinds of poisons. Boiled root is used as a purgative and stem decoction as a gargle in mercurial salivation and for washing teeth (Caius, 1989). Used as a cure for stomachaches. It is antispyhelitic, the roots improve appetite and also used in rheumatism. Also used as a remedy in the enlargement of liver and spleen (Anonymous, 1959). Lodha *et al.* (1990) reported ten compounds in it; four of these have been characterized as psyllostearyl alcohol, triacontanol, b-sitosterol and b-sitosterol-b-D glucoside.

Research needs : This is one of the important leguminous, non-spiny shrub of arid region. As the species of *Indigofera* are effective in greening the bare areas, it has great promise in rehabilitation of degraded lands. There is good scope of this species to utilize its potential as a herbal tooth brush.

***Lycium barbarum* L. (Solanaceae)**

Local name: Morali

This is distributed in Punjab and Rajasthan. In western Rajasthan, it is common on sandy soils forming open scrubs.

It is much-branched spinous shrub up to 2.5 m high. The stem and branches are white or grey, slender armed with sharp, conical spines; which often bear leaves

and flowers. The leaves are solitary or fascicled, variable in size and shape, 1-5 x 0.6-2.0 cm oblong, lanceolate or oblong-spathulate or linear and glabrous. Flowers are solitary or in fascicles of 2-5. The berries are about 6 mm in diameter, bright-red, with persistent calyx. Seeds are discoid or subreniform and minutely pitted. Flowering and fruiting occurs from October to January.

Therapeutic value : The leaves are pounded and mixed with ghee are applied to abscesses. The bark is pounded and the powder blown into the nostrils of horses against bronchitis (Bhandari, 1990). The berries are bitter, enriches the blood; useful in bleeding piles, scabies, toothache; also used as an aphrodisiac. In Yunani system, the leaves improve the eye sight (Kirtikar and Basu, 1935).

Research needs : Considerable diversity exists in this species in its plant type in the region. It is also traditionally used for salt making in the area. It needs attention for its suitability in the live hedge system. The other species *Lycium edgeworthii* Dun is also reported from the Rajasthan (Shetty and Singh, 1991), which is a rare

species in wasteland and scrub forests. This species also needs attention.

***Mimosa hamata* Willd. (Leguminosae)**

Local name: Jinjani

This shrub is distributed in Gujarat, Saurashtra and Rajasthan. In western Rajasthan it occurs in open sandy places, wastelands and on the hill slopes.

It is much-branched prickly shrub up to 2 m high. Branches are downy, with numerous straw-coloured, curved or straight prickles. Leaves are 2-pinnate, 1.5-5.0 cm long. The leaflets are 5-14 pairs, sessile and oblong. The flowers are pink or red in axillary globose heads. The pods are 3.5-8 x 1.0-1.8 cm, falcate and twisted with prickly sutures. The seeds are 6.0 x 4.0 mm and chestnut brown. Flowering occurs in August to November while fruiting from December to March.

Therapeutic value : 5 g of seeds pounded and boiled in buffalo milk is taken as tonic against weakness, but must not be taken in excess (Bhandari, 1990).

Table 1. Suitable shrub species for various landforms in western Rajasthan

Habitat	Species
Hills	<i>Ziziphus nummularia</i> , <i>Commiphora wightii</i> , <i>Euphorbia caducifolia</i> , <i>Grewia tenax</i> , <i>Balanites aegyptiaca</i> , <i>Cassia auriculata</i> , <i>Commiphora wightii</i> , <i>Cordia gharaf</i> ,
Rocky gravelly	<i>Dichrostachys cinerea</i> , <i>Ephedra foliolata</i> , <i>Euphorbia caducifolia</i> , <i>Grewia tenax</i> , <i>Grewia villosa</i> , <i>Indigofera oblongifolia</i> , <i>Lycium barbartum</i> , <i>Ziziphus nummularia</i>
Flat buried pediments heavy soils	<i>Capparis decidua</i> , <i>Ziziphus nummularia</i>
Sandy undulating buried pediments	<i>Leptadenia pyrotechnia</i> , <i>Haloxylon salicornicum</i> , <i>Ziziphus nummularia</i> , <i>Acacia jacquemeontii</i>
Flat aggraded order alluvial plain	<i>Capparis decidua</i> , <i>Ziziphus nummularia</i> , <i>Dichrostachys cinerea</i> , <i>Indigofera oblongifolia</i>
Sand dunes	<i>Acacia jacquemeontii</i> , <i>Calligonum polygonoides</i> , <i>Clerodendrum phlomidis</i>
Saline depressions	<i>Haloxylon recurvum</i> , <i>Salsola baryosma</i> , <i>Suaeda fruticosa</i> , <i>Suaeda nudiflora</i> , <i>Tamarix aphylla</i> , <i>Tamarix troupii</i>

Table 2. Suitable shrub for live hedges having medicinal value

Plant species	Nature	Remarks
<i>Balanites aegyptiaca</i> (L.) Delile	Spiny	Easily propagated through root suckers and flourish well in high moisture status.
<i>Clerodendrum phlomidis</i> L.f.	Non-spiny	Fast growth, good regeneration, less palatable and has esthetic value.
<i>Dichrostachys cinerea</i> (L.) W. & A.	Spiny	Dense canopy fast regeneration and supply fodder.
<i>Grewia tenax</i> (Forsk.) Fiori	Non-spiny	Slow growing but good regeneration and supply fodder
<i>Lycium barbartum</i> L.	Spiny	Unpalatable to cattle with dense canopy
<i>Maytenus emarginata</i> (Willd.) Ding Hou	Spiny	Long spines with browse tolerance helps in dense structure.
<i>Mimosa hamata</i> Willd.	Spiny	Less palatable, dense spiny structure

Research needs : Considerable diversity is observed in the pod and seed size in this species. This species has a good scope as a live hedge material.

Rehabilitation of Degraded Lands

In arid region shrubs have an ecological and socio-economic value especially in rehabilitation of degraded lands by strip plantation of shrub in village common lands, field boundaries, sand dunes, canal banks and road sides. The wastelands and other areas lying unused around the villages can be utilized for planting woody species having medicinal value (Table 1). The farmers can utilize the boundary of their fields by planting medicinally important shrubs (Table 2) without affecting the yield of crop. Halophytic species of medicinal importance have a prime place in rehabilitation of saline degraded lands.

Conclusion

Since a wide range of woody perennials occurring on a variety of habitats in extreme desert areas are able to survive in harsh climatic conditions, the supply of raw material from these even in the times of drought and low rainfall condition is assured. Besides, species having fodder value provide browse at the time of scarcity such as drought. Diversity in these shrubs in terms of variability in chemical constituents, fodder value and reclamation potential can be exploited for selection of superior types for introduction in different alternate land use system. Of special interest is variability in tolerance to heat and drought stress. Collection and systematic evaluation of this natural gene pool is therefore a prime requisite. These would require conservation *in situ* and *ex situ* for genetic improvement programme. Emphasis should also be given on dual purpose woody species viz., medicinal cum forage value, medicinal cum soil conservation, medicinal cum soil reclamation and also their suitability particularly as live hedge. Planting of drought resistant under-utilized shrubs having medicinal value will be useful in economic development as well as maintaining the ecological balance of the arid environment. So there is a need to create greater awareness amongst the inhabitants and farmers regarding the medicinal and economic value of these locally available under-exploited shrubs. It is also important to develop medicinal plants based farming systems (involving a judicious mixture of woody perennial medicinal species) in the existing farming system.

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Senna (*Cassia angustifolia* Vahl) - A Medicinal Plant for Barren Lands

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A rapidly increasing world population and the fast approaching geographical limitations of the world agriculture system are leading to expansion of agricultural activities on to marginal lands which are unsuitable for plant growth and development. Choice of crops is limited on such lands, particularly, in dry agro-ecosystems. Senna, (*Cassia angustifolia* Vahl), a tropical medicinal plant, has potential as a dryland crop for barren lands. Other common names for this shrub are Sanai, Marknadi and Sonmukhi.

Cassia angustifolia is a small shrub that is believed to have its origin in north Africa. It is found growing as perennial bushes in arid tracts of Somalia, Ethiopia, Sudan, Egypt, southern Arabia and their neighbouring countries. The ancient Egyptian doctors used senna over 3500 years ago to treat their royal patients and the elite. It was also used by the Arabian physicians as far back 9th century A.D. It has been reported as laxative and purgative since ancient times in Unani system of medicine. The plant is found growing in a wild state in certain coastal parts of Gujarat especially in the Bhuj region of India. Apparently, the plant must have been introduced into India from its endemic areas in North Africa sometimes in the past. Over the centuries the plant has become naturalized in India. Its cultivation is presently concentrated in the arid and semi-arid parts of Tamil Nadu, Rajasthan and Gujarat.

India is presently the main source of cultivated senna. Large quantities of dried senna leaves and pods and their partially processed material are exported to USA, European countries, Japan and Australia. In the importing countries the sennosides are added to various items of food and confectionery, besides the pharmaceutical preparations. Presently, senna is one of the major item of export from India in the area of herbal material and about 75 per cent of the Indian produce is exported in the form of leaves, pod and sennoside concentrate in the world market. Sudan is a major competitor with India growing the major quantity, the concern is on quality improvement. The demand for senna is observed to be ever increasing. China is increasingly becoming an important market for Senna

exporters in Tuticorin. The Port town in southern Tamil Nadu, along with Kutch in Gujarat and Bikaner/Pali-Marwar in Rajasthan, are among the three key senna cultivation areas in the country. Tuticorin has about 25 exporters, shipping out 6,000 to 8,000 tonnes of senna leaves a year, earning a forex of Rs 30 to 50 crore, depending on the market price. A medicinal herb to treat constipation, senna is also used to brew tea in many countries.

Description

Senna (*Cassia angustifolia* 2n=24 family - Caesalpinaceae) is a small perennial shrub of less than a metre in height with ascending branches. The leaves are compound pinnate, petiolated, about 10 cm long and bear 5-8 pairs of leaflets each on a small stalk. They are 2.5 to 5 cm long and 0.5-1.5 cm broad, oval lanceolate in shape with acute apex and smooth underneath. Variation in morphological traits as observed during trials at CAZRI, Jodhpur is presented in table 1.

Table 1. Variation in morphological traits in different accessions of senna

Character	Mean	Range
Plant height (cm)	38.1	34.6- 45.7
Pods/plant	15.5	10.8- 23.7
Pod length (cm)	3.62	3.41-3.80
Seed/pod	6.53	6.10- 6.82
Fresh leaf wt./plant (g)	4.67	3.38-6.54
Fresh stem wt./plant (g)	3.05	2.21-4.20
Fresh pod wt. /plant (g)	7.54	4.84-11.80
Dry leaf wt./plant (g)	1.90	1.31-2.51
Dry stem wt./plant (g)	1.38	0.98-2.29
Dry pod wt./plant (g)	2.54	1.73-4.19

Source: Singh *et al.*, 2005

The flowers are bright yellow in colour, arranged in axillary, erect, many flowered racemes, considerably extending the subtending leaf. It has short, ovate, membranous bracts, which fall off early. The pods are slightly curved, 3.5-6.5 cm long and up to 1.5 cm broad, light green in colour, changing from greenish brown to

dark brown or black on maturity. A pod encloses 5-7 obovate, compressed, smooth, pale whitish seeds.

Evaluations of various accessions for morphological traits under rainfed conditions at Jodhpur (Singh and Jindal, 2003; Singh *et al.*, 2005) and irrigated conditions at Bikaner (Kothari *et al.*, 2003) did not show any significant variation. However, the mean and range of various characters of 15 accessions is given in table 1. Use of different doses of gamma rays (10 to 50 kR) also could not create significant variability for improvement of desirable traits in senna (Jindal *et al.*, 2005).

Studies on reproductive biology undertaken at CAZRI, Jodhpur as given in table 2 showed that the species as both systems of pollination, i.e. self as well as cross pollination, latter being the dominant. No pods set when flowers were emasculated and left open showed that the species is not wind pollinated.

Senna crop is in the process of domestication. During last few years this crop has been adopted widely in arid parts of Rajasthan. In Bikaner, Sojat, Jodhpur and Jaisalmer region the crop is being cultivated on around 10 - 15 thousand ha. Most of area that has come under cultivation represents barren lands and sand dunes implying that the introduction of this crop will not affect the traditional crops. Rather it will help in generation of additional income through utilization of wastelands and will also have ecological impact through stabilization of sand dunes. The major contributing factors for spread of this crop in this region are:

- A hardy plant not prone to biotic interference, perennial nature
- Insect damage and collar rot or other fungal diseases infrequent in dry areas
- Deep root system and stress resistance mechanisms
- Crop diversification, resulting in promoting sustainability
- Employment and income generation throughout the year
- Low cost of cultivation and harvesting
- Short gestation period for income generation
- Easy post harvest technology and simple processing, easily marketable due to export potential.

Improved Varieties

Seeds collected from the wild plants and pooled together have been the resource material for the cultivation of crop in the different parts of the country. An open pollinated seed variety Sona was released for cultivation by CIMAP, Lucknow especially for the northern part of the country.

A superior senna (*C. angustifolia*) with high leaf and pod yields has been developed by the scientists at the department of Horticulture, Agriculture College and Research Institute (AC&RI), Killikulam, Thoothukudi district. It has been released for commercial cultivation by the Tamil Nadu Agricultural University (TNAU) in 2001. Released as "Senna KKM-1", this high yielding variety is a selection from Tenkalam local. It has 38 per cent higher leaf yield, and 70 per cent higher pod yield than the local varieties. Highly suited for the red soil belts of Tirunelveli and Thoothukudi districts, this variety does well as a rainfed crop.

Table 2. Pollination systems in senna

Mode of pollination	March-May 2001			July - September 2001		
	No. of buds / flowers used	No of pods formed	% fruit set	No. of buds / flowers used	No of pods formed	% fruit set
Selfing	250	1	0.40	225	Nil	0.00
Sibbing	1240	7	0.56	508	10	1.97
Apomixis	195	Nil	0.00	240	Nil	0.00
Cross pollination	280	Nil	0.00	342	7	2.05
Natural open pollination (Emasculated and kept open)				784	Nil	0.00
Natural pollination (buds counted and left as such)	200	NA	0.00	648	323	49.8

Source: Jindal and Singh, 2003

In an NATP project on Improvement of shrubs involving CAZRI, Jodhpur, RAU, Bikaner and GAU (now SDAU) Sardarkrushinagar, Gujarat improvement work was undertaken and population names Bikana was developed at Bikaner and Composite-1 having high leaf yield was developed at Sardarkrushinagar.

Agrotechnique

Senna is a plant of arid environment. The crop does well in the warm subtropical areas. It is usually cultivated in areas where there is bright sunshine and little rainfall. The areas that receive rains frequently and/or get waterlogged and where temperatures remain low for several months are unsuitable for the cultivation of senna. The most suitable areas for the cultivation of senna in India are the dry areas of Haryana, Rajasthan, Gujarat, Maharashtra, Madhya Pradesh, Andhra Pradesh and Tamil Nadu.

The sowing time of senna seed varies in the different parts of the country. It is arranged such that the flowering and the pod forming time of the plant do not coincide with the monsoon season. The seed rate is about 20 kg/ha for the rainfed crop and 12-15 kg/ha for crop raised under irrigation. The seeds may be broadcasted, dry or after pre-soaking. Scarification with H_2SO_4 for 12 minutes is reported to give high germination. They may be drilled in lines 30-50 cm apart at a depth of 1.5-2.5 cm using tractor driven mechanical device. In arid parts of Rajasthan crop is generally sown at the end of monsoon.

Senna could be economically grown under rainfed conditions. In most years, the crop needs no irrigations except under the conditions of prolonged drought. However, when it is grown as a semi-irrigated crop, the yield increased considerably. Even two light irrigations are enough to raise a good crop of senna, however, heavy irrigations are injurious to the crop.

One or two hand weeding followed by hoeing necessary for the removal of dicot and grassy weeds. Once the growth of senna plants picks up, the weeds get suppressed and further weeding is not necessary. The first weeding and hoeing should be done at 25-30 days and second one at 70-80 days from the sowing time. For 100 bigha about 100 persons are needed for cutting and 30 persons for leaf shedding. The labour rate is Rs. 60-70 /day. A good crop of senna gives 10 q/ha of dry leaves and 5 q/ha pods under irrigation and good management practices. The yield under rainfed conditions is about 7 q/ha of leaves and 4 q/ha of pods.

Sennoside contents were maximum in pods of *C. angustifolia* followed by those in the immature leaves and mature leaves. The sennoside a, b, c and total sennoside contents in the senna plants decreased under high salinity effect, while supply of calcium promoted production of these substances responsible for the therapeutic property of the plant.

Active Constituents and Uses

The leaves and pods contain the anthraquinone glycosides called the sennoside A and sennoside B which are used in pharmaceutical industry for preparing preferred laxatives. The plant has been used in the traditional system of medicine for the same purpose. Its material in the dry powdered or decoction form has been used as a stimulant, vermifuge and cathartic, and for relieving habitual constipation.

Two glycosides, one easily hydrolysable yielding emodin and actively cathartic, the other hydrolyzable with difficulty and slow in laxative effect are also present. These glycosides namely sennoside A and sennoside B have the same formula $C_{21}H_{20}O_{10}$ but differ principally with respect to linkage of glucose to the glycone moiety.

A reversed-phase column liquid chromatographic method for the analysis of sennosides A and B present in leaf and pod extracts of *C. angustifolia* has been developed using a Symmetry C18 column and a linear binary gradient profile. The method can be utilised for the quantitative determination of other sennosides as a baseline resolution for most of the constituents was achieved. The method is economical in terms of the time taken and the amount of solvent used (25 ml) for each analysis. The validity of the method with respect to analysis was confirmed by comparing the UV spectra of each peak with those of reference compounds using a photodiode array detector (Bala *et al.*, 2001).

Senna is valued for its cathartic properties. It is especially useful in the habitual constipativeness. It increases the peristaltic movements of the colon. The pods have the same therapeutic effect as of the leaves but they cause less gripping. Senna is contraindicated in spastic constipation and in cases of colitis. The cathartic principles of senna are soluble in water and dilute alcohol. Senna laxatives may take 8 to 12 hours to produce results. It thus, lowers bowels, increases peristaltic movements of the colon by its local action upon the intestinal wall. Senna, should be used for longer than 7 to 10 days. Chronic use of laxatives may lead to "lazy-bowel syndrome" - a dependency on laxatives to

have any bowel movements as the muscles of the stomach and intestines gradually lose the ability to contract without being stimulated by the laxative.

Individuals with an obstruction of the gastrointestinal, hemorrhoids, stomach ulcers, or an inflammatory bowel disease should avoid using senna laxatives because senna's irritating effects may worsen these conditions (Blumenthal, 1993). In addition, constipation may be a sign of a gastrointestinal disease, especially if it is accompanied by abdominal pain. *C. angustifolia*, is contraindicated in pregnancy. Some workers recommend caution during lactation as well.

If senna is used in high doses or for prolonged periods of time, it can lead to reduced potassium levels in the body. Low potassium levels can result in muscle weakness and potentially dangerous changes in heart rhythm. Diuretics such as furosemide and hydrochlorothiazide, may promote the loss of potassium from the body. Thus senna should not be taken at the same time as diuretics.

Gum

In addition to sennosides, *C. angustifolia* contains gum which was comparable to others utilised in pharmaceutical industry. Utilisation of the plants with higher gum content can make *C. angustifolia* a feasible dual source of gum and sennosides.

Owing to economic advantages in addition to the potential for improved process robustness and to reduce the pollution load on the environment, particularly in water treatment applications in developing countries, biodegradable and eco-friendly naturally occurring seed gum of senna can be used as coagulant (Rashmi *et al.*, 2002).

Issues and Prospects

Major issue in senna from farmers' point of view were market related aspects. For example during an interaction meeting held on 27th March 2005 at RAU, Bikaner farmers reported that traders pay for 3 kg less and deduction is for the weight of bag and other unwanted matter. Market prices are highly fluctuating. During 2002 rates went up due to drought and earthquake damage in Bhuj. Prices that were Rs. 17-21 have come down to Rs. 6.00 per kg.

The cost of production is Rs.3 - 4/kg. Sojat is emerging as market for senna leaves as well. Cost of cultivation per bighha comes to about Rs 1000/-. It includes Rs 125 for tractor, Rs 600 for 3 kg seed; Rs 100 for cutting of crop and threshing and Rs 100 for cleaning of the field. Farmers informed that one person/bigha gets employment/year. For 100 bigha about 100 persons are

needed for cutting and 30 persons for leaf shedding. The crop has got established in barren land of arid zone and is become a source of income round the year even during low rainfall years.

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Guggul - A Therapeutic Shrub

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Commiphora wightii (Am.) Bhandari, commonly known as guggul, is a shrub yielding gum-resin generally obtained by incision of the bark. This resin, normally referred as guggul, has been shown to have diverse medicinal properties like lowering of lipid activity anti-inflammatory activity, diuretic, expectorant, diaphoretic activity, etc.

It has a historical use in folk medicine and is today a highly commercially important target species. In the last few decades there has been a sharp decline in natural population of this species. There is hardly any commercial cultivation of this species. However, at Mangliawas near Ajmer in Guggulu Herbal Farm, more than 15,000 plants have been planted on the rocky site and the material so established is being used for research purposes on tapping of guggul and other related aspects.

Commiphora is a genus of about 185 species (Mahr, 1998). Out of these only 4 species are found in India, they are: *C. wightii*, *C. stocksiana*, *C. beryl* and *C. agallocha*.

Commiphora wightii is a much branched shrub or a dwarfed tree with crooked and knotty branches ending in sharp spines. Guggul exudes a resinous sap out of incisions that are made in its bark. The resin has been used for centuries as part of India's traditional medicine called Ayurveda.

Gugulipid has a long history of use in Ayurveda. The Atharva Veda, one of the four well-known holy scriptures (Vedas) of the Hindus, is the earliest reference to the medicinal and therapeutic properties of guggul. Detailed descriptions regarding the actions, uses, and indications as well as the varieties of guggul have been described in the Ayurvedic treatises, Charaka (1000 B.C.), Sushruta Samhita (600 B.C.), and Vagbhata (7th century A.D.). In addition, various Nighantus (medical lexicons) were written between the 12th and 14th centuries A.D. that were based on the Ayurvedic literature.

The list of traditional uses for guggulu is extensive. It has been indicated for healing bone fracture to inflammation, arthritis, cardiovascular conditions, obesity, and lipid disorders. Several other external and internal uses for guggul have been described in folklore and ethnomedicine as well. Although, several therapeutic uses were indicated for guggul, the Indian gum resin was mainly used for treating various types of arthritis.

Ayurvedic physicians extensively used guggul for treating arthritis and related conditions for centuries.

It generally grows in association with trees like 'Thor', 'Mitha jal' and 'Kair'. The rate of regeneration of the tree also increases with other trees. Age of the *Commiphora* tree can be determined by the increment rate of its diameter.

Distribution

The centres of origin of *Commiphora* spp. are the arid regions of South Africa, namely, Somalia, Madagascar, Botswana, Kenya and Zimbabwe and Asia: Sindh, Baluchistan and Pakistan. It is also found in the mountains of Niger, Tanzania, Welo, Yemen Arab Republic and Namibia.

In Indian sub-continent, it is found in Rajasthan, Gujarat, Madhya Pradesh, Karnataka and other low rainfall areas of South India. In Rajasthan, it is widely distributed in the regions of Jaisalmer and Ajmer; whereas, moderately in Jodhpur, Barmer and Bikaner.

Natural Variability

Nine characters were recorded in natural stands of *C. wightii* in the year 2000-2001 on 60 plants growing naturally in Beriganga area of CAZRI in rocky habitat. Plant height ranged from 60.00 to 320.00 cm with a mean of 171.92 cm. standard deviation 61.95 and coefficient of variation 36.03 per cent. The details of mean, range and standard deviation for canopy diameter, collar diameter, number of primary branches, and number of tappable branches and different seed related traits are presented in table 1.

Table 1. Mean, range and SD of shrub morphological and seed traits in *C. wightii*

Character	Mean	Range	SD
Plant height (cm)	171.92	60-320	61.95
Canopy diameter (cm)	28.47	85-625	127.36
Collar diameter (cm)	7.51	2.00-19.00	3.31
No. of primary branches	3.27	1.00-10.00	1.64
No. of tappable branches	3.77	0-12	3.61
Average diameter of tappable branches (cm)	4.59	0-11.40	4.04
Length of seeds (cm)	0.63	0.40-0.90	0.14
Width of seeds (cm)	0.40	0.20-0.70	0.12
Weight of 100-seeds (g)	4.31	3.40-5.20	0.36

The coefficient of variation for nine characters in total population (n = 60) of *C. wightii* revealed that there was high variability for number of tappable branches (95.75%), average diameter of tappable branches (88.01%) and 100-seed weight (83.52%), moderate for number of primary branches (50.15%), and low for canopy diameter (44.15%), collar diameter (44.07%), and low for plant height (36.03%), width of seeds (30.00%) and length of seeds (22.22%).

High variability for number and diameter of tappable branches may be attributed to the fact that branches of diameter more than 6.00 cm were selected as tappable. In some plants branches of the required diameter were absent; whereas in some the number of such branches was as high as 12.

Propagation

By seed

Seed is the major propagation source in nature. Monsoon season creates conducive atmosphere for germination. The temperature during monsoon ranges from maximum 30-37°C to minimum 20-25°C and relative humidity is high. Mature seeds are washed, along with clay and soil, to the crevasses between rocks and germinate there.

Another way of germination is between 'Thor' (*Euphorbia cauducifolia*), which has a property of retaining moisture within its periphery. Mature seeds along with silt are washed in between 'Thor' plants and germinate there. 'Thor' plants are also said to retard termite infestation, which cause major damage to *Commiphora* plants (Tajuddin *et al.*, 1994).

During our experiments large amount of seed set and their germination below guggul was observed where the plants were irrigated regularly. The overall growth of such plants was poorer than those raised using cuttings.

Besides being washed alongwith clay and soil, another way of seed dispersal is by birds. Depending upon the frugivore diversity the rate of seed dispersal ranges from 9 to 66 per cent. Some of the species which help in dispersal are: lesser vasa parrot (*Coracopsis nigra*), ant (*Aphaenogaster swammerdami*) and one lemur species.

The seeds germinate poorly due to coat hardness. Germination of seeds stored at ambient temperatures, ranging from 24-30°C, is maximum. Seeds collected from around anthills germinate better than those collected from under the tree and germination decreases after 12 months

of storage with no germination after 18 months (Randrianasolo, 1989). Dark coloured seeds give better germination than lighter ones. At Nakoda (Rajasthan), mature fruits produce 2 types of seeds: black and white with only the black ones being viable (36.25%). Seeds sometimes produce 2, 3 and 4 seedlings also. The best time of collection is mid-February to mid-March and of sowing is 20-30 June.

By cutting

C. wightii can be successfully propagated vegetatively by stem cutting. Cuttings 20-30 cm long and 1.5-2.0 cm diameter can be planted at a depth of 15 cm, in nursery beds in the month of June. Hormones can be used to enhance rooting. Once rooted, the cuttings can be transplanted in the fields during monsoon. Weeding and irrigation is necessary for 2-3 years after planting.

Air layering using *C. wightii* solution at 500 and 1000 ppm also gives good rooting. Increase in number of shoots and better regeneration can be obtained by coppice regrowth.

Our studies on vegetative propagation using auxins (IBA, IAA and NAA) at concentrations 2000, 4000 and 6000 ppm, showed that dip of cutting for few seconds in 5000 ppm IBA solution was enough to initiate good growth of cuttings. The results were much better when cuttings were left at room temperature for two days before hormone treatment and putting in nursery bag (Table 2). Beginning of March has been identified as the best month for raising plants of guggul using cuttings.

Table 2. Sprouting of cuttings of guggul put in nursery during March

Treatment	Days for sprouting	% sprouting up to 90 days
Fresh cutting	60	30
Fresh cutting + 5000 ppm IBA	60	100
Two days old cutting	30	100
Two days old cutting + 5000 ppm IBA	15	100

Micropropagation

For *in-vitro* propagation, media requirements of *Commiphora* are very specific. It can be micropropagated through forced axillary branching on MS medium supplemented with benzyladenine (BA) and kinetin. Shoot formation is initiated using MS medium supplemented with 17.8 μ M BA, 18.6 μ M kinetin, 100

mg glutamine and 10 mg thiamine HCl/litre and 0.3 per cent activated charcoal. Shoots are rooted by treating them with both IAA and IBA for 24 hours in darkness and transferring to low salt basal medium with activated charcoal (Barve and Mehta, 1993).

Somatic embryogenesis can be achieved by growing immature zygotic embryos (2-3 mm) on B₅ medium containing a low concentration of 2,4,5-T, kinetin, IBA, IAA or NAA. Somatic embryos of explants supplemented with 2,4,5-T and kinetin are white and of various shapes; whereas, those of medium supplemented with IBA and kinetin are green and well developed (Singh *et al.*, 1997).

In a report where cell suspension cultures and immobilized cells were tested for guggulsterone production, it was observed that, in suspension cultures it was 4.5 to 5 times lower than in leaves of intact plant whereas, in immobilized cells it was 2.5 times lower.

Reproductive Biology

In natural habitats, most plants of *C. wightii* are females, either isolated or in groups. Plants maintain their sex in subsequent years. Seed set in females was not dependent upon the presence of pollen. Hand pollination experiments and embryological studies have confirmed the occurrence of non-pseudogamous apomixes, nucellar polyembryony and autonomous endosperm. Anthers from male and bisexual plants, though produce functional pollen grains, the pollen tubes fail to grow beyond the proximal one third of the style (Gupta *et al.*, 1998).

Our studies showed that days required for buds to become flowers ranged from 2 to 7 days with a mean of 4.10 days. Days required by the plants from flower stage to fruit initiation ranged from 2 to 8 with a mean of 5.20 and standard deviation of 1.30.

Guggul flowers twice in a year. First period starts at the end of March and continues till the end of May. Second period is from the last week of October to mid-December. Flowering is asynchronous. On an average, 4.1 days are required for the buds to develop into flowers, and 5.2 days for flowers to initiate fruiting.

Flowers of both the flowering periods bear fruits. Out of every 1.8 flowers, only 1 is able to set fruit. Percentage of fruiting is 57.70 per cent. Fruit is an ovoid drupe, of approximately 0.7 cm length and 0.5 cm width. Only 1 seed per fruit was observed which had approximate dimensions of 0.7 x 0.4 cm, and 100-seed weight of 4.3 g. Fruits turn reddish on ripening. Ripening takes about 1 to 1½ months.

The plants starts to set leaves on the onset of monsoon. The leaves are of leathery texture. In all the marked plants, leaves started falling with the onset of winter, but in some plants they continue to stay on the plant till the onset of dry summer season (only 3-4 plants).

Flowers from about 50 plants were observed under stereomicroscope and dissected to determine the sex. All the flowers studied were female flowers having conspicuous gynoecium. Stamens were present in rudimentary form Gupta *et al.*, (1996) have also reported presence of predominantly large number of isolated and groups of female individuals. Female plants set fruits irrespective of presence or absence of pollen by non-pseudogamous apomixes.

Chemical Constituents

The gum resin of *C. wightii* is reported to consist of alpha pinene (4.75%), myrcene (3.50%), eugenol (14.70%), candinene (5.50%), geraniol (6.20%), methyl heptanone (17.50%), (+) alpha phellandrene (5.10%), (+) limonene (6.50%), (n) bornyl acetate (7.30%), 1,8 cineole [eucalyptol](3.50%), (n) linalool (8.70%), methyl chavicol (5.40%), alpha terpineol (4.00%) and several undefined compounds (Saxena and Sharma, 1998).

C. wightii is a source of oleo gum resin obtained from the plant by incision of bark. 'Guggulipid', the standardized product from the extraction of oleo gum resin from *C. wightii*, was marketed as a hypolipidaemic agent (Nagarajan *et al.*, 2001). The chemical composition of oleogum-resin from different sites (in Rajasthan) shows considerable variation. Guggulipid, a group of long chain linear aliphatic tetrols with hydroxyl functions at C1, C2, C3 and C4 positions, have also been isolated from oleogum-resin (Kumar and Dev, 1987).

Gum Tapping and Collection

After the plant achieves physiological maturity, gum is tapped during December and February. Plants of about 7.5 cm basal diameter are suitable for tapping. The main stem and thicker branches are given incisions at uniform distances of 30 cm and an angle of 60°.

The latex oozes out through the wound as a yellow fluid, which slowly hardens to form the oleo gum resin. The resin is ready for collection after 10-15 days of first incision. The latex accumulates in big lumps, and usually occurs in vermicular pieces, which are pale yellow or dull green in colour with a bitter aromatic taste.

After the first collection has been carried out, subsequent collections are made every 10-15 days during the rest of the season, i.e. upto May and June. Little or no resin is formed after June when rain sets in. The resin is completely soluble in most of the organic solvents and castor oil, drying oils and turpentine. It mixes well with vegetable waxes, stearic acid and resin.

Traditional tapping techniques are unproductive; so several workers have proposed simpler techniques, which help to enhance the oleo gum-resin production also. The ethephon application 48 hours before tapping and use of oblique cuts (made with Mitchie Golledge knife) enhances the production by 22 times (Bhatt *et al.*, 1989). Besides, the techniques like applying a paste of horse or wild ass urine, oleogum-resin and CuSO_4 around the cut dipping of knife, before giving incision, in a solution of 100 mg powdered *C. wightii* and 200 ml clean water ((Hocking, 1993), ethephon at the rate of 400 ml/tree have also been used.

Poor techniques associated with tapping of gum resin and adverse climatic conditions have led to the total destruction of the tree, in its natural habitat, and now it is fighting for its survival. According to the I.U.C.N. red data book dealing with threatened plants, this tree has been mentioned as vulnerable due to over-exploitation.

Medicinal Uses

C. wightii has a wide range of usefulness in common ailments. In Rajasthan, it is also used as a common folk medicine. Use of *C. wightii* as medicine is also mentioned in literature of ancient times. Indian Pharmacopia also recognizes *C. wightii* as a medicinal plant whose ingredients are variously used in pharmaceutical industry (Gupta, 1990).

Guggulipid, a mixture of lipid-steroids isolated from oleogum-resin of *C. wightii*, is a potent hypolipidaemic agent (Kar *et al.*, 2000). It also acts as hypocholesterolaemic (Dog *et al.*, 2001); effective in blood pressure and other heart diseases, diabetes and reduces chest pain. Z-C. guggulsterone present in guggulipid has a thyroid stimulating action. A new cultivar with increased sterone content has been developed by CIMAP and released (Anonymous, 1997). Sesquiterpenes and terpenoids found in the bark exudates have an antimicrobial action. Antibacterial activity is reported against pathogenic bacteria like *Staphylococcus aureus*, *Escherichia coli*, *Proteus mirabilis* and antifungal activity is seen against *Pseudomonas acruginosa* and *Candida albicans*.

C. wightii is also known for its anti-inflammatory, antiseptic and astringent properties (Rangari and Donglikar, 1994). It is also used in eczema in children, amoebic dysentery, diarrhoea and other stomach complaints (Claeson *et al.*, 1992).

It also acts as antischistosomal, fasciolicial and calcium antagonist. It decreases viability of P388 tumor cell lines. Reports on its use as male contraceptive in Pakistan have also been published (Shah *et al.*, 1997).

Essential oil is used against helminthes like tape worm (*Taenia solium*) and hook worms (*Bunostomum trigonocephalum*). Oleo-resin and oil are mosquitoicidal against *Culex pipiens* larvae, reduce reproductive potential of *Tribolium castaneum*, are molluscicidal against egg clutches of *B. alexandrina* and *L. cailliaudi*, alcoholic extracts are antiamoebic and are insecticidal for cotton leafworm. Leaf extracts show nematicidal properties against *Meloidogyne incognita*.

The oleo gum-resin has a balsamic smell and is used in agarbatti industry and also as a fixative in perfumery. Young branches are also used as toothbrushes.

Production and Trade

Starting from the sixth year, one plant of *C. wightii* yields 200-500 g of dry guggulu in one season. The gum which comes to the market can be graded into three categories: (i) best grade of guggulu is that which is collected from thick branches and is free from adhering bark; (ii) second grade is usually mixed with bark, sand and is of dull colour, (iii) third grade is usually collected from ground which is mixed with sand stones and other foreign matter.

The villagers, after collecting guggul bring it to the middleman, who in turn sells it to the wholesale dealers. The chief market of guggul is Kutch division in Bhuj. Five other lesser markets are Anjar, Nakatrana, Mundra, Mandvi and Gandhidham. In Rajasthan, Beawar and Balotra are the chief markets. Delhi is the important centre to which *C. wightii* is sent for marketing.

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Prospects of Shrubs in Rainfed Regions of Southern Peninsular India

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Man has been depending on the natural resources for his survival. Such dependence has been in harmony with nature for centuries, increase in human and livestock population necessitated the extension of cultivation to marginal and wastelands to meet the ever increasing demand for food fodder, vegetables, timber, medicines, etc. The unsound farming systems as well as changes in land use practices are the primary reasons for the deterioration of one of the key resources, the soil, which sustains the food and nutrition security of people the world over. The carrying capacity of the natural resources is already overstretched. Modern agricultural production technology may rise the carrying capacity of the land but it cannot be sustained beyond certain limits.

The challenge to sustain food production at a desired growth rate is difficult for a country like India since it has a large proportion of rainfed lands which are bestowed with the problems of poor resources like shallow soils, low available water holding capacity (AWHC), and inefficient rain water use ; high soil and climatic variability, excessive degradation of natural resources, undulating lands, poor entrepreneurial ability of farmers. So the productivity of crops in such areas is low and uncertain resulting in poor economic condition. Alternate land use technologies and management strategies are therefore necessary to sustain rainfed agriculture. It provides on-

farm sources, which will enhance rural livelihoods by generating cash for resource poor rural households.

Agroforestry has not only great potential but also helps in conservation of natural resources and contribute to the sustainability of the fragile ecosystem. Many Agroforestry systems have been developed but, not been adopted by the farmers. The main reason is due to the long gestation period of the tree component (Solanki and Bisaria, 2002).

Shrub based systems are important in rainfed agriculture for utilization of fallow, and marginal lands. Bushes provide wide spectral potential in sustenance of agriculture as they provide food, fruits, fuel wood, medicines, fibre etc. They meet the demand of the people and also elevate the socio-economic status and standard of life. The distinguishing feature of the shrubs planting is mainly because they are perennials with smaller canopy compared to the trees. They offer least competition with associated crop for moisture and light. Plantation of economic shrubs with arable crops would improve the production and income from rainfed areas. Some of the problems of rainfed regions and adaptability of bushes to such problems are presented in the table 1

Experiments at Central Research Institute for Dryland Agriculture (CRIDA) have revealed that the

Table 1. Compatibility of bushes to rainfed regions

Problems	Compatibility
Ill distributed rainfall, and frequent dry spell	Drought resistant, Can be cultivated with minimum organic inputs, Quality of the produce is better under stress
Soil erosion, Shallow soil, Excessive degradation of natural resources	Deep root system, Quick growing , provide cover throughout the year, and reduce degradation
Menace of cattle grazing in Agroforestry systems is high	Many are non grazable, Wastelands can be utilized, can also be used as fence
High initial investment in establishment of trees, Longer gestation period.	Bushes have short gestation period. And start economic yields from 2-3 years. Intercrops can be taken up with bushes for a longer period compared to trees
Economic instability due to arable cropping	The bushes can be harvested 2-3 times in a year. Hence it provides employment round the year. High export value

bushes are likely to ensure better returns due to efficient utilization of land and rainfall. Further, planting these crops may minimize the risk of crop failure due to biotic and abiotic factors (Korwar and Pratibha, 1998). The potential bushes for drylands are Henna, Bixa, Indigo, curry leaf, etc (Table 2).

Keeping the above issues in mind, an attempt has been made to discuss the economic potential and agro technologies for important bushes.

Annatto (*Bixa orellana*)

Annatto (*Bixa orellana*) is a tropical bush, which yields bixin from seed coat. It is world's second most important natural colorant (after caramel) yielding yellow to orange colour (Evans, 2000). It has a special interest among food processors and cosmetic companies because the natural colour is safe for consumption. In the early 1930 there was a surge in interest among chemists and nutritionists in annatto as a possible source of carotene, especially when the British committee on food colours in 1954 recommended that use of coal tar colours, yellow 3 yellow AB and yellow 4 are prohibited in food industries. Annatto was used in lipstick manufacturing world wide (Srinivasulu and Mahapatra, 1989). The dye is used in some regions as textile dye (Moron, 1981). In the beginning of this century, annatto faced competition with synthetic colours. But latter it gained importance since Red dye No 3 was banned by USFDA in 1990 because of carcinogenic effect.

The market for both EU and US is expected to grow steadily. Keeping in view the market demand for this crop it can be cultivated commercially in large scale in India. Not much authentic information on agrotechnique of annatto is available for rainfed regions. Hence an attempt was made to develop the agrotechniques to maximize the yield and bixin.

Bixa is a quick growing shrub, canopy is more or less conical and the foliage is dense. It grows 2-4 m

tall. The flowers are arranged in panicles. Generally the flowers are white which give green capsules and the second type is a pink flower, which gives red capsules. Both the capsules give red colour seeds which yield orange colour. The bixin content and yield varies among different bushes in the plantation irrespective of the pod size and colour. (Pratibha and Korwar, 2002). Hence the bixin content varies with the genotype rather than the pod color or shape.

Annatto does not require fertilizer when it is cultivated in medium to high fertile soils. It has pronounced growth and yield response to increasing fertilisers suggesting that mineral/organic fertilizers are important for long term successful production of crop. The foliar nutrient analysis indicated that it responds to phosphorus fertilization (Elias *et al.*, 2002). In low fertile soils the flowering and fruit yields were influenced by nitrogen and potassium fertilization. High leaf nutrient concentration and response to increase fertilizer input annatto is considered to be a relatively nutrient demanding (Schroth *et al.*, 2001).

The farmers in India usually do not apply any fertilizer with a opinion that it does not require any fertilizer and it should be cultivated organically. But after 2-3 years, phosphorus and Mg deficiencies were observed. Vermicompost increased yield and bixin content. By 45% and 15%, respectively over farmers practice. Annatto fits well into Agroforestry system provided other trees do not shade it, as sunlight is necessary for its cultivation. The trees are managed as bushes. There was a chance to minimize the risk of crop failure due to biotic and abiotic factors by cultivating legumes in the interspace of annatto. It was observed that they increase the soil fertility and offered additional income to farmers.

Under favorable condition, the first crop may be obtained in about 18 months after planting, but full yield is obtained after 3 or 4 years. Experiments at CRIDA, Hyderabad showed that *Bixa* can successfully be

Table 2. Potential bushes for South India Peninsula

Common name	Scientific name	Economic part	Use	Chemical constituent
Annatto	<i>Bixa orellana</i>	seed	Food colorant	Bixin
Henna	<i>Lawsonia inermis</i>	leaf	Cosmetic	Lawsonone
Indigo	<i>Indigofera tinctora</i>	leaf	Textile	Indigo
Curry leaf	<i>Murraya koengi</i>	leaf	Spice	-
Senna	<i>Cassia augustifolia</i>	Leaf, pod	Laxative	Sennosolides
Aloe vera	<i>Aloe vera</i>	leaf	Cosmetic, medicinal	Aloin

Pratibha and Korwar (2002)

cultivated in areas receiving 700 mm and above annual rainfall in medium deep red soils. About 500 plants can be grown in a hectare (4.5 m x 4.5 m) and each plant yields 1-1.5 kg of seed from 3rd year onwards giving a gross income of Rs. 25, 000 to 30,000. (Pratibha *et al.*, 1998)

After extraction of the pigment, the dye extracted annatto seeds are generally, considered as waste. Wurts and Torreblance (1983) have, after detailed study, concluded that it is possible to use these seeds as a feed, when mixed with other materials, as a food for human consumption. Dye extracted Annatto seeds when fed to the poultry deepen colour of the egg yolk and the flesh.

Indigo (*Indigofera tinctoria*)

The blue colour is rare in nature and as such it is treasured wherever it is found. There are not many plants, which yield blue colour. (Shakuntala Raunani, 1989). The most popular blue dye is obtained from plants like *Indigofera tinctoria*, *Isatis tinctoria*, *Polygonum*, *Gymnema tingens*, *Wrightia tinctoria* and *Galega tinctoria*. Of the above plants *Indigofera tinctoria* is the important multipurpose legume species in the tropical countries. Natural *Indigofera* produces much higher quantity and the quality of indigo than the temperate plants (Nikki Padden *et al.*, 1999). Indigo has a thirty-fold higher pigment precursor content than woad (*Isatis tinctoria*), and is thus a superior source of indigotin. (Huxtable, 2001). Indigo is perhaps the oldest, first to arrive and last to depart colour in the natural colours. The leaves contain the blue pigment. The main colouring matter which is used is Indigotin this is present in the form of glycoside indican. The indican content varies in different species. It also varies according to season, age of the plant. The leaf of the young plant usually has smaller percentage of coloring matter. Indigo cultivation practically ceased in India after the Second World War barring few isolated pockets in A.P and Tamil Nadu.

It fixes atmospheric nitrogen and improves the soil fertility and therefore can be grown as intercrop in horticultural and other tree plantations. It can be successfully cultivated in drylands both as a sole and intercrop. The major gap in indigo is on the agronomy and chemistry of dye extraction and was addressed at CRIDA, Hyderabad to develop suitable agrotechniques and dye extraction procedures for indigo.

Indigo is sown directly through seeds at a spacing of 30cm x 10cm. It germinates well within 10

days. Application of nitrogen significantly improved the biomass yield. A dose of 20 kg N/ha increased the biomass by 20%. Application of nitrogen might have increased the availability of nitrogen, which in turn helped in better growth of the plant.

The dye content was significantly influenced by nitrogen. Application of nitrogen decreased the dye content by 13% in both the years.

Application of 60 Kg phosphorus / ha increased the dye content and biomass, but beyond 60 Kg / ha the dye content decreased. Among the sources of organic and inorganic fertilizers, vermicompost application recorded higher biomass and dye content. This was followed by castor cake.

The dye content increased with the growth of the crop. Maximum dye recovery was recorded at 50% little pod stage. Little pod stage recorded 46% higher dye content than the other two stages of harvesting. Increase in interval of harvest increased the vegetative growth and recorded optimum leaf stem ratio. This might have contributed towards the higher dye recovery.

Harvesting at 50% little pod stage recorded 58.42 and 72.69 kg/ha dye yield in 1997 and 1998, respectively. This might be due to higher biomass yield and dye recovery in this stage as compared to the other two stages.

The nutrient content of the plant material did not decrease even after dye extraction. Hence the material can be used as manure. The plant material after dye extraction also has higher nitrogen content. The material can be used as green manure. It was tested on different crops like senna, Indigo, Andrographis. It was found that the yield in these crop has increased when compared with inorganic fertilizers and FYM application. To ensure a regular supply of dye even in off-season, the dye was extracted from the leaves of the plants by fermentation method. The extraction procedures were modified at CRIDA to obtain higher yield and quality of the dye.

The waste liquor obtained after dye extraction also had nutrients and this can be applied to the crops. The indigo liquor obtained after dye extraction also had pesticidal (antifeedant) properties. Rotenoids and diterpenoids present in *Indigofera tinctoria* might be responsible for the pesticidal properties (Rao *et al.*, 2004).

Henna (*Lawsonia inermis*)

Henna, (*Lawsonia inermis*) is an important dye-yielding crop. The leaves of the plant yield an orange colour. Its cultivation is concentrated in Rajasthan. The crop has been widely introduced to other parts of India. Prior to wide spread availability of synthetic dyes, this crop was widely used in textile dyeing, and as an herbal dye. Cattle do not graze the plant, hence it can be grown as fence to protect crops and orchards from animals. It can be used for soil conservation (Kolarkar *et al.*, 1981). Henna is adaptable to a wide range of climatic conditions. It is tolerant to drought condition. Hot dry weather with prolonged drought favours high quality henna. The yellow flowered henna is mostly cultivated in arid and semi-arid regions. There are no released varieties in India. However morphological variation and difference in yield and quality exists in different accessions. Hence considerable scope exists for germplasm selection for high yield and lawsone content. Research studies were initiated at CRIDA to identify superior accessions with different accessions collected from Rajasthan and Andhra Pradesh. The studies indicated that the collections from Pali recorded higher yields when compared to other accessions whereas accessions from Sojat recorded higher lawsone content.

The henna is adaptable to wide range of climatic conditions. It is tolerant to drought condition. Hot dry weather with prolonged drought favours high quality henna. The correlation coefficients were worked out between rainfall, temperature vs. yield and quality to study the influence of environment on yield and quality. It was observed that the quality of henna was significantly negatively correlated with rainfall and minimum temperature, whereas it was positively correlated with maximum temperature. However it was also observed that only some accessions had significant correlation with environmental factors, while other accessions do not have any significant correlation with environment. Hence selection of accessions, which do not respond much to environment, may be given priority. (Korwar and Pratibha, 2004)

Henna is propagated by both cuttings and seedlings. However seedlings are preferred over cuttings as the survival of seedlings (88%) is better when compared to cuttings (67%) The better survival of seedlings than cuttings is due to better root growth than cuttings.

Cuttings recorded higher yield than seedlings. However the quality in terms of lawsone is higher in seedlings than cuttings. Early flowering was observed in cuttings than seedlings. Due to flowering the photosynthates are diverted to flowers and seed formation. Hence the photosynthates available for synthesis of secondary metabolites are reduced which in turn reduce the lawsone content. (Pratibha and Korwar, 2004). In agroforestry system seedlings were transplanted at 2 x 1 m spacing whereas in sole planting it was planted at 60 x 30 cm spacing (Roy *et al.*, 2003). When the crop is planted at 2 x 1 m spacing microsite improvement improved the survival yield and quality of henna (Pratibha and Korwar, 2004). The input levels vary enormously in different locations depending upon soil type.

Senna (*Cassia angustifolia*)

Senna is a cash crop and earns good foreign exchange. It is native of Saudi Arabia and cultivated in Tamil Nadu, Karnataka, Andhra Pradesh and Gujarat. The crop is well suited to drylands as it is drought tolerant, and is non grazable by cattle. The leaves and pods are widely used in Ayurveda, Unani and Allopathy for its laxative properties. This property is mainly due to chemicals viz., sennosides A and B. The demand for senna is increasing in the international market.

Curry leaf (*Murraya koenigii*)

The curry leaf is used mostly in South Indian dishes for aroma. The western world is fast taking enthusiastically to Indian curry leaf especially those who prefer their food to be tangy without being too hot. The leaf has carminative, anti-diabetic and anti-hypertensive properties. It has many nutrients and vitamin C.

The plant is well distributed and grows under varying climatic conditions. It is found throughout India in almost all the states. The bush yields approximately 10 t/ha/year fresh leaf under rainfed conditions.

Higher returns were obtained when Suwasini variety was cultivated as shrub in SAT (Korwar and Pratibha, 1998). Moreover, with proper training curry leaf plant can be cultivated as a shrub (bush) in rainfed regions. If curry leaf is planted at a spacing of 4 x 1 m intercrops can be cultivated for a longer period and farmers can get additional returns. (Korwar and Pratibha, 2003).

Karonda (*Carissa carandus*)

It is a short statured shrub, which is very hardy and thrives well under rainfed conditions without much care. The crop starts bearing from third year and gives economic yields for 50 years. The bush can be used as fence. The fruits either green or pink coloured. The fruits are used for pickle, squash and osmo-dehydration.

Aloe (*Aloe barbdensis*)

In last five years demand for gel of *Aloe barbdensis* has increased many fold. It is considered as treasure of Indian medicinal plants. The species has considerable demand for its medicinal properties with specific utility in the cosmetic industry. The leaves contain aloin and its content ranges from 4 to 4.5%. Owing to the increased preference to herbal cosmetics, the demand is on the rise. Hence Selection of aloin rich varieties and scientific cultivation will be remunerative.

It flourishes on dry sandy soils in areas with low rainfall. It is propagated through root suckers. Aloe plantation gives commercial yield from second year upto an age of 5 years. In each harvest, 16-20 tons of fresh leaves are obtained in an hectare.

Economics of Bushes

Several studies were carried out at CRIDA, Hyderabad during 1996-2004 to evaluate the yield potential and economics of important dye yielding crops. The experimental site receives a mean annual rainfall of 760 mm and climate is semi-arid tropical with alfisols as a predominant soil order (pH 8.5, O.C 0.2 %, total N 0.025 %). The economics of the crops are presented in the table 3. The data reveals that the cultivation of bushes is economical than the regular arable crops like sunflower, sorghum. The paper describes the efforts made to improve the productivity of bush-based system to increase the economic returns per unit of land.

Table 3. Economics of Bush cultivation

Scientific Name	Yield (Q/ha)	Price (Rs/kg)	Net Returns (000/ha)
<i>Bixa orellana</i>	Seed : 5-10	30	30
<i>Lawsonia inermis</i>	Dry leaf : 2.5 t	15	25
<i>Indigofera tinctora</i>	Biomass : 25-30 Dye : 50	750	35
<i>Murraya koenigii</i>	Leaf : 10	3.50	15
<i>Cassia aungustifolia</i>	Leaves : 10-15 Pods : 1.5-5	15	28
<i>Aloe vera</i>	Leaves : 15		20

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Henna (*Lawsonia inermis* L.) A Promising Dye Yielding Shrub

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The common garden shrub henna/ mehndi, a native of North Africa (Egypt's arid area or perhaps Ethiopia), is well known for its hedge forming ability and production of flowers with an intoxicating fragrance. Egyptian people have been using henna since very early days of civilization for medicinal and cosmetics purposes like dying hair, skin, nails, etc. The ancient Arabic name Henna or Hinna is by far the most used and well known for all the names. Hinna, meaning to dye red, appears to have originated in Arabic speaking Persia. In Hindi called Mehndi, possibly derived from Sanskrit word "Madyantika". Commercially it is grown mostly for its leaf crop and to lesser extent as an aromatic crop for its floral essence.

Distribution

It occurs naturally in North Africa, perhaps Egypt or Ethiopia. It is primarily distributed in the Mediterranean North Africa and the Arabia peninsula countries of Algeria, Morocco, Cyprus, Egypt, Libya, Ethiopia, Saudi Arabia, Syria, Lebanon, Turkey, Iraq and Iran. There the natural stands of henna are found along water courses and extend up to the arid regions due to their ability to withstand hot and dry conditions as well. Secondary centre of distribution of henna include the Sub-Saharan West Africa (Nigeria, Ghana, Guinea, Gambia, Burkina Faso, Liberia, Mali, Mauritania, Niger, Senegal, Sierra Leone, Sudan, Togo, Cameroon, Zanzibar, Tanzania, etc.), the South East Asia (India, Pakistan, China, Sri Lanka, Malaysia, Indonesia, Philippines, etc.), the Caribbean Islands, Australia and Mediterranean Europe (Spain).

Ecological and Climatic Requirements

Henna can be grown on wide variety of soil and climatic conditions. The biophysical limit of henna in terms of annual precipitation is 200-4200 mm (Anonymous, 2004). It prefers deep, fine sandy loam to sandy clay loam, and well-drained soils in younger and older alluvial plains. Even poor stony and sandy soil can also become its abode. This crop shows resistance to soil salinity. Soil having pH between 4.3 to 9 with gravels and pebbles in it may also prove useful. It is believed that dry, hot iron/calcium (calcareous) bearing soils produce henna with high lawsone content. Most fertile soils produce henna with low lawsone levels. However, both aspects need field

level verification. It requires 20-35 °C temperature during active growth period and, hot, dry and sunny (cloud free) weather conditions with RH < 50% at maturity for higher dye content (Singh *et al.*, 2005b).

Agri-History

Henna is abundantly cultivated in Egypt in gardens for its strong smelling of flowers and farm crop for its leaves since 2000 BC (Gode, 1999). Henna appears to have reached India around the maurayan dynasty, for use by the rich and royal as hair color and perfume. Its commercial cultivation started much later. Prior to henna, Indian used laksa tree dye to stain their hands. Other botanicals like alta, turmeric, kumkum, myrtle (*Myrtus communis*) alkanet, indigo and madder were also in use prior to henna in India. Though henna is widely distributed in African and Asian continent, but systematic cultivation of henna initiated in Egypt during Mohammedan era. Mohammedan rulers introduced it in Indian sub-continent in Sind and Faridabad/ Gurgaon around 712 AD and 1200 AD respectively (Kumar *et al.*, 2005). In Rajasthan, it started around 100 years back at Bhawani, Kota and Sojat. The area under henna rose from 157 ha in 1953 to 35000 ha in 2003 at Sojat (Anonymous, 2003)

Economic and Ecological Uses

All over the world the shrub is widely used as herbal hair dye and for staining body skin in the popular art form called 'mehndi'. The dried leaves are powdered and used as wet dye pack for the purpose. Besides this, various parts of plant are used as medicine under traditional Ayurvedic or Unani health care system and as veterinary treatment. The essential oil from its flowers is used in perfumes. Henna leaf extract has also been found to offer protection from various plant diseases and pests as a natural pesticide (Singh and Lodha, 2005). Before the advent of synthetic dyes the henna dye was extensively used for textile printing particularly wool and silk.

In India it is primarily cultivated as a dye crop for its dye-rich leaves. The leaves contain about 1 to 3 per cent of the naphthoquinone dye lawsone on dry weight basis. Most of the commercial area of the dye crop occurs in West Rajasthan in Pali district adjoining the Rajasthan desert. Besides this it is also grown in commercial gardens for extraction of essential oils used in essence

industry as in Uttar Pradesh (Kannauj) and Madhya Pradesh (Ujjain).

Henna is a hardy shrub capable of growing under diverse soil and climatic conditions. It has quick regeneration ability and can tolerate hot and dry conditions. Therefore, it has been found suitable for re-vegetating marginal areas such as gravely and sandy wastelands and for checking wind and water erosion in arid and semi-arid regions. In drought prone areas, it may act as drought proofing crop as it has the ability to produce even with 150 mm rainfall (Rao *et al.*, 2005)

Brief Description

Lawsonia inermis L. Syn. *L. alba* Lam. (family Lythraceae) is a tall shrub to small tree, 2-6 m high. It is glabrous, multibranched with a spine tipped branchlets which are green when young but turn red with age. Leaves are opposite, entire, glabrous, sub sessile, elliptical, broadly lanceolate (1.5-5.0 cm x 0.5-2.0 cm), acuminate having depressed veins on dorsal surface. It has whitish, small fragrant flowers in large terminal cymes. Each flower has 4 sepals, 2 mm calyx tube with 3 mm spread lobes. Petals are obovate, white or red and stamens inserted in pairs on the rim of calyx tube. Ovary is 4 celled, styles up to 5 mm long and erect. Fruits are small, brownish capsule, 4-8 mm diameter, mainly seeded, opening irregularly into 4 splits. Style is persistent, seeds 3 mm across, angular with thick seed coat. This woody shrub has longevity of up to 50 to 100 years with exceptional regeneration capacity when coppiced. Both seed and stem cuttings can be used for its propagation.

Phenology and Reproductive Biology

Genetic improvement of plant species is possible if phenology and reproductive biology is thoroughly understood. The vegetative and reproductive periods of henna are not well defined and indicate indeterminate growth habit. Under tropical conditions the shrubs grows luxuriantly and flowers several times in a year. However, under the sub-tropical climate the plant mostly flowers twice during spring and the monsoon season. Under the arid and semi-arid conditions of Rajasthan, Singh *et al.* 2005 found maximum flowering in the month of September requiring an average 16 days period to complete anthesis. The plant exhibited maximum intensity of vegetative growth during the monsoon periods, perhaps in response to the increased availability of soil moisture and moderate temperature during the period. Length of individual inflorescence had a range of 2.40 to 9.0 cm with a mean value of 5-6 cm. Maximum mean length of inflorescence

was 7.2 cm whereas minimum was 4.1 cm. Number of flowers per inflorescence ranged in between 27 to 142 with mean value of 68. Percentage viable pollen grains at full bloom ranged from 62 to 99 per cent with a mean of 86 per cent. Viability of pollens of same plants after 15 days ranged from 46 to 93 with a mean of 71. On an average 20.2 per cent decrease in pollen viability was noticed in between full bloom to 15 days after bloom. Berries, green when young, turn blue black later on, are non-edible. Length of fruits ranged from 0.20 to 0.50 cm with mean of 0.30 cm. Width ranged from 0.4 to 0.8 cm with mean value of 0.50 cm, weight of 100 fruits were 5.1g. Number of seeds per fruit was 37.8 and 100-seed weight was about 0.05 to 0.10 g. Flowering is asynchronous in henna and it lead to 42% fruit setting under open pollination conditions. According to Miczack (2001) it is self-pollinated crop. However, presence of large number of insects belonging to *Zygoptera*, *Coleoptera*, *Catopsella* sp. and some beetles during blooming may cause cross pollination. So there is need for more study in this area.

Natural Variability and Breeding

Henna appears to have been introduced in the country around the Mauryan dynasty period (Gode, 1999) and began to be cultivated indigenously much later. The commercial fields of henna in Rajasthan that began to come up about 100 years back are heterogeneous and seem to represent the genetically diverse plant material brought in from other regions that started growing henna much earlier such as in erstwhile Punjab, UP, Madhya Pradesh and Gujarat.

Phenotypic observations indicated the prevalence of two types of the yellow-flowered henna in the extant field populations of Rajasthan. Locally designated 'desi' and 'muralia', they exhibit diverse morphological and reproductive behaviour. The 'muralia' type henna is characterized by a much woodier canopy with small grayish green leaves, abundance of spine tipped branchlets and relative absence of flowering compared to the leafy canopy, large sized green coloured leaves, fewer spine-tipped branchlets and good to profuse flowering behaviour of the 'desi' type of henna. It is observed that Sojat henna has more lawsone content than henna produced in other parts of country.

Further, among the 'desi' henna material that is generally more productive in terms of leaf yield, considerable variability has been observed for traits like plant height, canopy spread, leaf length and width, dry

leaf yield, 100-seed weight and dye content of the plants in the sojat region and material brought from other parts of country (Singh *et al.*, 2005a). There was ample amount of variation in populations of henna in the fields. If henna is an inbred species as mentioned by Mickzack, 2001, this variability can be exploited through simple phenotypic selection to develop superior high yielding varieties for cultivation. Since foliage is the main economic part of henna dye crop it may be desirable to select for late and reduced flowering intensity. It is opined that high genotypic x environment interaction and effect of age on productivity of henna under coppice system needs to be taken into account during selection. So far little formal breeding has been done in henna to improve productivity. As the seed is collected from the henna fields, the possibility of collecting immature seed can't be ruled out and hence germination of such seed is hardly 20%. As a result farmers may have to use 7-8 kg seeds for planting one-hectare land. Singh *et al.* (2005a) advocated the adoption of participatory approach for henna improvement in view of its minor status and limited cultivated area. This would involve the close cooperation of henna farmers in the selection; evaluation and testing of new genotypes.

Biochemical Parameters of the Products of Economic Value

Henna is used mostly for dying and staining hair or skin primarily in the form of wet paste of its dried leaf powder. Pulverized leaves powder consists of the physical remnants of the diverse histological features of whole henna leaf. These include broken pieces of cuticle and epidermis of leaf lamina, monoclinical crystals of calcium oxalate (15-40 microns in diameter), rosettes of leaf parenchyma tissue or druses, sections of vascular bundle fibres and vessels with annular thickness. Further air-dried leaf powder contains about 3-10 per cent moisture and minor volatile substances. Henna powder is rich in colouring pigments amounting to 12-15 per cent by weight (Paranjape, 2001). Among them lawsone or 2-hydroxy-1,4-naphthoquinone is the main dye compound for which henna is famous as a natural dye stuff (Lal and Dutt, 1933). It occurs at varying concentrations from 1 to 3 per cent or even more in rare occasions. The powder also contains gallic acid, glucose mannitol, fats, resins (about 2 percent) and mucilages (CSIR, 1962). Other organic compounds found are lutedin and its glucosides; lacoumarin, laxanthones, fraxtin, slopotetin and its esculetin and the phenolic glucosides, lawsoniaside and lalinolside. Quality of henna powder is determined by its colour, purity and its dying property and fineness (BIS,

1985). Browning of dried leaves indicating moist conditions and leakages of dye during the post-harvest curing (drying) phase is undesirable. Similarly thin lamina often found under less light intensity (as due to natural shedding of leaves in irrigated stand, dense population shading by trees in the field or prolonged overcast conditions) is considered less conducive to expression of dye and therefore not desirable. It has been observed (Roy *et al.*, 2005) that the leaves harvested and dried in October (autumn) had more dye content and produced the desired bright green colour powder.

Lawsone can be estimated by spectrophotometric method, chromatographic methods in the laboratories. Its flowers are used to prepare scent called henna attar. It is extensively used in Mohammedans countries. Henna leaves have the property of antifungal, antibacterial and antivirus etc. So it is in use in preparing ayurvedic medicines. It has the ability to control many plant diseases and insects etc.

Present Status and Scope of Henna for Crop Diversification in Farming System

Henna cultivation occupies about 40,000-hectare area in the form of field, hedges on bunds and as ornaments in the garden in India. Out of this Pali district of Rajasthan occupies around 35,000-hectare area. The area that was only 157 ha (<5% of total area in the country) in 1953 rose to 35,000 ha in 2003-04 in Pali district (Anonymous, 2004). The area under henna plantation in Pali district increased from 16408 ha in 1991-92 to 30418 ha (2000-01) with an annual compound growth rate (ACGR) of 7.75 per cent, while other crops either had low or negative growth rate in the same period (Khem Chand *et al.*, 2002). The favourable soil-climate conditions increasing awareness among farmers regarding this crop and industries started in the area played a great role in expansion of area under its cultivation in this part of arid Rajasthan. The occurrence of frequent drought also encouraged farmers to divert area in henna as farmers hardly get any income from arable crops during drought situation while henna gives at least some returns during agriculturally harsh conditions. Henna is cultivated in dense plantations as an annual ratoon rainfed crop under no use of fertilizer/ FYM etc. Therefore, there is risk of losing its productivity in the long term. There is need to develop scientific management techniques for achieving sustainable higher yield level from our henna plantations.

A NATP workshop in collaboration with CAZRI, RRS, Pali on "Issues and Prospects of henna cultivation

and trade in Arid and Semi-arid Region" was organized at Sojat on 26th September 2004. Various issues related to its production were raised. Problem faced by farmers and attempts made by CAZRI, Jodhpur under NATP and AP Cess fund (ICAR) schemes on henna to resolve these problem are highlighted in following paragraphs.

Low percentage of seed germination : In traditional nursery technique seed takes 15-20 days to germinate and germination percentage is hardly 20%. As a result farmers have to use 6-8 kg seed to plant one-hectare area. Studies conducted on treatment with salt (3%) or acid scarification (80% H₂SO₄) improved the germination to the extent of 60-70 per cent and seed took 7-10 days to germinate.

South westerly winds combined with moisture and nutrient stress induce early flowering resulting low yield of impure quality of henna : Generally farmers grow dense population of henna at a spacing of 30 cm x 30 cm with an intention that certain mortality may occur due to low precipitation and termite attack. Highly dense plants compete for moisture, light and nutrients particularly in low rainfall years. Low rainfall coupled with southwesterly winds induces early flowering and resulting low yield. Inclusion of berries with leaves causes deterioration of quality of henna product. This problem can be resolved by selecting high yielding genotypes having late flowering through participatory plant breeding approaches. Among different genotypes khedbram, Dhanduka, S-8 and S-22 have been found late flower bearing and give high leaf yield. Further improvement is required on developing a variety acceptable to farmers in the region. Among cultural practices widely row spacing 60 cm x 30 cm combined with *in situ* moisture conservation technique (inter row or inter paired row water harvesting) may help in utilizing the water, nutrients and light resources properly. This technique has been developed at CAZRI, RRS, Pali and one year established plantation provided encouraging results. Widely row spaced crop provided 17 per cent higher yield of henna dry leaf than that of densely planted farmers technique. When *in situ* moisture conservation was integrated with widely row spaced, it resulted in 10-12 per cent more yield. Thus it provided 27-29 per cent higher yield owing to more number of intact green leaves and less flowering and berries formation. Thirdly application of farmyard manure at the rate 5 t per ha improved the yield of henna by 12 per cent while 60 kg N + 40 kg P per ha improved the yield of henna by 19 per cent. Application of such nutrients had no bad effect on dye content. Application of nutrients will help in restoring

the productivity of henna for longer period. Integrated management of improved technology may increase production by 54% (fig. 1) Farmers generally remove flowers and berries but it is expensive being labour intensive practice, hence flowers can be used to make scent. Henna flowers contain volatile oils like beta-ionone and its derivatives, 2-phenolethanol, etc. (Wong and Teng, 1995). Hence, it would be better if some scent industries established around Sojat to resolve this problem and provide employment opportunity in the region.

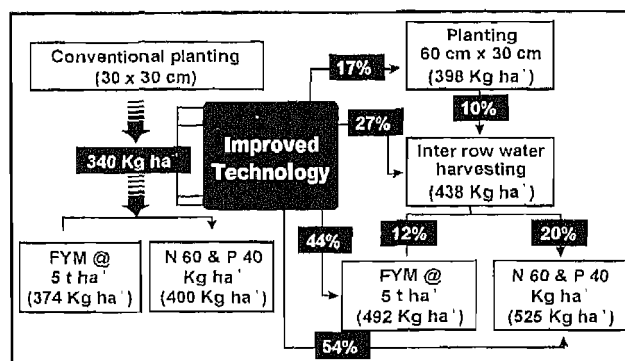


Fig. 1. Improved technology for henna cultivation

Leaf shedding at base near maturity cause considerable reduction in yield : Shedding of lower leaves amounts to 10-15 % losses. Sometimes farmers are forced to harvest immature leaves, which cause deterioration of henna quality owing to improper curing of leaves having high moisture content. As a result leaves turn brownish and fetch less price in the market. Thus there is need to develop improved cultivation, agrotechnique, balance nutrition, biofertilizers, hormones. Application of GA increases vegetative growth and lowers leaf shedding and seed production (Devedjyan *et al.*, 1987). Widely row spacing combined with inter-row water harvesting helped in better retention of green leaves until harvest (Singh *et al.*, 2005). Also application of balance nutrition in the form of FYM or inorganic fertilizers helped in better production of leaves (Rao *et al.*, 2005). However, further investigation are required on this aspect.

Termite damage : Termite attack during plantation year and old plantation is prevalent and causing considerable damage to plants. Application of Chloropyriphos during new plantation and with rain in the old plantation may prove useful in controlling termite. Some of biocontrol methods under testing are use of friendly fungi (*Metarrhizium* and *Beauveria*). Caster semilooper also appears during heavy rains.

Weeds infestation : Ephemeral, annuals and perennial weeds come profusely after the onset of monsoon. Henna

planted at a spacing of 30 cm doesn't permit mechanical intercultivation and hence manual weeding is common practice. It is very expensive and farmers are not able to remove the weeds in time. Weeds compete for water, nutrient and light and cause considerable reduction in production of henna. Studies conducted at CAZRI, RRS, Pali revealed that application of atrazine @ 1.0 kg a.i. per ha controlled most of the weeds. However, wider row planting (60 cm) facilitated cultural operation with tractor in between the rows. It removes the weeds and conserves the soil moisture.

Harvesting- a cumbersome and expensive job : Manual harvesting is quite expensive and need skilled labourers, which are reducing day by day as people are shifting to cities to earn their livelihood, round the year. So there is need to develop improved, labour & time reducing harvesting equipments for henna.

Small and marginal farmers generally do not grow henna owing to its higher initial cost and secondly they are interested to have grains/ pulses/ oilseeds for their daily uses. For them henna based intercropping system with legume is under research and it may help to generate the income of farmers along with their traditional crops. Besides, henna can be planted on marginal and gravelly soils, which are not being cultivated. This would help in raising the income of farmers in the region if they brought such uncultivable wastelands under henna cultivation. Other areas having semi-arid environments in Gujrat, Haryana, MP, Maharashtra, AP and Karnataka have lot of scope for its cultivation in future.

Issues Related to Present Usage, Export, Economics and Marketing

Henna leaves are being used as marketing product in Pali district. Henna is used as a scent crop at Kannauj and Ujjain of UP and MP, respectively. Its seeds, flowers and leaves are also in use to prepare ayurvedic medicines. Crop residues are either burn or kept on bunds. Scope of henna residues as to conserve moisture and control weeds needs further investigation.

Henna cultivation has been proved to be a profitable enterprise for farmers in the drought prone areas of western Rajasthan. With an average expenditure per hectare of about Rs. 25,000 on initial planting and a recurring expenditure of Rs. 14,000 (almost 70 per cent being on farm labour), it provided average net return of about Rs. 12,500 under rainfed situation (Khem Chand et al., 2005). Inadequate availability of skilled labour during transplantation and harvesting operations is a major

constraint and cost factor. This could be ameliorated by mechanization of inter-culture operations and use of more efficient harvesting tools or machinery. Support price and direct purchasing of leaves from farmers through govt. agency would further help in expansion of henna cultivation in the region.

India is the major producer and exporter of henna leaves in the world. These are used for manufacture of dyestuff and other related herbal cosmetic products, and also for religious purposes in Islamic societies. Most of the quality production comes from the henna fields spread over 35,000 ha in Sojat and surrounding areas in western Rajasthan. In 2003-04, out of the estimated production of 39,000 tons dry leaves about 30 per cent of it worth Rs. 91 crore was exported to Turkey, UAE, USA and Middle East countries. The henna trade in between 1995-96 to 2003-04 showed ACGR of 9 per cent. However, proper storage of farmers produce in mandi requires facilities of shed and godown. It would help in maintaining the quality of product.

Owing to the extensive domestic consumption pattern and generally persistent demand for high quality Indian red henna in the overseas market there is more or less an assured market for henna leaves both within and outside the country. In response to this as well as the drought hardy nature of henna and the relative ease of its cultivation farmers have had opted for this cash crop at an increasing rate in the arid fringes of Pali district in west Rajasthan. The area under henna in the district grew at the average rate of about 7 per cent annually during the 1990s. So vigorous has been the spread of henna farming in this tract that an exclusive market (mandi) for henna leaf trading and large number of henna processing units (180) has come up at Sojat, its epicentre.

Research Needs

Although henna is a minor commodity its cultivation provides an attractive means of livelihood to farmers in drought prone marginal rainfed areas of arid and semi-arid regions. Some of the researchable thrusts are highlighted below-

- Development of late flowering genotypes
- Understanding physiological bases for early flowering and leaf shedding and their management from the breeding angle.
- Soil and climatic analysis for developing high lawsone containing genotypes.
- Integration of planting geometry, water harvesting and balance nutrition (organic/ biofertilizers).

- Development of integrated weed controlling measures to minimize labour cost on weeding etc.
- Intercropping as a diversified farming system for small and marginal farmers.
- Scope and promotion of henna in other rainfed areas of arid and semi-arid regions.
- Judicious use of nutrient and water (irrigation) so as quality of henna may not be affected.
- Physiological measures for the control of early flowering and formation of berries in henna plantation.
- Post harvest drying and sheds etc. to control losses caused by unseasoned rains etc.
- Development of low cost harvesting machine

Conclusion

The area and production of high quality henna in the country need to be increased further to meet future requirements and also boost foreign exchange earnings. It is pertinent, therefore, to investigate the above constraints related to henna cultivation and production. The value of henna leaves in the market could be further enhanced by encouraging the organic farming and by the promotion of the other diverse potential uses of henna.

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***Aloe vera* in the Indian Arid Zone**

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Aloe vera known as Ghikanwar, Guarpatha, or Ghrithkumari belongs to family Liliaceae. It is a stoloniferous succulent shrub native to West Indies but now naturalized in India. It is Kathaligida, Lolesara, Kumari in Kannada, Musabbar in Kashmiri, Kattavala in Malayalam, Elwa, Korpad, Kunwar pata in Marathi, Kattazhai, Sirukattashai, Chirukattali in Tamil, Manjikattali, Chinnakalabanda in Telugu and Ghiqwara in Urdu (Anonymous, 1985). It has acquired prominence in last couple of decades because of commercialization of some 250 products prepared from it. In view of its growing importance, research programmes have been initiated in various institutions in India and abroad. This body of knowledge on *Aloe vera* is being presented in this paper.

Taxonomy

Aloe has over 200 species of which *A. vera* is commercially most important. *Aloe vera* has short caudex, usually simple. Leaves fleshy, densely resolute, ensiform, above 30 cm long and 4 cm wide, pale green, sessile tapering to a blunt point with horny teeth, deltoid at margin. Younger leaves have spots which usually disappear with age, peduncle forked, upto 1 m high, racemes dense, rachis glabrous, pedicels erectopate, bracts small, ovate. Perianth 2-3 cm long, orange-yellow, constricted above ovary. Stamens not exerted, capsule oblong, glabrous, shortly stipitate. Flowering in December-January. Fruiting in February. Seeds triquetrous or flattened, sometimes winged testa black, albumen fleshy, embryos straight. Plants however, show enormous variability in its morphological features.

Geographical Distribution

It is widely distributed in tropical and subtropical countries of Africa, Madagascar, Socotra, India, China, Mediterranean region, Canary islands, Spain, Italy, East and West Indies and host of other countries. In India, it is dominant along coastal Gujarat, Maharashtra, and entire south India. Sporadic occurrence in natural wilderness has been reported from rest of the states of India.

Ecological Distribution

It is a succulent shrub, which can withstand both physical and physiological water scarcity. This makes it survive in a large variety of ecological situations ranging from

seashores for seaside landscaping to sandy hummocky lands in semi arid to sub-humid areas and on rocky areas with skeletal soil. It is one of the preferred plants as vegetative barrier for soil and water conservation because of its spreading root system. In Pushkar area, the croplands located on windward sandy hummocks support it on their farm boundaries and irrigation channels. It also occurs as ruderal specially around a ditch where rain water accumulates. In Aravallis near Beawar Masuda-Desuri to Sirohi-Bamanwara tract, it occurs abundantly around water bodies, exposed rocky slopes in crevices or along water courses. It was seen growing on rocky terraces in Bhadrarjun hills in Jalore. Sporadic field plantations of it have been seen in Pipar, near Jodhpur while it is grown as field crop in Bikaner district and Kutchchh areas. It has recently been planted on windward dune flanks in Laxmangarh, Sikar with success. Throughout the country, it is planted in graveyards. However, in Jaisalmer and Barmer areas, we found it growing in temple backyards or even right in front of dairy. It occurs abundantly under *Prosopis juliflora* in grazinglands in Bhinmal area of Jalore or as understorey on the rocky slopes of Mount Abu. Versatility in its distribution makes it an 'ecological flagship' species in arid conditions.

Uses

History of uses of Aloe vera

Cosmetic use of *Aloe* dates back to 1500 BC when Cleopatra used it as skin aid. Arab traders spread it far and wide around 6th Century trading it as far as Asia. It is mentioned in German medical records of 12 century and in the compendium of *Materia Medica* to the Chinese Ming dynasty. Treating wounds by its external application was a practice by Greek Physician Dioscorides. Its use for eczema was common in China, India and Tibet. The United States Dispensatory mentions the use of aloe gel as early as 2300 years ago. It is repeatedly referred in the Holy Bible and was extensively used in India as long ago as in BC 4000. Its therapeutic, cosmetic and other uses are official in Indian and British pharmacopocia (Srivastava and Singh, 1996).

In Ayurveda, it is prescribed for a large variety of disorders and ailments which included purgation, eyes problems, rejuvenator, increases muscular strength,

promotes virility, cures abdominal tumours, antidotes for poison, relieves effect of burns, cures skin diseases, antispasmodic and antidyspnoic. It is also indicated in splenomegaly, hepatomegaly, glandular enlargements and inflamed painful parts of the body (Satyavati *et al.*, 1976).

Medicinal uses

Dried juice of leaves and pulp are used in Indian system of medicine. For stomach, it is a tonic in small doses while it is purgative, emmenagogue and anthelmintic in large doses. It is a remedy for intestinal worms in children. Hair growth can be stimulated by applying Aloe dissolved in spirit. Pulp confection is given in piles, while its mixture with honey and turmeric is effective in coughs and colds. Its ethno medicinal uses are detailed elsewhere in this proceeding. Painful inflammations and chronic ulcers are relieved with intake of its leaf juice (Nadkarni, 1954). Lewis and Elvin Lewis (1977) reported gel's efficacy in pain relief and itching due to radiation burns. This stops keratosis and ulcerations, thus preventing it from malignancy. Bhandari and Mukerji (1959) also claimed that flesh Aloe leaf gel is effective in treatment of X-ray reactions. Its therapeutic actions as alterative, stomachic, cathartic, antihelminthic have been well established by many workers (Cheney, 1970; Reynold, 1950; Yogi *et al.*, 1982). It has become an important cosmetic blend because of its moisturising, softening and healing actions on skin (Anonymous, 1987, Henry, 1979; Leung, 1978).

Chemistry

Leaf extract of *Aloe* contains an array of chemical compounds, the predominant being aloins, emodin, anthraquinone derivatives, chrysophanic acid and coumarin (Chopra and Ghose, 1938; Bhandari and Mukherji, 1959; Reynold, 1985). The name 'aloin' was given to a crude material from which barbaloin could be isolated. Barbaloin is an anthracene glycoside (Mapp and McCarthy, 1970). Chemically, it is a 10-glycopyranosyl derivative of aloe emodin anthrone [10-(1-deoxyglycosyl) aloe emodin anthrone]. Indian species also contain isobarbaloin while *Aloe ferox*, another commercial species contain an amorphous barbaloin and aloinosides A and B (Anonymous, 1987). The percentage of barbaloin in Indian aloes population varies from 5.53 to 22.76 per cent of dry weight of the exudates (Srivastava *et al.*, 1990).

Chemical properties of Aloin vary depending on the variety of aloe from which it is obtained. It is, by and large, a yellow microcrystalline powder with a faint odour

of aloes and intensely bitter taste. This turns dark on exposure to light and air. Aloin is soluble in water and alcohol (90%) but sparingly soluble in chloroform, solvent ether and in benzene (Anonymous, 1996). Chemical studies have revealed that it contains a large number of bioactive compounds in varying proportions which include aloin, aloe-emodin, aloetic acid, homonatalion, aloesin, aloesone, emodin, chrysmminic acid, chrysophanic acid, apoise, galacturonic acid, calcium oxalate, choline salicylate, saponins, uronic acid, sugars, mucopolysaccharides, 7-hydroxy chromone, coniferyl alcohol, glucosamines, hexuronic acid, amylase, allinase (Henry, 1979). *Aloe vera* juice upon neutron activation analysis revealed that it has 4.7 per cent calcium, 1.43 per cent sodium, 6.6 per cent potassium, 12.2 per cent chloride and 0.01 per cent manganese (Maharen, *et al.*, 1977).

Cultivation

Aloe vera is propagated through root suckers. Being succulent, it grows well in drylands and poor soils without much care. It has a relatively shallow root system. It however, prefers well drained soils free from waterlogging. It can be planted in field by suckers at 50 x 50 cm distance or 50 x 75 cm distance depending upon availability of water. Application of N, P and FYM to sweet Aloe in Bikaner revealed that N alone or in combination with FYM increased the size and fresh weight of leaves (Pareek *et al.*, 1999). In optimum conditions of Jodhpur and Bikaner, when irrigated at 15-30 days intervals, the plant establishes very well and produces a flush of leaves. As the outermost ring of leaves approaches and touches surface, 2/3 of the leaves in a plant can be cut leaving 1/3 to grow further. As many as 3-4 cuts in a year are being taken by farmers in Bikaner. Since these are preferred to be grown in organic manure, a preliminary study on FYM application of 2.5 and 5 t/ha at CAZRI has revealed its growth to be best in 2.5 t/ha of FYM application. This study is in progress to arrive at final recommendations. Likewise, *Aloe vera* planted as vegetative barrier in the farmer's fields as well as experimental fields of CAZRI resulted in an increase in the yield of crop in the intervening space by virtue of conserving rainwater in the sandy soil (Sharma, 1999). It has been reported by Heggars *et al.* (1993) that irrigation directly affect get composition and hence role of irrigation in standardizing the gel composition needs in-depth study at field level experiments. Studies on impact of flood irrigation vis-à-vis drip irrigation currently in progress at CAZRI will further add to our knowledge on this aspect. Further studies are also needed on spacing, row and mixed cropping and as a plant in agroforestry system in order to promote it as alternate landuse crop.

Harvesting and Yield

There are two ways of harvesting its leaves: Destructive and Non-destructive. In destructive method, plants is cut below at root. Whole cut plant is packed as such for sending to pharmacies which prefer this harvest because there is no loss of juice as leaves are not cut at base. Farmer gets 70-100 per cent more return of this harvest. In non-destructive harvesting, upper 1/3 rosette of leaves is left on plant and lower 2/3 rosette is cut and packed. Fresh leaves are sold @ Rs.5-10/kg. NABARD has estimated Rs.11400 to Rs.15000 per acre per year as net profit. Even if it is Rs.5000 per acre considering all risks, it is a profitable venture in arid conditions.

Natural Variability

Forty four populations of Indian *Aloe* collected by NBPGR were evaluated by Srivastava *et al.* (1990) for botanical and chemical variability. It was concluded that Aloin content was positively correlated with short, broad and thick leaves. Eight promising lines were identified for comparative evaluation and domestication. Leaf age also plays a crucial role in terms of Aloin content. Per cent Aloin was very high in the young leaves of different *Aloe* species and it declines, as the leaf grows old and matures. However, it is the mature leaf that forms the produce of market. They also reported absence of isobarbaloin in 13 accessions necessitating a revision of taxonomy of Indian *Aloes*.

In order to understand this taxonomic problem, Darokar *et al.* (2003) investigated germplasm diversity in *Aloe* species at molecular level using RAPD and AFLP analysis of their DNA at CIMAP, Lucknow. This study of 21 accessions of four species, i.e. *Aloe vera*, *A. perryii*, *A. arborescens* and *A. saponaria* revealed that *A. perryii* was closer to *A. vera* complex while diversity within *A. vera* complex was more. *A. saponaria* was distinctly different. Thus, there was some overlap across species and accessions (Darokar *et al.*, 2003).

Studies carried out in the past three years at CAZRI have also revealed enormous variability in its morphology. A total of 38 accessions from Jaisalmer, Barmer, Jodhpur, Nagaur, Ajmer, Sikar, Ganganagar and NBPGR, were collected and planted in Botanical Garden. The average leaf length of the collections varied from 48 to 71 cm, width 7.0 to 10.5 cm, thickness 1.1 to 2.4 cm and fresh leaf weight 126.38 to 518.43 g per leaf. From these collections, those *Aloe vera* were selected which are known as "Khara" and "Meetha" in Bikaner. Analysis of 12 juice samples of Khara variety and 8 of Meetha

variety revealed that the juice content ranged from 0.75 to 3.1 ml per leaf. Aloin content in Meetha variety was negligible (0.0005-0.0127 g per 100 ml juice), but Khara variety had very high content of 2.63 to 5.60 g/100 ml juice (Fig. 1). Highest content (5.60 g/100 ml juice) was found in samples from Churu, followed by those from Bhinasar in Bikaner district (5.57 g/100 ml juice). Samples collected in July-August contained higher aloin of (10.00 to 15.40 g/100 ml juice) that that in other seasons. Aloin juice content was the maximum during February-March.

Aloin content was correlated with leaf length, width, thickness, fresh weight and leaf juice to develop correlation matrix (Table 1).

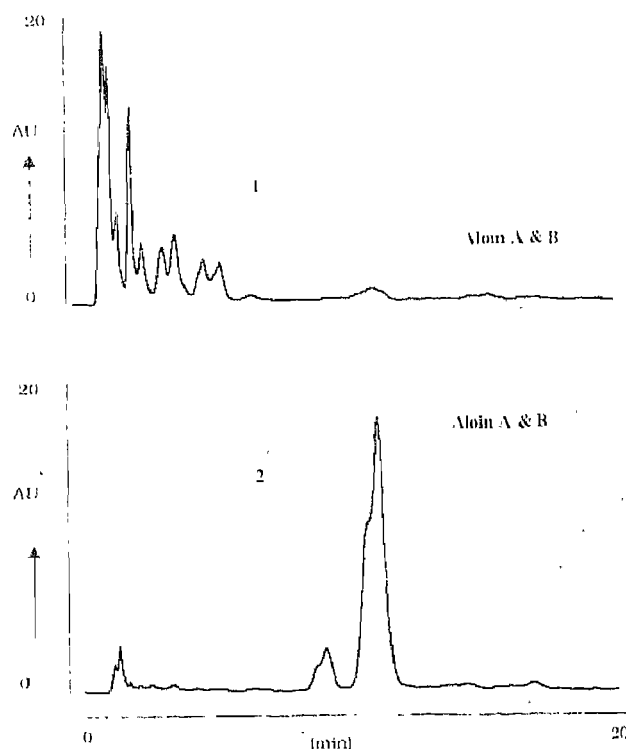


Fig. 1 HPCL chromatography of yellow sap from (1) *Aloe vera* var. Meetha (1.5 ml/100 methanol), and (2) *Aloe vera* var. Khara (0.5 ml/ 100 methanol) (Anonymous, 2003)

Leaf width and fresh leaf weight could be correlated with Aloin content through following equation: $Y=9.679-1.632x_1+0.02x_2$ ($R^2 = 0.967$), where x_1 = leaf width (cm); x_2 = leafs fresh weight (g). Promising selection can therefore be made on the basis of these parameters.

Clinical Validation

There are four types of *Aloe* (Wallis, 1961) in the market.

Socotrine Aloe : A semi solid, opaque, brownish yellow pasty material dried on gentle heat to remove moisture when it turns to hard, dark brown mass. This is alcohol

Table 1. Correlation matrix of *Aloe* leaf parameters

Parameters	Leaf length (cm)	Leaf width (cm)	Leaf thickness (cm)	Fresh leaf weight (cm)	Juice per leaf	Aloin (g/100 ml juice)
Leaf length	1	0.6696**	0.0473	0.5544*	0.1088	-0.1726
Leaf width	-	1.0000	0.2581	0.6936**	0.3208	-0.1802
Leaf thickness	-	-	1.0000	0.6957**	0.6863	0.6406
Fresh leaf weight	-	-	-	1.0000	0.6459**	0.4178
Juice per leaf	-	-	-	-	1.0000	0.4931
Aloin (g/100 ml juice)	-	-	-	-	-	1.0000

* Significant at 0.05; ** Significant at 0.01

soluble, extremely bitter, nauseous taste with unpleasant odour. This is obtained from *Aloe perryi* grown in Zanzibar and Soaetra.

Zanzibar Aloe : It is a hard deep reddish brown with agreeable odour and less bitter in taste. It is probably from *A. perryi* but botanical identity is not conformed.

Cape Aloe : Dark reddish brown to blackish with clean glossy fracture with distinctly sour odour, it is obtained from *Aloe forex* Miller and hybrids of this species with *Aloe africana* and *Aloe spicata* growing in Cape of Good Hope in South Africa.

Caracao Aloe : A yellowish to reddish-brown or chocolate brown mass which breaks with a dull waxy even fracture. It is obtained from *Aloe vera*.

The above commercial products can be confirmed by putting its powder in a lactophenol mount under microscope. Their crystalline types and shapes are entirely different and can be easily distinguished.

Aloe vera is non-toxic in its gel or any of its products (Anonymous, 1977). Aloin could cause irritation on skin in higher concentration. Safety data on various *Aloe* based cosmetics and gels have confirmed that these have no harmful effects (Henry, 1979). Singh *et al.* (1973) reported that *Aloe vera* juice in the form of an ointment in vaseline promotes wound healing by thermal burns and radiation injury in albino rats. Content of hydroxyproline and mucopolysaccharides were increased in animals given its gel (Singh *et al.*, 1973). Teradaira *et al.* (1993) also reported the efficacy of its juice in treatment of gastric ulcer.

Lectins isolated from gel portion of its leaves have strong haemagglutination and mitogenic activities (Winters Wendell, 1993). 'Aloes compound', a preparation containing 'aloes' as main ingredients effectively treated infertility associated with irregular menstrual cycles.

Polysaccharides in the gel have different size chains small, medium and large. Smaller chain polysaccharides are anti-inflammatory. The medium sized polysaccharides are anti-oxidants, antibacterial, antiviral and stimulates tissue's own regeneration process.

The longest chained polysaccharides, the beta-glucomannans have been called Acemannan, which enhances immune system and tissue regeneration. A large number of patents have been obtained on *Aloe*'s such products in USA. In fact International *Aloe* Science Council Inc. has made the analysis of *aloe* by Nuclear Magnetic Resonance (NMR) spectroscopy (Diehl and Teichmuller, 1998) as an official certification of these products to caution the consumer about fake/adulterated *aloe* products. Large industrial units claim that *Aloe vera* loses its efficacy, if the leaves are not refrigerated within 4 to 6 hours of their removal from field or these should be taken directly for production. Applying too much of heat and pressure for too long a time also spoils many of its ingredients. So its cold processing is now followed (Aloecorp, 2000). Management of psoriasis with *Aloe vera* gel has been reported by Syed *et al.* (1996). Thus, a variety of uses have been clinically also confirmed.

Future Research Needs

- A large number of researchers have been working on *Aloe*'s various aspects. In order to avoid duplication, a network of Indian Researchers on *Aloe* is needed.
- Variability in *Aloe vera* in different biogeographic regions of India needs to be collected and evaluated for different bioactive compounds.
- Agro-techniques suiting different agro-climatic zones need to be developed.
- Harvesting and processing need to be standardized with respect to maintenance of bioactive compounds.

- Pharmacological standards of different formulations of *Aloe* also need a serious review.
- A proper marketing and price support from government is required to promote it as a dryland crop.

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Fibre Yielding Shrubs of Indian Arid Zone

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There is growing awareness of utilizing the newer plant resources all over the world. Utilization of native shrubs, that constitute a major part of woody vegetation, is important to livelihood of the people in arid zones. Many such species offer considerable scope for the extraction and use of fibres for cordage, ropes and handicrafts. Fibrous nature of the plants is a survival mechanism against hot dry winds. A number of plant species like Aak (*Calotropis procera*), Kheep (*Leptadenia pyrotechnica*), Sinia (*Crotalaria burhia*), etc have fibrous nature (Table 1.) and natives of the region have been using such plants in various ways such as for making ropes, baskets, thatching for roof and storage structures and as mulch material. There is good scope of making various other articles like bags, clothes, mats, carpets, and other articles at village level by utilizing local plants and, wherever needed, blending them with cotton or rayon, etc (Varshney *et al.*, 1981). Distribution, biology and uses of some of the important fibre yielding plants of Indian arid zone are described here.

Kheep [*Leptadenia pyrotechnica* (Forsk.) Decne]

It is widely distributed in India, Pakistan, Iran, Israel, Arabia and northern and sub Sahalian Africa (Ali, 1983). In India, it is widely distributed in western Rajasthan as a typical species found on sand throughout the area.

It is an erect, much branched often leafless with watery sap, bushy shrub upto 1.5 m high but sometimes attains a height of 3 m (in protected sites). Leaves are 2.5-6.5x 0.2-0.3 cm, sessile, linear or linear lanceolate and caduceous. Flowers are greenish yellow in lateral umbellate cymes. Follicles are 7.0-14.0 cm long, terete, lanceolate, tapering to a slender beak, and glabrous. Seeds are 5-7 mm long, ovate lanceolate and glabrous. It flowers from August to December and fruiting occur during November-march.

Table 1. Fibre yielding plants in western Rajasthan

Species (Family)	Local name	Plant part used	How used
<i>Abutilon indicum</i> (L.) Sweet (Malvaceae)	Kanghi, Tara-kanchi	Stem	Used for making ropes
<i>Calotropis procera</i> R.Br. (Asclepiadaceae)	Aak	Stem	To make cordage and ropes
<i>Crotalaria burhia</i> Buch.-Ham. (Leguminosae)	Sinia	Twigs	To make ropes, baskets
<i>Leptadenia pyrotechnica</i> Decne. (Asclepiadaceae)	Kheep	Twigs	To makes ropes and baskets
<i>Agave</i> spp. (Amaryllidaceae)	Agave	Leaf	For cordage and ropes

The dominant patches of Kheep accumulate sand particles resulting the formation of sand mounds. In many places the dunes and interdunal plains are usually barren except for some *L. pyrotechnica*, alongwith *Areva* spp., *C. burhia* plants. It represents a degradation stage of *Calligonum polygonoides* (Mehor-Homji, 1977).

Fibre value

Kheep is traditionally used for making ropes for local use. Its fibre was much used in Sindh for making ropes to draw water from wells, as water does not rot it. A considerable work has been done on the quality aspect of its fibre which is reported to be of good quality. Mojumdar *et al.* (2001) reported high alpha-cellulose and low lignin contents of its fibre with favorable length/breadth ratio, which make it suitable for use in blending with cotton or polyester fibres to produce blended textiles yarns and in pulp and paper industries. In Pakistan too, considerable research has been done in respect to fibre quality aspects. Jamil (1970) and Jamil *et al.* (1971) have accomplished that 'kheep' fibre is better than most of the bast fibres and can be ranked along with flax and ramie in quality. Laghari (1983) reported that Kheep fibre accepts silk dyes, but not dyes suitable for cotton or wool.

Presently it is one of the species in arid tract as domestic fuel wood in the rainfed region of western Rajasthan due to shortage of quality fuel wood like Phog (*C. polygonoides*), Khejri (*Prosopis cineraria*). However, it is not supposed to be a good fuel wood for cooking due to much smoke, hazardous for women. Kheep is also used as strong live hedge around the field boundaries. It checks the soil erosion and also protects from wild animals.

Since long it is extensively employed for thatching purpose. In western Rajasthan it is used for making huts in rural areas. Being a drought hardy shrub it play an important role in arid ecosystem as a greening vegetation even in the time of less and erratic rainfall. Kheep showed high potential local raw material for checkerboard or parallel hedges as micro wind breaks to halt the movement of sand prior to planting work in sand dune stabilization programme. It has good fibre potential in the area and can be very well utilized in small scale cottage industries.

Sinia (*Crotalaria burhia* Buch.-Ham.)

In India, it is distributed in Punjab, UP, MP, Rajasthan and Gujarat. In western Rajasthan, it is found throughout sandy areas.

It is low, much- branched xerophytic undershrub. Leaves are very variable, the lower larger, the upper very small, 1.5-5x0.4-0.8 cm, subsessile, oblong, usually rounded, pale green and silky. Flowers are yellow with reddish streaks. Pods are 5x4 mm densely pilose, beaked and brownish. Seeds brown, shining, notched at hilum and compressed. It flowers after rainy season and pods mature in late winter months.

Considerable diversity in Sinia exists in the arid region. Based on distinct morphological variations *C. burhia* populations have been classified as erect bushy and sub-erect spreading forms by Prakash and Sen (1987). They opined that the condensed growth of the erect bushy forms helps the plants to withstand strong desert winds and to accumulate sand particles against the danger of uprooting.

Fibre value

Stem fibre is traditionally utilized for strong ropes and cordage in western Rajasthan. Bast fibre is extracted from the stem by the Bhil and Garasia tribals for ropes and cordage. Sometimes the ropes are made by twisting the live plants to tie the bundles of the fuel wood (Singh and Pandey, 1988).

The dry plants are chiefly used for thatching the huts and binding purpose. Dry plants of Sinia are also used in checkerboard or parallel hedges to halt the movement of sand in sand dune stabilization. *C. burhia* in arid region has an important role in initial colonization of the bare dunes. It is also used as mulch material. Sinia plants are commonly used in traditional system in Birani Badi, as a micro windbreaks.

Aak [*Calotropis procera* (Ait.) R.Br.]

This is an erect, glaucous, much- branched shrub, with copious latex. It is woody below with pale corky bark, and coarsely succulent-herbaceous above. It reaches heights of 2-4 m. Leaves are opposite, broadly ovate to oblong, sessile, cottony-pubescent on both surfaces and weakly auriculate at the base. They are 10-20 cm long and 6-12 cm wide. Inflorescence is an umbel-like cyme on peduncle. The flowers have ovate-triangular corolla lobes that are pale-green white with purplish tips. Follicles in pairs, ellipsoid or ovoid with coma silky- white seeds. It flowers almost throughout the year. A number of insects have been reported as pollinators in this species having unique cross pollination mechanism.

Fibre value

Traditionally it is utilized for making cords and ropes from fibre extracted from stem. Fibre contributes 6 % of its stem dry weight (Paroda, 1979). The floss from the seeds is used in stuffing the pillows. The bast fibres obtained by retting stems of *C. procera* for a period of 8 days possessed fineness and strength comparable with those of cotton. However, the small staple length, high percentage of small fibres and lack of convolutions gave problems in spinning (Varshney and Bhoi, 1988).

Kanghi [*Abutilon indicum* (L.) Sweet]

It is distributed throughout hotter parts of India. In western Rajasthan it is found in wastelands in most of the area. This is an erect shrub, reaches 1-1.5 m in height. Stem is woody when old. Leaves are ovate, acuminate, cordate, toothed, velvety on both sides and 5-6x 3-6 cm in size. The flowers are yellow with brownish-black seeds.

Fibre value

Stems on retting, yield fibre used for making ropes. Leaves and seeds are rich in mucilage and are used as demulcent and laxative

Sisal (*Agave sisalana* Perrine)

This is a plant with leaves in basal rosette clustered at the apex of terminal meristem. Leaves are long (40-60 cm) lanceolate, apex spinescent, margin spinous or smooth thick, with glaucous surfaces. Inflorescence on a 2-5 m tall woody stalk or bole. Flowers in panicles, zygomorphic bracteate with united perianth divided into six limbs joined below in a tube. Stamen 5-6 on the base of perianth. Stamens-6 on the base of perianth, exerted. Ovary inferior, three carpelled, three celled axile, style very slender, filiform. Flowering and fruiting after 10-12 year years and thereafter plant dies. Large number of

bulbils appear in the axils of the panicle in clusters. Plant produces large number of suckers throughout its life with maximum numbers at the time of flowering after which mother plant dies. Leaves are the source of vegetable fibre. In the bole of inflorescence, a bud is removed and a cavity is scooped from which a sugary sap exudes. This exudate is fermented to make 'Pulque', the national drink of Mexico (Purseglove, 1975).

Fibre value

For extraction of fibre, 2/3 of total plant leaves in the lower part of rosette are harvested three years after planting. Such harvesting is continued every year up to flowering (10-12 years). Over 300 leaves are produced by a plant in its entire life. It yields 2t/ha/year of fibre. Leaves less than 45 cm are not economical; longer leaves are hence preferred. Sisal fibre is a long, lustrous strong and durable as it has following composition (Table 2).

Table 2. Chemical composition of Sisal fibre (Sundararaj and Thulasidas, 1976)

Sisal fibre	Chemical composition
Cellulose	65.8%
Semi-cellulose	12.0%
Pectin	0.8%
Lignin	9.9%
Water soluble substances	1.2%
Oils + Wax	0.3%
Water content	10.0%

Source: Sundararaj and Thulasidas, 1976

Other uses

Sisal yarn can be chopped to reinforce plaster boards and for strengthening bituminized paper. The leaves contain hecogenin used in partial synthesis of the drug cartisone. Sodium pectate is manufactured from sisal waste and waxes are also extracted from it. Poles are used for building while their pith as filling material.

Research needs : Nine species of *Agave* were tried for adaptability and yield trials from 1980-85 at CAZRI, Jodhpur. Of these, *A. cantala* produced maximum number of leaves (40/plant) per year. It also yielded maximum (6.0%) fibre on green weight basis. An average of 70 suckers produced per plant per year were maximum. It flowered in 6 years. *Agave sisalana* was next in order followed by *Agave americana* and other species. There is however, a need to carry out its large-scale plantation trials. The above three species could be selected for finally growing. It is important to record that local farmers have

shown disliking for this plant as live hedge as its spine injure them as also their livestock. It should be prospected for growing only on marginal lands.

Plants Yielding Material for Mats and Baskets

Those woody shrubs with slender stems having more of fibre and amenability to twining are suitable for basket making and for mats. A list of nine such shrubs of value in making baskets and mats (Table 3) revealed that all these plants are common on wastelands, where these form gregarious colonies whether on sandy, rocky or saline wastes. Hence, these can be safely exploited for economic benefit to rural poor, besides generating employment opportunities.

Table 3. Plants used for baskets, mats in western Rajasthan

Species (Family)	Local name
<i>Acacia jacquemontii</i> Benth. (Leguminosae)	Bawali
<i>Alhagi maurorum</i> Medik. (Leguminosae)	Jawasa
<i>Grewia tenax</i> (Forsk.) Fiori (Tiliaceae)	Gangan
<i>Grewia villosa</i> Wild.	Gangan
<i>Tephrosia falciformis</i> Ramaswami (Leguminosae)	Rati Biyani
<i>Aschynomene indica</i> L. (Fabaceae)	-
<i>Tamarix aphylla</i> (L.) Karst. (Tamaricaceae)	Jhau
<i>T. droica</i> Roxb.	Jhau
<i>Vitex negundo</i> L.	Nirgundi

Conclusion

Abundance of aforementioned shrubs (Bhandari, 1990) in almost all desertic landscapes offer a unique opportunity for their commercial exploitation as ropes, cordage, mats and baskets and their vigorous marketing as biodegradable material. Some of these have promise to be used in cloth making too. Hence, the obvious research directions are two -1. Standardization of product processing including harvesting techniques for value addition and 2. Collection and study of natural variability in respect of these traits so as to select the promising accessions for large scale plantation. This will have dual benefits: 1. The precious germplasm will be saved from large scale exploitation that might happen after their commercialization. 2. These socially acceptable material will boost the rural economy. However, in order to achieve above, understanding of biology, propagation, and production potential is essential so as to assess cost-benefit analysis before finally recommending these species in the alternate land use system of desert.

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Salvadora in the Degraded Saline Habitat of Arid Region

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The genus *Salvadora*, (Family - Salvadoraceae), is distributed in warm regions of Africa and Asia. In Indian desert, it is represented by only two species i.e. *S. oleoides* Druce, commonly found growing on sandstone mostly in arid regions, and *S. persica* L. that has a wider range of distribution in sandy plains. These two species are small trees with shrubby appearance and have wonderful ability to grow in desertic situations in sandy and barren lands, under low rainfall and dry weather conditions, and can live up to 100 years. These withstand even in the annual rainfall 50 mm to 500 mm and can tolerate temperature range of -3 to +45°C and pH 6.5 to 8.5. At Central Arid Zone Research Institute, Jodhpur efforts are being made to identify genotypes yielding more seeds with high oil content, free or resistant to pests and diseases.

Geographical Distribution and Description

Salvadora persica L.

It is popularly called as Meswak, Arak, Rak and Toothbrush tree in the Arab and Khara Jal in India. It is native of Sub-tropical to Tropical Africa and also reported to be grown widely in Egypt, Tanzania, Middle East, India, China, Persia and Malaysia. In India, the natural area or range of distribution is confined to Rajasthan, Gujarat, Haryana, and Punjab and to some extent in Andhra Pradesh, Karnataka and Tamil Nadu. It has a wider distribution as compared to *S. oleoides*, and occurs often on saline soils. It is also planted on the bunds of the tanks and in open places near the villages and sometimes planted in cemeteries.

It is much branched, large straggling shrub or evergreen small sized tree with spreading or drooping glabrous, more or less glaucous branches. Leaves are opposite, decussate 3-6 x 2-4 cm, elliptic, lanceolate or ovate, obtuse and often mucronate at the apex, somewhat fleshy or coriaceous. Flowers are greenish, yellow in axillary and terminal compound 5-15 cm long inflorescence. Fruit is a berry, 6-7 mm in diameter, globose smooth, red when ripe, with or without seed, with persistent yellow cup of calyx. Seeds are 1-4 mm in diameter, sub-globose, smooth and brown. The fruits and leaves have peculiar pungent flavour.

S. oleoides Druce

It is known as Mitha Jal; fresh fruits are commonly referred as Pilu, grape of the desert) and dry fruits as Khakan. *S.*

oleoides is more abundant in sand dune regions near Indo-Pakistan border. Its occurrence in all the habitats particularly in ranns and Khadins (low lying depression zones in the piedmonts of plateau where runoff is embanked for the entire rainy season) shows that it is facultative halophyte, which has remarkable tolerance to aridity, salinity and water logging.

It is much branched, evergreen shrub or a small olive like tree with short twisted, hollow trunk. Branches are divergent, stiff and pendent with grey bark. Leaves are 4-8 x 1-2 cm, whitish green, coriaceous or somewhat fleshy when mature, linear-lanceolate or elliptic lanceolate, acute or sub obtuse and glabrous. Flowers are greenish white, sessile, in erect, compact, axillary, paniculate spikes, often clustered and shorter than leaves. Fruits are 4-5 mm in diameter, subsessile, ovoid-globose berry, yellowish white when ripe, dark brown or reddish brown when dry with persistent calyx and 1-seeded. Seeds are dispersed by the birds.

Propagation

Natural regeneration of *Salvadora* is by seeds, coppice, natural layering and mostly by root suckers. A thicket of impenetrable growth is often formed by a parent shrub surrounded by a ring of root suckers, while seedlings spring up under its shade. Seeds are dispersed by birds and often come up under other nurse shrubs such as *Capparis decidua* or *Tamarix* spp.

Artificial propagation is easiest by direct sowing of seeds. Fruits are collected in May-June, immediately de-pulped by rubbing and then washed and dried. They cannot be stored for longer periods. No pre-treatment is required for germination. Fresh seeds sown in May showed germination up to 87.0% within 15 days of its sowing (Jindal *et al*, 2004). Nursery can be raised using saline water of 15 dS m⁻¹ by placing the bags in 20 cm deep trenches and the saplings can be grown for 90 days in polybags. Black polythene bags are ideal for raising saplings for better seedling establishment and sapling growth. The saplings are to be protected from peacocks and caterpillars, which eat away the leaves. The saplings of three months age are ideal for transplanting to the field.

Salvadora plants can be raised through tissue culture of axillary buds of selected plants. The technique for rapid multiplication of *Salvadora* plantlets can be

achieved in three phases, i.e. sprouting of axillary buds, multiplication of shoots and development of rooted plants and this all can be achieved within 6-9 months. At NCL Pune, process of propagation through tissue culture was standardised (Mascarenhas *et al.*, 1987).

Flowering and Fruit Production

S. persica

Flowering starts in November and ends in March-April. Peak period of flowering is December. Studies done at CAZRI showed that there were 93.6 flowers per inflorescence and till February 71% of inflorescences dropped all the flowers/fruits. 28% had only one fruit and 1% had only two fruits. 34 flowers out of ten thousand set into fruits and rest drop as such (Jindal *et al.*, 1997). But this is not the situation with the plants growing in natural habitats may be due to presence of pollinators, pollen grain or physiological reasons like favourable temperature and availability of moisture. Under well-managed conditions, seed yield is reported as under:

Year	Seed yield kg/ha
I	Nil
II	700
III	850
IV	1400
V	1800

S. oleoides

Flower initiation usually takes place in December-January and its peak bloom is in February-March. The flowers of December to February drop without fertilization. In Feb.-March, on an average inflorescence have 44 flowers from which 10.7% develop into fruits and rest drop without fertilization. A good tree yields fruit about 30-40 kg. Rural women and children usually collect the fruits early in the morning in the month of May. A rural woman can collect fruits up to 15-20 kg by the afternoon if collection is started in the early morning. Fresh fruits are sold in the local market or dried.

Variation for Fruit and Seed Related Characters in *S. oleoides*

Fully matured fruits collected from Rajasthan in 1994 had a significant variation in fruit size, colour and taste. 100 fruit size varied from 19.1 to 36.1 g with its mean weight 29.0 g. Fully matured fruit colour ranged from dirty green to light rust to light red to deep red. 100-seed weight ranged from 2.27 to 3.49 g with its mean 3.07 g, seed oil content from 31.2 to 43.8% with mean 38.0%

(Jindal, *et al.*, 1999)

But when exploration was made in May 2003 of Gujarat state, values were different. These were: 2.83 g, ranging between 1.95 to 3.75 g for 100-seed weight, 47.5% (41.0-55.4%) for oil content may be due to combined effect of time, space and genetic constitution (Jindal *et al.*, 2004).

Breeding System

Somatic chromosome number in both the species is $2n=24$ (Kumar *et al.*, 2002). Apomixis is absent in both the species. In *S. persica* studies done during March showed maximum fruit set (54.4%) in sibbing, followed by selfing (17.2%), open cross pollination (14.0%) and natural open pollination (8.4%). In *S. oleoides*, selfing (7.55%) was maximum followed by sibbing (5.20%) and natural open pollination (3.60%). These values show that in both the species self-pollination is dominant and methods of improvement for self-pollinated crops can be employed for genetic improvement of these multipurpose shrubs for immediate gains.

Agrotechniques

Prior to planting, the field should be made ready and pits measuring 30 cm x 30 cm x 30 cm at a spacing of 4 m x 4m is ideal for planting *Salvadora* on saline black soil. Farmyard manure at 1 kg/pit and DAP at 50 g per pit may be applied prior to planting. Best period for transplanting is during the monsoon (July-Sept.). Saline water as life saving irrigation can be given in first year. Ammonium sulphate at 100 g/plant at the time of flowering enhances berry formation and seed yield.

Irrigation

Salvadora normally does not require any irrigation, as it is planted in the field during monsoon (July-September). For better yield during summer about 20 litres of water up to a salinity of 20 dS m⁻¹ per plant is sufficient for about 15-20 days.

Plant protection

There are no major pests and disease in *Salvadora*. Mortality of seedlings in nursery due to damping-off can be managed by proper drainage system and by treating the seeds with Thiram @ 0.2%. Witches' broom affects the floral parts of flowers and most frequently occurs in *S. oleoides*, in comparison to *S. persica*. In some cases in old shrubs wood rotting fungi also attack during rainy season. *Cistanche tubulosa* Wight, an obligate phanerogamic root parasite, commonly occurs on

riverbed terraces with *S. oleoides* and *S. persica* as the preferred hosts (Aggarwal, 1984).

Pharmaceutical Uses

S. persica

Almost all the plant parts have been found to be medicinally important and possess pharmaceutical applications. The best among these uses is its wide use in the toothpaste preparations. The MESWAK toothpaste has *Salvadora* bark extract as the active ingredient. The stem bark extract is composed of trimethyl amine, an alkaloid which may be salvadorine, chlorides, high amounts of benzyl isothiocyanat fluoride and silica, sulphur, vitamin C, small amounts of tannins, saponins, flavenoids and sterols. Root bark contains resin and traces of alkaloid called "Salvadoricine", Trimethylamine and ash containing large amount of chlorine. Berries contain large amounts of sugar, fat and alkaloid. Seeds also have nitrogen (4.8%), potash (2.8%) and phosphoric anhydride (1.05%).

Root bark is used as tonic and stimulant in low fevers to cure blisters. The roots are used as toothbrush to strengthen the gums, cleaning of teeth and fights dental caries. Stem bark is used in gastric troubles and as an ascarifuge. The fresh bark is vesicant and stimulant. Leaves are used as purgatives and for curing asthma and cough. The poultice has application value in piles and tumours. Leaf juice is used in scurvy and also in rheumatism. The floral oil is stimulant and laxative. It is used for leprosy, headaches, gonorrhoea and de-worming. Berries are carminative and diuretic and given in enlargement of spleen, rheumatism and tumours. Seed oil is used as a stimulant over painful rheumatic parts of the body and all over the body after childbirth. It is also used as a tonic and purgative.

S. oleoides

Leaves are used to relieve cough and are given to horses as a purgative. Root bark is used as a vesicant and it helps in regularising the menses in women. Fruits are sweet and edible; the pulp contains glucose, fructose and sucrose. Fed to cattle, they are said to increase their milk yield. They are employed in the treatment of enlarged spleen, rheumatism and low fever. Believed to produce tingling and small ulcers in mouth, when eaten fresh and one at a time. Seeds of *S. persica* are similar to those of *S. oleoides* in colour and size, and contain 35-47% pale yellow, solid fat. Seed fats of these two species are almost identical in composition and used for similar purposes. The oil tends to have a disagreeable odour but this vanishes on purification, it is inedible- due

to the presence of various substituted dibenzylureas - but its fatty acid composition (lauric, 20%; yristic, 55%; palmitic, 20%; oleic 5%) is excellent for making soaps and it makes a good substitute for coconut oil and is a potential industrial substitute (Jindal *et al.*, 1995). The seed cake is valued as cattle feed for it has 27% crude protein and 22% carbohydrates, also used as fertilizer.

Wood Quality

Wood of *S. oleoides* is light red or yellow, moderately hard and possess small irregular, purple heartwood. Its density is 608-865 kg/cu.m. It is not a good fuel, but mixed with deodar and pine scrap wood, it is used for building bricks. It is used for building purposes, agricultural implements, persian wheels and the knees of boats. Its fuel value is 7000 BTU/lb as compared to 8050 for *Prosopis juliflora*, 7900 of *Ziziphus nummularia*.

The wood of *S. persica* is soft, white, easy to work and takes polish well. Its density is 609-721 kg/cu.m. and like *S. oleoides*, it is also not a good fuel. It is fairly termite resistant, so was used by the Egyptians for coffins (CSIR, 1972)

Other Benefits

Apart from the economic aspects, these species help in eco-restoration of the degraded saline wastelands, community wastelands, coastal belts, degraded pasture/ grazing lands (Singh and Kar, 1997), gypsum mine spoils (Rao and Tarafdar, 1998).

Conclusion

- There is enough variation for economic traits in both the species. For immediate gains this can be exploited by collecting the seed from good trees.
- These species can be grown on roadside plantation; can be included in social forestry.
- Can be used for reclamation and development of degraded pastures, gypsum mine spoils in arid zones, degraded forestlands and highly saline soils where arable farming is not possible.
- Besides greening the wastelands, these species provide income to the rural sector due to its industrial value of the oil, pharmaceutical importance and fodder value.

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Arid Shrubs for Livestock

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Broadly speaking, animal agriculture can be classified as commercial and non-commercial. The bulk of commercial animal agriculture is practised in semi arid and irrigated system and based on modern animal techniques, as seen in poultry, dairy and buffalo production. These intensive production systems are based on adequate supplies and economic usage of enriched feeds to ensure profitable returns. Seldom do trees and shrubs form the major source of the diet to commercial production system. However, most of the arid animal agriculture is non-commercial range grazing supplementing diets with shrubs and trees. The owners are resource-poor, uneducated small holders rearing animals on inputs mostly available on farm and ranges. Of these, shrub fodder constitutes a major part of the diet of range grazing animals, particularly sheep and goats.

Up till now the scientists have focussed mainly on grasses, crop residues, trees and horticultural fodder and little attention has gone in identifying different shrubs, excepting *Z. nummularia*, and *Z. mauritiana* for their nutritional, anti-nutritional factors and also health management values. With the increased area (from 7.6 m ha to 10.2 m ha) under crops, which pay dividend hardly 2 times out of every 5 years, and decline in culturable waste, pasture and fallow lands (from 8.7 m ha to 6.7 m ha), it has become all the more essential to identify and increase the fodder shrubs not only in these shrinking lands as agro forestry system, but also on field boundaries and road sides for increased fodder availability. A few of the shrubs have very potent medicinal values for animals, which also need to be examined and used.

Shrubs as Animal Fodder

Shrubs constitute a very important component of animals diet because of their palatability and higher level of nutrients. Some of the commonly available on farm shrubs are given in Table 1. Green shoots and young fruits of *Calligonum polygonoides*, *Haloxylon salicornicum*, *Capparis decidua* are relished by camel and cattle. *Calotropis procera*, *Grewia tenax* are relished by goats

only *Z. nummularia*, *Acacia Jacquemontii*, *Sesbania bispinosa* by all the livestock species.

Nutrient Composition

A few arid shrubs have been analysed for their nutrient composition. Crude protein, crude fibre, ether extract, nitrogen free extract and ash contents have been analysed (Bhatia, 1983). The shrubs in general have 10-12 per cent crude protein and 12-30 per cent crude fibre (Table 2). Hence, shrubs intake by animals will supplement the protein contents of the total feed intake. High roughage supplements with fodder shrub concentrate will increase the total digestibility of feed and crude proteins.

The shrubs are also rich in minerals like, Iron (30-50 ppm), Manganese (10-30 ppm), Copper (8-10 ppm), Zinc (35-50 ppm), Calcium (0.21-0.53%), Magnesium (0.041-0.1%) and Potassium (0.5-0.7%) (Vinod Shankar *et al.*, 1980). Hence, shrubs will compensate for deficiency of these minerals, which is often come up in range grazing animals.

Shrubs as Medicines for Livestock

Most of the synthetic drugs are costly, beyond the reach of herders and associated with drawbacks such as their residual effects in milk, faeces. However, many indigenous shrubs have been reported to possess medicinal values such as anthelmintic, antipyretic, anti-diuretic etc. (Table 3).

Butea frondosa and *Vernonia anthelmintica* have been studied in detail for their anthelmintic properties (Singh, 2005). The extracts of *Butea frondosa* leaves and seeds possessed ovicidal and larvicidal property against *H. contortus* (Fig. 1). The aqueous, alcoholic, chloroform and ether extracts have been found to have significant effect on egg hatching of *H. contortus*. At the concentration of 1.25 mg/ml, the corrected mean egg hatching (%) ranged from 0.86 ± 0.49 (alcoholic) to 3.56 ± 0.99 (ether). The ED₅₀ value for egg embryonation was 0.993 mg/ml with chloroform extract and for egg hatching the values were 0.399, 0.623, 0.648 and 0.761 mg/ml with alcoholic, aqueous, ether and chloroform extracts, respectively.

Types of shrubs

No.	Name	Occurrence	Fodder
1	<i>Acacia Jacquemontii</i> (Ba-banvali)	Commonly found in sandy habitats	Leaves, young branches and pods used as fodder for goats.
2	<i>Calligonum polygonoides</i> (Phog)	Grown naturally on sand dunes	Flowering buds, young fruits and braches browsed by animals
3	<i>Calotropis procera</i> (Akra)	Naturally occurring on wastelands.	Leaves preferred by goats.
4	<i>Capparis decidua</i> (ker)	Leafless spiny shrub occurring naturally on rocks and gravel plains	Young branches preferred by camel and goat.
5	<i>Clerodendrum pholomidis</i> (Arni)	Commonly found on wastelands	Tender twigs preferred by camels.
6	<i>Crotalaria burhia</i> (Shinia)	Abundant in dry sandy habitats.	Excellent fodder for camel.
7	<i>Euphorbia caducifolia</i> (Danda Thar)	Fleshy shrub, Abundant in rocky habitats	Used as fodder for cattle
8	<i>Grewia tenax</i> (Gangren)	Common shrub in the waste lands	Leaves as fodder for goats.
9	<i>Haloxylon salicornicum</i> (Lana)	Found naturally in sandy plains and salty land.	Mixed with fruits of <i>Calligonum polygonoides</i> and used as fodder for camel.
10	<i>Leptadenia pyrotechnica</i> (Kheemp)	Leaf less branched shrub. Abundant in dry sandy soils	Young branches and leaves used as fodder for camel.
11	<i>Lycium barabarum</i> (Morali)	Branched spinous shrub commonly found on sand dunes	Leaf fodder for camel
12	<i>Maytenus emarginataus</i> (Kankera)	Spiny shrub common in waste lands	Leaf fodder for camel
13	<i>Mimosa hamata</i> (Jinjani)	Abundantly found on sand dunes	Leaf fodder for cattle
14	<i>Sesbania bispinosa</i> (Ikad)	Commonly found after rains in arid Rajasthan.	Leaves as fodder for animals.
15	<i>Ziziphus mauritiana</i> (Bordi)	Most Common species of the area, sometimes cultivated.	Leaves good fodder for goats, cow and buffalo.
16	<i>Ziziphus nummularia</i> (Bordi)	Commonly found in all habitats	Leaves known as 'pala' used as fodder for animals.

Table 2. Chemical composition of some shrubs

Shrubs	Local name	Crude protein	Ether extract	Crude fibre	NFE	Ash
<i>Calligonum polygonoides</i>	Phog	7.40	-	12.50	67.30	9.10
<i>Cassia auriculata</i>	Tarwad	10.90	-	12.50	67.30	9.10
<i>Grewia tenax</i>	Gangan	10.30	-	18.90	61.10	9.50
<i>Prosopis juliflora</i>	Khejri Bilayati	21.40	-	20.80	50.00	7.70
<i>Tribullus terrestris</i>	Gokhru	18.46	2.85	36.97	23.94	17.78
<i>Ziziphus mauritiana</i>	Beri	8.60	1.70	30.10	48.18	11.42
<i>Ziziphus nummularia</i>	Pala	14.25	4.34	15.73	57.12	8.56

Oral administration of *Butea frondosa* bark at the dose rate of 1.0 g/kg body weight resulted in 34.82 per cent reduction in faecal egg count (FEC) in goats

infected with gastrointestinal nematodes (GIN) (Fig 2). Intake of alcoholic extract of *B. frondosa* seed led to 82.93 per cent reduction in FEC on day 10th post infection (PI) at the dose rate of 100.0 mg / Kg body weight. In other trial, it showed efficacy to the tune of 97.10 and 48.57% on day 3 and 5 PI, respectively at similar dose rate.

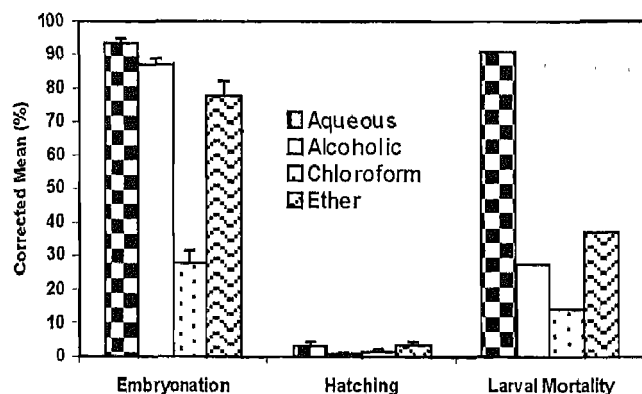


Fig. 1: In-Vitro effects of various extracts of *B. frondosa* on eggs (@1.25 mg/ml) and Infective larvae (@ 20.0 mg/ml) of *Haemonchus contortus*

Table-3. Major shrubs for treating different ailments in animals

	Name of the shrub	Ailments
1	<i>Butea frondosa</i>	Intestinal worms
2	<i>Tagetes patula</i>	Intestinal worms
3	<i>Vernonia anthelmintica</i>	Intestinal worms
4	<i>Calotropis procera</i>	Cracking udders
5	<i>Cassia angustifolia</i>	Gastric problems
6	<i>Citrullus colycynthis</i>	Cuts and wounds
7	<i>Prosopis juliflora</i>	Foot pad disease
8	<i>Leptadenia pyrotechnice</i>	Arthritis
9	<i>Ricinus communis</i>	Stomach disorders
10	<i>Capparis decidua</i> with sesame oil	Fractured bones
11	<i>Z. nummularia</i>	Cuts and wounds

The extracts of *Vernonia anthelmintica* seed possessed ovicidal and larvicidal activity. They were also effective against adult *H. contortus* and *A. galli*. Various extracts of *V. anthelmintica* were tested in-vivo. Out of these only ether extract at dose rate of 6.0 ml/sheep could reduce the FEC by 41 per cent on day 10th PI in sheep experimentally infected with *H. contortus*. However, its alcoholic extract (@ 100.0 mg / Kg body weight) caused 88.57 per cent reduction in FEC on day 3 PI but no effect was observed on day 5 PI in goats infected with *H. contortus*.

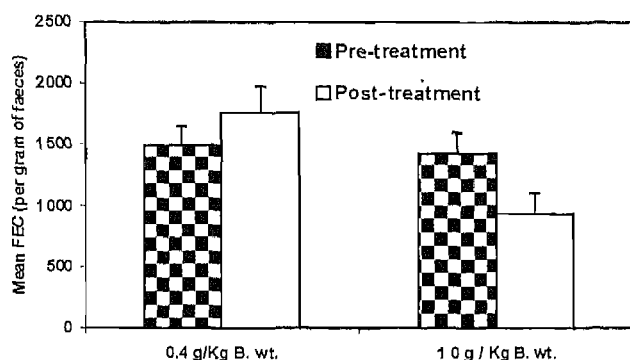


Fig. 2. In-vivo effects of *B. frondosa* bark on faecal egg count in goats naturally infected with gastrointestinal nematodes.

Incorporation of Fodder Shrubs in Farming System

The competitive land use between crops and livestock exerts considerable pressure against utilization of arable lands for planting fodders and pastures. In this situation, a number of approaches have been suggested in order to incorporate fodder shrubs in farming system without competing with crops (Topark-Ngarm, 1990). Four ways in which shrubs can be incorporated are

Planting shrubs fence around the household: Fodder shrubs such as *Z. nummularia*, *Z. rotundifolia*, *Z. mauritiana* can be grown as living fences, which provide not only human food and fuel wood but also animal feed.

Shrubs on uncropped lands: In many of the most intensively cropped areas of the region there are pockets of land which can not be used for cropping. These may be in the form of farm boundaries and forest margins, which could be used to grow some shrubs.

Component species in inter-cropping: In this system, fodder shrubs like, *Z. mauritiana* and *Z. Nummularia*, *Z. Rotundifolia* etc. are grown in alternate rows or rows adjacent to food crops. Shrubs are pruned once or twice for fodder to reduce competition and shading during the growing period of the crops.

Future Policies

Policies to promote the use of shrubs for fodder and animal health are almost non-existent. Little attention has been given as to how shrubs may be used effectively for livestock. A useful way to look at likely policy impacts is to consider three facets of shrub development.

Environment: The technical and socio-economic domain in which shrubs exist and factors influencing productivity use and distribution etc.

Behaviour: This component includes forest and range grazing laws, property rights and pastoral treaties, if any.

Performance: This would include the impact of the environment and behaviour on animal productivity, joint products (fuel, fodder and meat), total contribution to fodder, carrying capacity etc.

It is clear that for policy purposes we must understand the environment and behaviour norms of the key players (herders, animals, marketing functionaries-the buyers and sellers) for achieving the explicit targets for animals and environment.

Whereas technical information on the nutritive value of most shrubs exists, there is less information on utilization patterns at farmers' level. Nor do we have good data, which collates farmers' responsiveness to feeding different shrubs. Health implications of various shrubs, excepting a few, are also not clear. To develop a long term planning strategy whereby shrubs become integral part of livestock farming system, it is important that further information on nutritional, antinutritional and therapeutic factors and micro variables relating to their use as fodder and health component of animals are gathered. This will

help us to develop an economically viable grass+shrub nutritive diets and disease management in animals on farm low cost resources.

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Phog (*Calligonum polygonoides* L.) - An Important Arid Shrub of Rainfed Farming System in Western Rajasthan

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Phog (*Calligonum polygonoides* L.) is an important component of natural vegetation of the Thar Desert. This is a drought resistant shrub providing fodder, fuel and food. It is also an excellent binder of shifting sand dunes. Its heavy exploitation for fuel wood over the years has endangered its natural population in western Rajasthan. This paper describes its potentials for rainfed farming system in arid region.

Distribution

Calligonum polygonoides L. is widespread from eastern Saudi Arabia to the Thar Desert. In India, Phog is distributed throughout western Rajasthan particularly in the extremely arid areas on sand dunes and sandy plains. It is one of the pioneer species, that colonizes freshly deposited sands. Within western Rajasthan it occurs in almost all the districts. *C. polygonoides* is the dominant constituent of shrub associations viz., *C. polygonoides* + *Clerodendron phlomidis*, *C. polygonoides* + *Haloxyton salicornicum*, *C. polygonoides* + *Acacia jacquemontii*. In the extreme arid regions it is found in mixed vegetation (Charan and Sen, 1985). It is the commonest shrub of psammophytic scrub desert, which occurs on all the three types of dunes of the old system (parabolic, longitudinal and transverse and sometimes on loose sand in more arid parts with rainfall less than 400 mm and dry season exceeding nine months (Gupta and Prakash, 1975). Charan and Sen (1979) opined that *Calligonum polygonoides* does not occur beyond the phytogeographical demarcation for the arid region, which is further, supported by phytosociological studies made by Sen (1966).

Botanical Description

Calligonum polygonoides is a xerophytic shrub. Being leafless, it is perfectly adapted to harsh conditions of Thar Desert (Charan and Sen, 1979). It attains height of 2-3 m with very deep penetrating roots. Young branches are green and shining and stems are modified as phylloclades. Flowers are small, numerous light pinkish with a pleasant odour. Fruits are oblong and densely clothed with reddish brown bristles.

It flowers profusely and the flowering may start from the year of establishment. The flowering occurs from

February to March. The flower buds locally known as "phogla" are available for a very short period, i.e. 1-2 weeks. The fruits mature in the first week of April and most of them fall in the end of April depending upon the climatic conditions. Phog is a prolific seeder and a well-grown shrub can produce 1.5 to 3.0 kg of fruits.

Reproductive Biology

Phog is propagated by seed as well as vegetatively. The single seed remains enclosed in nut type fruit. The single seeded fruit is treated as seed unit as it is not segregated from the fruit. Seed is monoembryonic and endospermic having epigeal germination. The seeds do not require any special pre-treatment for germination and 5 mm depth is sufficient. November-December is best time for germination provided there is winter rainfall. Bishnoi and Gautam (1991) reported that 20 ± 2 °C is the optimum temperature for germination that starts after five days of sowing in favorable conditions. It is prolific seed producer but the reproductive capacity of plant is low due to damage caused by insect in early stage of seed development.

Table 1. Seed output and characteristics of *Calligonum polygonoides*

Particulars	Value
Seed output per plant (number)	38177.5 ± 15469.2
Damage of seed (%)	12.5
Germination percentage	68.0 ± 5.4
Reproductive capacity	25960.7
Average weight of 100seed with bristle (mg)	1220 ± 15.9 to 2289 ± 54.0
Average weight of 100seed without bristle (mg)	820 ± 18.0 to 1721.25.0
Length of seed (mm)	4.60 ± 1.15 to 6.43 ± 1.10
Breadth of seed (mm)	1.83 ± 0.72 to 3.08 ± 0.65
Shape index (L/B)	2.08 to 2.44
Size Index (L x B)	8.64 to 19.80
Volume of 100 seed (ml)	0.8 to 2.0
Length of bristle (mm)	8.0 ± 3.1 to 15.0 ± 2.1

Source : Bishnoi and Gautam (1991)

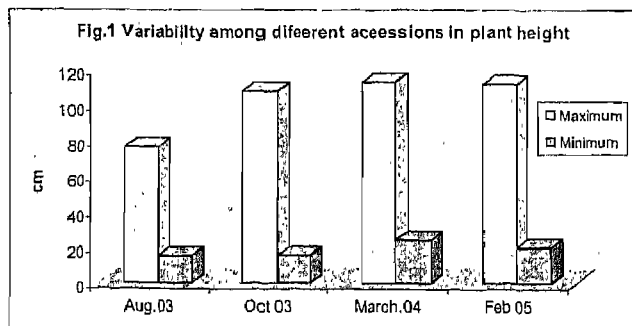
Germination study was carried out in seventy accessions of Phog (*Calligonum polygonoides*) collected during 2002 in both lab and field conditions. Relatively higher germination was recorded in dehusked seeds (without bristles) as compared to husked seeds. Length of radicle varied from 1.5 cm to 12 cm with average of 6.5 cm, and plumule length varied from 1.5 to 4.0 cm with average of 2.5 cm at two-leaf stage under laboratory condition. However, low germination was observed in field (nursery) condition. In nursery condition germination started in few accessions after 15 days of sowing only. Maximum germination in most of the accessions was recorded between 22-28 days after sowing.

Table 2. Germination in Phog (*Calligonum polygonoides*)

Attributes	Laboratory		Nursery
	Husked	Dehusked	
Germination initiation (days after sowing)	6	5	15
Maximum germination (days after sowing)	8-10	7-8	23-25
Germination (%)			
Range	0-100	0-100	0-83
Average	68.7	80.0	34.4

Natural Variability

A remarkable variability is exhibited by *C. polygonoides* in its shape and size. Most mature plants have open and scraggly crown. Seventy accessions of Phog collected from 50 diverse sites of western Rajasthan comprising Bikaner, Churu, Hanumangarh and Sri Ganganagar districts are under evaluation at CAZRI, RRS, Bikaner. These accessions showed considerable variation in plant type, growth, phenology, fruiting, and bristle characteristics and reproductive capacity. The plant height varied from 20 to 112 cm after 30 months of planting (Fig. 1). The fruit length varied from 6-26 mm with bristle and from 4-8 mm without bristles. The bristle length varied from 2-18 mm in different accessions. The 100 fruit weight with and without bristles ranged from 0.83 -3.49 and 0.73 - 2.57 g, respectively.



Economic and Ecological Uses

Phog has great economic and ecological importance in western Rajasthan. Besides supplying fodder, food and fuel wood it arrests wind erosion, stabilizes sand dune, improves water regime, improves soil biological activity, thermal balance, microclimate and crop yield. It also causes changes in the distribution of insects, mammals, birds, pathogenic microflora and weeds. Some of important ethnic uses of Phog are outlined in Table 2.

Present Status and Scope

Role in rainfed farming system

Being a component of traditional agroforestry system, Phog has an important place in farming system of western Rajasthan. Traditionally its branches are spread as mulch during summer in the crop fields by the farmers (Bhimaya *et al.*, 1961) and supposed to increase the soil fertility in crop fields. The farmers also claim the higher yield of Bajra (pearl millet) grown in a field, which carried a good stand of Phog plants during the previous year. This may be due to the addition of substantial quantity of litter, which contributes to soil fertility. A mature plant sets on an average 22.5 kg of leaves and fruits each year (Kaul, 1965). Singh *et al.* (2004) reported that incorporation of phog in the field resulted in higher yield of groundnut. *In situ* green manuring of volunteer plants of phog is also a practice in area surrounding Bikaner and supposed to have favorable effect on crop yield. An experiment has started at CAZRI, RRS, Bikaner to assess the performances of Phog in rainfed agri-silvi-pasture system (Plate 3). Results of first year growth clearly indicate that height and canopy cover of Phog considerably influenced by associated component (Fig 2). Phog attained maximum height in association with Sonamukhi followed by arable crops, dhaman grass and Sewan grass. Highest canopy cover of Phog was recorded in association with crops and least in association with grasses.

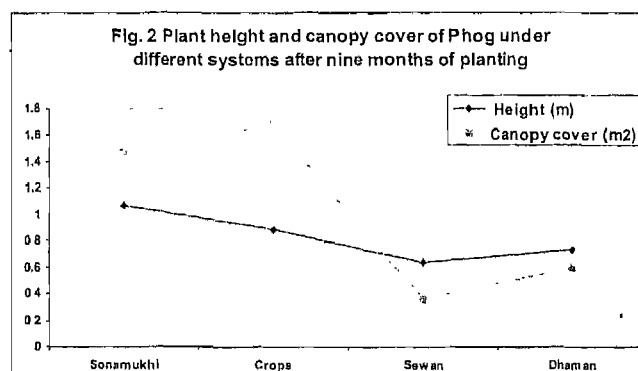


Table 2. Ethnic Uses of *Calligonum polygonoides* in western Rajasthan

Uses	Parts Used	Remarks
Food	Flower buds, young branches	Flower buds locally called Phogla are used in preparing traditional dish called Rayata by mixing with curd during summer after light boiling or frying. Young branches are also chewed to quench the thirst.
Fodder	Green shoots, phyllodes, fruits	Camel browses young green and fleshy branches preferably. It is also used as fodder for sheep, goat and cattle particularly during scarcity period. Dried phylloclades called Lasu are collected, stored and fed to livestock with other feed materials such as guar phalagati (cluster bean) or moth bean husk. The fruits also form a nourishing feed for milch cattle and camel.
Fuelwood	Branches, root	It has been the chief source of domestic fuelwood and still the most preferred fuelwood species among villagers.
Medicine	Branch, root, flower buds	Branch decoction is used for sore gums. Root decoction mixed with 'Katha' is used as gargle. The flower buds are supposed to have a cooling effect and are used against sunstroke. Juice of branches is used for eye washing as an antidote when the milky juice of Aak (<i>Calotropis procera</i> (Ait.) R. Br.) enters into eyes (Bhimaya et al., 1961). Phog is recently included in 10 medicinal herbs to be used in 'Charak Programme', which is started for the army personals in arid region for curing the ill effects of high temperature and extreme climatic conditions.
Live hedge	-	Used as live hedge to demarcate boundaries of agricultural fields and to protect home yards and agricultural crops from domestic as well as wild animals.
Social & Religious	Flowers	Used in worship in Gangor festival.
Mulch	Branches	Spread as mulch during summer in the crop fields.
Material for huts	Twigs and trunks	Used for making the huts and animal sheds by local inhabitants.

For rehabilitation of degraded lands

Excellent adaptation to xerophytic conditions coupled with shrubby nature having widely spreading root make Phog an ideal species for arresting wind erosion and sand dune stabilization. Study conducted by Singh *et al.* (2004) revealed that phog occurs in sand dune and interdunal plains having sandy to sandy loam texture, alkaline in reaction with a pH values of 8.0 to 8.6 and non-saline (EC 0.13 - 0.38 dS m⁻¹) and poor organic carbon content. These soils, widespread in western Rajasthan, have a severe limitation of topography and texture for crop production and can be rehabilitated easily with the plantation of shrubs like Phog. Plantation of Phog not only improves the habitat alone, but also improves the soil fertility in terms of increasing organic carbon. The soil samples collected from open space and below the plant canopy showed significant differences in organic carbon. It increased from 1.4 g kg⁻¹ in open space to 2.5 g kg⁻¹ under the of shrub canopy.

Issues Related to Extent of its Present Usage

Potential as a food

The flower buds of Phog are traditionally used for preparation of local dish called Rayata. It is supposed to have cooling effect and thus preventing ill effects of scorching heat in summer. Preliminary analysis of flower buds of local collection from Bikaner conducted by Singh *et al.* (2005) showed that it is a rich source of crude protein and total carbohydrate, with low fiber content (Table 3).

Table 3. Nutrative value of flower bud of Phog

Nutrients	Content (%)
Crude protein	16.87
Total carbohydrates	71.12
Fiber content	9.07

An attempt to explore the nutritional composition and possibility of culinary use of Phog was made by Choudhary and Goyal (2003). The overall mean acceptability scores for standardized Phog products viz.

spicy vegetables, Parantha, Raita, Kadi and simple vegetables were 3.41 to 4.63 on five point scale indicating "good" to "very good" acceptance. They further concluded that one serving of Phog products (ranging from 5 to 30 g per serving) was found to be providing 3.01-25.23 g protein, 5.18-22.02 g fat, 1.36-6.67 g crude fibre, 8.21- 87.3 g carbohydrate, 83.56-226.46 kcal energy, 0.55-2.82 mg iron, 45.1-170.1 mg calcium, 100.04-220.2mg phosphorus, 13.5-24.41 mg sodium, 36.05-184.6 mg potassium and 0.43-4.39 mg vitamin C. Thus Phog has potential to become an important item of food basket of local inhabitant, who can't afford costly vegetables due to their poor economic base.

Potential as fodder

Animal husbandry is the major livelihood in the western Rajasthan. Deficit fodder availability due to scanty rainfall coupled with shrinking and degrading grazing land is a major constraint for sustainable livestock production in western Rajasthan. Green/dry phylloclades of Phog locally known as Lasu having good digestibility (Table 4) is considered as potential top feed (Gaur *et al.*, 1982) particularly for camel.

Table 4. Nutritive value of Lasu

Particulars	Value
Digestible crude protein (%)	4.1
Total digestible nutrients (%)	54.4
Nutritive ratio	1:12.3

Saxena (1988) opined that Phog is good fodder for camel in the arid zone and emphasized that as the twigs contain 7.4 % crude protein this can be mixed with feed materials such as guar or moth husk. Chemical analysis of shoots made by Bishnoi and Gautam (1991) (Table 5), Dhir *et al.* (1984) and Sharma *et al.* (1984) (Table 6) indicated that it contains fairly good amount of nutrients.

Table 5. Chemical composition of Phog shoots

Nutrient	Content (%)
Crude protein	6.41 ± 0.16
Crude fiber	23.13 ± 0.97
Total carbohydrates	81.99 ± 0.86
Nitrogen free extract	62.1 ± 1.07

Source: Bishnoi and Gautam (1991)

Table 6. Concentration of macro and micro elements in Phog

Macro-elements		Micro-elements	
Element	Content	Element	Content
Calcium (%)	3.48	Zinc (ppm)	39.1
Potassium (%)	1.33	Mangenesse (ppm)	30.4
Magenesium (mg/100g)	0.71	Copper (ppm)	10.1
Sodium(mg/100g)	0.07	Iron (mg/100 g)	171
Phosphorus (mg/100g)	0.12		

Source: Dhir *et al.* (1984) and Sharma *et al.* (1984)

Further, results of chemical analysis of seed carried out at CAZRI, RRS, Bikaner showed that it has fairly good amount of nutrients (Table 7) and thus can be used as concentrate alone or mixed with other feed materials for insuring nutritional security of livestock in western Rajasthan.

Table 7. Nutrient composition of Phog seeds on dry weight basis

Nutrients	Content (%)
Crude protein (CP)	12.1
Ether Extract (EE)	1.9
Crude fiber (CF)	29.6
Ash	7.4
Total Carbohydrate (TCHO)	78.62
Acid Digestible Fiber (ADF)	44.3
Neutral Digestible Fiber (NDF)	68.25
Organic matter (DM)	92.6
Nitrogen Free Extract (NFE)	49.0

As an ornamental shrub

Moreover, due to its less water requirement as compared to other trees and shrubs, some of its types like bunchy type of inflorescence can be utilized in the gardens and park.

Range improvement potential

Field and nursery studies have revealed that its germination is inhibited by high temperature. As scarcity of rainfall coincides with the proper germination temperatures, i.e. winter rainfall plays an important role in its germination. If these conditions become favourable, as in this year in March 2005, good germination of Phog was observed under natural condition particularly in the

protected areas following rainfall in the first week of February. Very good seedling population was seen in March 2005 in a protected site at Chhatargarh, 70 km away from Bikaner. Therefore, range seeding of this species is quite feasible with relatively low expenses in the sandy areas, when there is sufficient winter rainfall.

Conclusion

Phog (*Calligonum polygonoides*) is an important multipurpose shrub and a boon to the Thar Desert. But this boon is now so much overexploited that Mann *et al.* (1977) remarked "digging phog is a regular vocation and gives employment to a large number of people and make use of their camels when not otherwise occupies. The digging of roots loosens the soil and accelerates the wind erosion. Unless alternative sources for meeting the fuel needs are developed, the process is likely to continue and will add to the desertification of the area". And this overexploitation continues unabated. It is in high demand as fuel wood in Plaster of Paris industries. So decline in its population is due to large-scale cutting, digging of roots and also changes in the traditional farming system. The plantation of this species will not only provide permanent vegetation cover, but also fodder, firewood and building materials for local use. Moreover its protection and introduction in sandy wastelands/sand dunes will help in maintaining the ecological balance of arid ecosystem. In view of above its in situ conservation should be encouraged by protecting and preserving existing areas. Singh *et al.* (2004) outlined following measures for its protection and conservation:

- Collection of good quality of seeds from the Phog dominated areas and their dissemination in those areas, which are devoid of Phog shrubs particularly dune fields.
- Farmers should be encouraged to plant Phog on the field boundaries.
- Campaigning in the villages to educate people not to do digging of its roots for the fuel wood and other purposes especially in rainfed areas.
- Awareness among the farmers should be created for its importance as fodder during drought, sand dune stabilization, soil conservation, use as live hedge around the field boundaries, its medicinal value as food and for conservation of arid environment.

- Inclusion of Phog in large-scale Forest Plantation Programme especially for the sand dune stabilization and roadside plantations in arid region.
- Launching people participation programme through Panchayats, schools, colleges, Agricultural Universities for increasing area under its cover.

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***Capparis decidua* - A Multipurpose Shrub**

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Capparis decidua (Forsk.) Edgew, locally known as Kair, belongs to Caper family, Capparidaceae and is an important indigenous shrub found growing on farm boundaries, orans, gochars and wastelands. It is widely distributed in arid and semi-arid tracts of India. Hooker (1960) has listed 234 species of *Capparis* in Index Kewensis. Of these, 26 species are reported to occur in India. Of these species *Capparis decidua* is an important constituent of desert ecosystem and plays a significant role in the rural economy of northwest arid regions of the Indian sub-continent. The natives of Thar desert recognized the importance of this shrub long ago. This indigenous multipurpose shrub has played an important role in the rural economy of western Rajasthan as it provides food (pickle and vegetable), fodder and fuel, etc. Besides, it is known to have medicinal value in cardiac and gastric troubles, is commonly used as biofence and its termite resistant wood is used by rural people for making handles, cart wheels, etc. At present the immature fruits are collected from natural stands by the rural people in the month of March-April particularly, women and is an additional source of income for the rural poor.

Travelling through the vast Thar desert, one could easily conclude that wide range of variability is available in this species for growth habit, compactness, fruiting and flowering. If proper selection is made from available variability, it makes an excellent crop for extreme arid areas of Rajasthan and Gujarat states where a few species can survive and can be domesticated (Chundawat, 1990). One of the major disadvantages of this species is that it is slow growing. It appears to have credulous potential for improvement as a multipurpose plant. Improvement of this shrub will require information on its phenology, propagation techniques, reproductive biology and variability existing in the region, which can be exploited for developing an ideal shrub. The present paper describes information gathered on these aspects during last five years.

Distribution

Capparis decidua is found in several states of India viz., Gujarat, western Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana and Punjab. It is locally referred as Kair in Rajasthan, Karil in Uttar Pradesh, Ker in Gujarat, Teent in Haryana, Della in Delhi and Punjab, and Nepti in

western Maharashtra. Its natural habitat is pediment plains all over the dry regions. It is also found growing in central India, Deccan and is indigenous to tropical Africa, Arabia, Sind, Baluchistan, Socotra, Egypt and India. It grows on all types of wastelands in arid zone and other soils. Kalyan-Singh and Singh (1994) reported that *C. decidua* grows well on soils with lower sodicity (pH <9, ESP <35, ECe <4dS/m).

Botany

Capparis decidua is a straggling xerophytic shrub or tree attaining upto 6m height having deep root system. The leaves are smooth, small, linear-oblong, and acute and appear only on the young shoots (older branches are leafless). Stipular thorns are sharp, straight and orange yellow in colour. Flowers occur in many flowered corymbs, on old branches or on short lateral shoots; pedicel slender. Sepals, four; outer pubescent, subvalvate, lower sepal very saccate acuminate, upper much smaller ovate-oblong, concave inner sepals elliptic, acute with floccose margins. Petals are red. Fruit globular and size of a small cherry.

Natural Variability

During surveys while travelling through arid and semi-arid tracts of Rajasthan and Haryana it was visible that wide range of variability is available for growth habit, spiny habit, plant spread and compactness of canopy, time of flowering and fruiting, etc. in *C. decidua*. While selecting the shrubs for commercial exploitation, shrubs with good growth non-spiny or less spiny branches and open canopy were preferred. The primary criteria, in addition to the above was good fruiting. The late fruiting types were not preferred as the fruits set in hot months are likely to have poor quality. At present *C. decidua* plants occur in orans, gochars and on wastelands in scattered pockets. In farmers' field they occur mainly on bunds or farm boundaries. Chundawat (1990) has opined that if proper selection is made from available variability, *C. decidua* can make an excellent crop for extreme arid zone of Rajasthan and Gujarat states where a few species can survive and can be domesticated.

Two distinct plant types were observed. Few plants were having tree form whereas majority occurred as bushes. It cannot be concluded that these are two

different ecotypes. It appears that plant attains tree form when it grows from seed and remains undisturbed. On the other hand, plants that get exposed to biotic interference may tend to produce more shoots and also propagates through root suckers. This view is supported by the fact that *C. decidua* occurred singly in tree form and mostly in clusters in bush form in orans and gochars. Many other arid zone trees in the region also show similar behaviour.

The results of the survey during 2000 and 2001 have clearly demonstrated that vast variation is available both for morphological as well as fruit and seed related characteristics (Table 1). Fruit is the economic trait in this species and the variability in fruit related traits is of interest to the breeder. The coefficient of variation for pulp wt/fruit was 70.4 per cent, fresh ripe fruit weight 64.4 per cent, pulp-seed ratio 61.9 per cent, seed weight/fruit 49.5 per cent, and number of seeds/fruits 43.5 per cent. The variability for fruit length and fruit breadth was less than that in other fruit related traits. The high variability in fruit weight, pulp weight and pulp-seed ratio indicates that there is very good scope of selection for these fruit characteristics.

The variation for height and spread was also ample, coefficient of variation being 43.8 per cent and 48.1 per cent, respectively for these two characters. The exploitation of this variability will depend upon our needs. If the species is to be developed on wastelands then fast growing types with better height and spread will be desirable. However, if the species is to be developed as a horticultural crop then selection parameters may be slightly different. Further, it may be necessary to develop cultural practices for uniform growth and flowering in this species.

Table 1. Coefficient of variation in different traits of *C. decidua* in natural stands

Trait	CV (%)
Pulp wt/mature fruit	70.42
Fresh ripe fruit wt.	64.41
Pulp-seed ratio	61.90
Seed wt./fruit	49.47
Plant spread	48.13
Plant Height	43.77
No. of seeds/fruit	43.53
Fruit width	26.89
Fruit length	22.65
100-seed wt.	20.00
Internodal length	14.95
Internodal angle	02.74

An interesting observation related to plant spread was that in natural population the spread was more in north-south direction than in east-west direction indicating that more growth takes place in north-south direction so as to avoid high heat load. In established population, no difference in the spread was observed and it can be attributed to regular and close spacing.

The coefficient of variation for 100-seed weight, internodal length and internodal angle were 20.0, 14.9 and 2.74 per cent, respectively. It appears that 100-seed weight is relatively less affected by the environment and has limitations of its range. Even though, variation for internodal length and internodal angle are less but these traits along with other traits contributing to compactness of shrub are very important.

The shrubs with different degree of compactness were observed during survey. The shrub with less branch angles, shorter internodes, large size spines and zigzag pattern of terminal branches as indicated by internodal angle contribute towards compactness of the shrub. In few cases, the shrubs were so compact that it was not possible to pluck the fruits. Selection of proper morphology with respect to compactness is essential and the endeavour has to be selection of plants having long internodes, no spines and almost straight terminal branches. Such shrubs will appear open and it will be very easy to harvest the fruits.

In the present scenario, where there is no commercial cultivation of this species and green fruits are harvested by the rural people, it is obvious that more fruits will be picked up from the non-spiny open type shrubs having early fruiting. At present, the demand for kair is very high and mass harvesting of green fruits is likely to lead to skewed perpetuation of different plant types. The plant type from which it is most difficult to pick up the fruits is likely to pass on maximum seeds to the next generation. Hence, with the present rate of harvesting there is every likelihood that the desirable types may decrease in frequency and even disappear leading to loss of valuable germplasm. Modern methods of cultivation also do not favour the existence or perpetuation of the species.

Very limited information was available on natural variability in *C. decidua* prior to this study. Variability in flower colour in natural stands of *C. decidua* was reported by Shekhawat (1999) wherein brick red and yellow coloured flowers have been observed. A report on dimorphism in seeds of *C. decidua* revealed the presence

of two distinct seed types. Small seeds had 20-seed wt of 375 mg, 4.67 x 3.67 mm size and were pale violet with white markings, while large seeds had 10-seed wt of 471 mg and 6.17 x 4.67 mm in size and were cream-coloured.

Phenology

Foliation

Phenological observations over two years on 20 even-aged plants have clearly shown that foliation in *C. decidua* populations occurs upto three times in a year during the months of June-July, October and January-March and can be referred as summer foliation, pre-winter foliation and winter foliation respectively (Fig. 1). The winter seems to be the dominant period of foliation and all plants bear leaves during this period. Summer foliation occurs only in few plants and that also not regularly in every year.

Water stress and environmental factors are likely to effect the foliation patterns. For example, in 2002-2003 pre-winter foliation started early and in most of the plants started producing leaves in September instead of October. The year 2002 has been a severe drought year and the total rainfall received during the whole season has been 39.1 mm. The severe stress condition seems to have led to early foliation. Further, in no case continued foliation from September-October onwards could be observed in contrast to the situation in 2001-2002 where five plants showed this type of foliation pattern.

There is vast variation for this trait between plants within a season and in the same plant during different years in this species, which is commonly described as a leafless shrub. It is not, however, possible to infer the contribution of leaves as the stem and branches are also green and some photosynthetic activity must be going on even when leaves are not there. Leaves are more of a reflection of moisture availability in the deeper layers and normally appear a month or so before flowering. As reproduction is high energy consuming activity, it is possible that leaves supplement the food requirement and help to generate better food reserve.

Flowering

Flowering takes place during summer as well as winter months (Fig. 1). Summer flowering initiates in February and March. Flowering continues upto July in few plants whereas in others there is break in flowering during April.

Winter flowering generally starts in September-October and goes upto November-December. There is wide variation in flowering pattern between plants and within the same plant over different years. Shekhawat (1999) has also reported that flowering takes place three times in a year i.e. in February-March (Ambe Bahar), July-August (Mrig Bahar) and October-November (Hast Bahar).

In some of the trees the flowering continues from March to November in varying intensities. This pattern of flowering was observed in most trees in 2002 than in 2001. The year 2002 has received annual rainfall of 39.1mm rainfall whereas the rainfall was 437.2 mm in 2001. The flower initiation in 2002 was early during winter in most of the plants.

Fruiting

Green fruiting in summer was observed in March-April in most of the plants. There was a second flush of green fruits in May-July. In some of the trees, however, green fruiting may appear to be continuous from March to July (Fig. 1).

During winter fruits were set in the month of October and November. Few trees had green fruits in December 2001 whereas none of the trees was observed to have green fruits in December 2002. It may be observed that even the trees showing continuous flowering from March to November-December did not produce fruits continuously. Generally in August-September no green fruits were available. Some of the trees did not produce fruits in winter. Thus different trees produced green fruits once twice or thrice within a year and pattern within same tree was not uniform over years.

Phenological observations indicate that there are high intra-population variations suggesting high degree of homeostasis in the species. Even though, *C. decidua* produces leaves, flowers and fruits two to three times in a year but the peak flowering occurs during summer months and maximum mature fruits are available just before onset of monsoon. Apparently, it looks paradoxical that plant should produce flowers and fruits during the driest period when there is maximum water stress. But a close inspection will reveal that this is an important adaptation for continuity of the race. By producing flowers about 1-2 months before the rainy season the species ensures that the seeds are available in ground when rainfall season starts. The plant can afford this behaviour because of its ability to draw moisture from deeper layers.

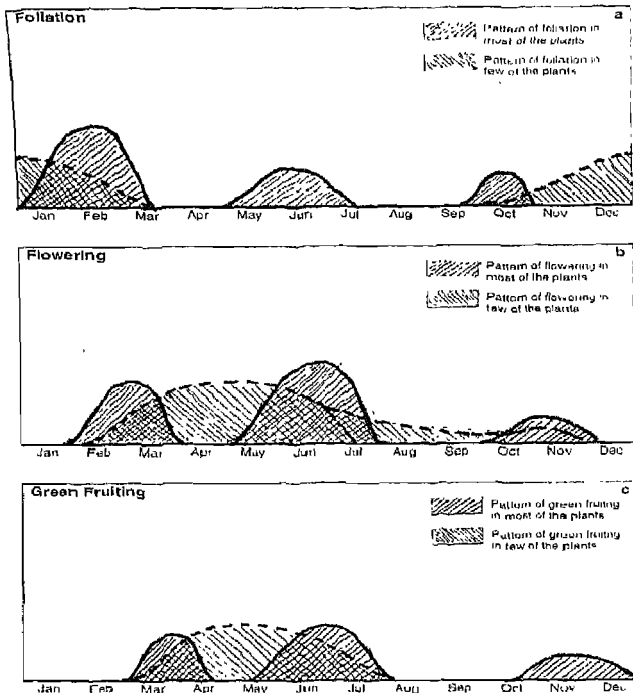


Fig. 1. Pattern of (a) foliation (b) flowering and (c) green fruiting in *C. decidua*

Seed dispersal

In *C. decidua*, the seed dispersal appears to be through birds. The mature red fruits of *C. decidua* are palatable and hence dispersal can also be by fruit burst, squirrels, other animals or even human beings. The mature fruits are not marketed but as observed during surveys, are eaten by children and graziers. The size shape and other characteristics of the seed indicate that seed is not dispersed by wind.

Reproductive Biology

The flowering was asynchronous and the transformation of buds into flowers on a raceme takes about six days. There were about three to four flowers on a raceme. The opening of buds is normally sequential; the buds close to the base open first. The pollen viability is high (88%) it being slightly more in March flowering.

The flowers are large, highly conspicuous and coloured, attractive and have large stamens of different sizes that bend slightly downwards. All the floral characters along with asynchronous flowering and foliation at the time of flowering apparently suggest that pollination is by insects. As the blooming takes place in March-June period when hardly any food is available, the visits by large number of insects is expected. Many of these are predators, and some of the hymenopteran and dipteran insects like bees and flies are likely to be pollinators.

Black ants can be observed sucking nectar from flowers while squirrels feed on corolla parts, but their role in pollination is uncertain. Pollination by insects has also been observed in other *Capparis* species (Eisikowitch *et al.*, 1986 ; Dafni *et al.*, 1987)

In a systematic experiment during 2001 and 2002 to determine the mode of pollination, it was observed that when flowers are emasculated and left as such for open pollination, there is very poor fruit set. The little fruit set that has occurred may be due to random visits of insects or by wind. There was also low fruit set in both selfing and sibbing where individual flowers and inflorescences were bagged (Fig. 2). The setting of seed indicates that there is no self-incompatibility. At the same time low fruit set shows that degree of pollination is very limited in the absence of insects.

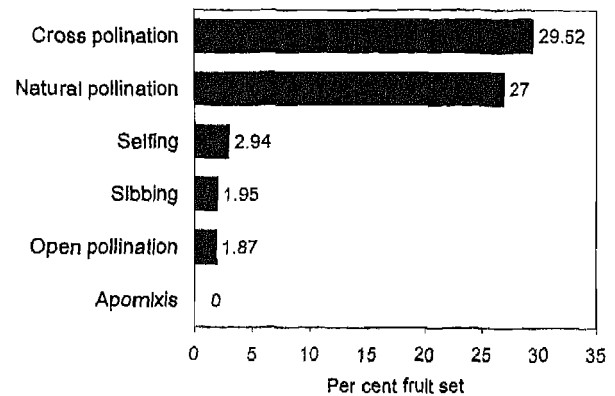


Fig. 2. Fruit set in different methods of pollination in *C. decidua*

There was hardly any difference in cross-pollination by hand and in natural open pollination. The fruit set in the two cases was 27 and 29.52 per cent respectively. Shekhawat (1999) also reported maximum pollination in cross pollination. Hence the pollen transfer by an external agent leads to good fruit set that is around 30 per cent. This value is much higher than that observed in other arid zone trees. Studies have shown very low fruit set in arid zone tree species like *P. cineraria* and *T. undulata* where on an average 1-2 per cent flowers develop into fruits. The high fruit set in *C. decidua* can be attributed to lack of competition of space due to long pedicel and gynophore of the fruit. Further, the green branches of stem may be able to provide more continuous supply of nutrients leading to better fruit set.

The variation observed in flower colour, morphological traits and fruit and seed related characters in nature also confirmed that the species is highly cross-pollinated. Some degree of self-pollination by insects while moving within the same shrub cannot be ruled out. Low

fruit set in selfing is not an indication of less self-pollination but only indicates that selfing is possible and its extent is very low in the absence of pollinators. In practice more self-pollination may be taking place. This inference gets support from the observations during survey where reasonably good fruit set was observed even in totally isolated single shrub, with no other shrub in visible range.

Associated Insects and Microflora

Xylocopa finestra, a carpenter bee found in *Capparis* is a useful pollinator. In Jodhpur district, this species hibernated from late November to early February and occasionally during warm spells (Sharma, 1981).

Stenozygum fieber, a beetle has long been associated with *C. decidua* (Ahmad and Khan, 1983). *Bruchidus obscurus* (Coleoptera) were found on the leaves of *C. decidua* in Dehradun forest in UP but rarely found in Rajasthan (Arora and Tewari, 1984).

Highest density of termites was observed in *C. decidua* with 114.6 nests/acre in plant communities of eastern Baluchistan (Kayani *et al.*, 1985). Reports on investigation of locust by spider web (*Stegdiphys sarasinorum* Karsch) was studied at Bikaner. Web spun on leaves and branches of *C. decidua* trapped insects from *Coleoptera*, *Lepidoptera*, *Diptera*, *Hymenoptera* and others. Biology of pierid *Belenois aurota* collected from *C. decidua* in Rajasthan has been reported by Chandra (1988).

Fruit rot disease on *C. decidua* caused by *Dichomera capparidis* in arid and semi-arid regions of western Rajasthan has been reported by Gehlot *et al.* (2001).

Vegetative Propagation

C. decidua has been reported to naturally propagate through root suckers which are thrown up to 5 m from the shrub. The ability to produce root suckers is a good indication of regenerative ability. The ability to produce shoots is also a fair indication of its power for vegetative propagation.

Our efforts to propagate the species by collecting root suckers, separating the sprouts and raising them in the nursery during 2001-02 met with a limited success. Few sprouts that produced shoots and survived up to 1 year in nursery failed to survive in the field beyond two months. It appears that the suckers survive in nature by remaining dependent on mother plant for prolonged period and there early separation during our collections has been lethal.

The trial on identifying best month for collection of cuttings showed that there is variation in sprouting of cuttings taken from different plants. In one case no sprouting was observed in any of the month whereas in another case 20-40 per cent sprouting was observed in seven out of 12 months. This may be a reflection of genetic variation or the food reserve available in the cuttings. February-March and July-September appear to be the suitable months. However, all collections may not behave in the same manner. Further, out of 240 cuttings planted in different months only one produced roots. This clearly indicates that *C. decidua* is a hard to root species and application of hormones is necessary.

Even use of hormones IBA, IAA, BNOA and commercial preparation like Shridex B₂ and B₃ did not yield very promising results. Hormones, particularly IBA led to enhanced sprouting but the rooting response was, in general, poor. The earlier studies made by Meghwal and Vashishtha (1998) also showed that the time of planting had marked influence on rooting and sprouting and this species is very hard to root. The rooting response of the species was reported to be poor and the best results were obtained during rainy season.

Experiment by Bhargava *et al.* (2000) using cuttings of *C. decidua* of 15-20 cm length and 1-1.5 cm diameter and treated with IBA at 3000, 5000 and 7000 ppm alone or in combination with 1000 ppm Thiamine showed that maximum sprouting (25%) occurs in 5000 ppm IBA.

A method for micropropagation of *C. decidua* from mature trees using nodal explants was developed by Deora and Shekhawat (1995). *In-vitro* micropropagation was achieved from mature trees using nodal explants and seedling explants from cotyledonary nodes, cotyledon and hypocotyls on MS medium supplemented with bezyladenine (BA 1,3 and 5 mg/litre). Rooting medium with IBA 1 mg/litre was proved best for rooting.

Root Studies

Roots play an important role in anchoring as well as transport of water and nutrients particularly in arid zone where water is major limiting factor in the growth. Our studies on development of roots in nursery showed that during first three months a single tap root is developed and at 6-month stage it starts developing few secondary roots. At 12-month stage, number of secondary branch develop even though the tap roots continues to dominate.

In arid zone the relative proportions of root shoot may be more important than their individual values. The high shoot-root ratio has been observed in nursery. Less growth in shoot and more growth in root can be an important adaptation for initial establishment in arid areas.

The studies on root system of a mature shrub on rocky site at Beriganga (Fig. 3) have clearly shown that roots penetrate upto nearly 4 metres. The major roots tend to go deep by growing directly downwards and the lateral branches spread to great distance. These roots are also not superficial and their terminal ends tend to go deep. It is for this very reason that *C. decidua* does not compete for moisture with crops whose root zone is upper one meter or so. The root biomass comprised of major portion of the plant biomass and has the shoot-root (w/w) in mature plant was 0.68.

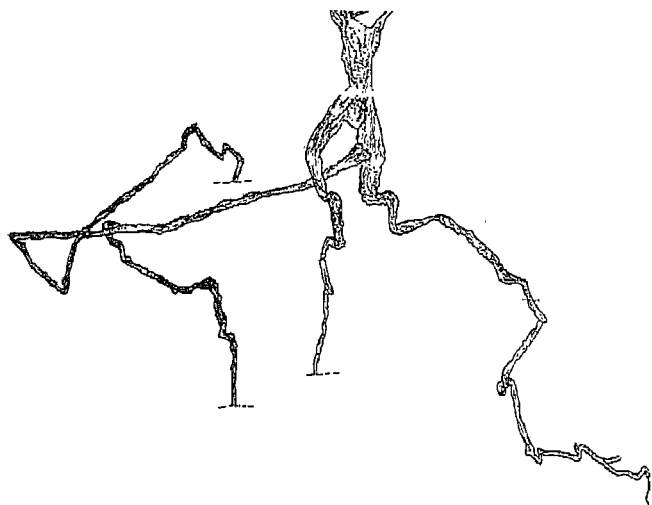


Fig. 3 Root pattern of a mature plant of *C. decidua*

Chemical Composition

The ripe fruits of *C. decidua* contained 55% of total pulp of the total fruit weight including moisture (56%), crude protein (8.6%), true protein (5.02%), total sugars (1.8%), reducing sugars (1.1%), P (0.057%), K (1.026%), Ca (0.055%), Mg (0.055%) and ascorbic acid (7.81 mg/100 g) Thus, this fruit is rich in protein and mineral matter (Khera and Singh, 1975).

The unripe fruits of *C. decidua* consisted of protein (14.88%), fat (7.43%), ash (5.96%), crude fibre (12.32%) and digestible carbohydrates 59.41 per cent DM. It also included mg/100 g of b-carotene (5.4), ascorbic acid (120.7), calcium (90.0), phosphorus (179.0), iron (3.5), copper (1.1), zinc (1.6), manganese (1.9); phytic acid (304). Total protein fraction include albumin 53 per cent, globulin 16 per cent, prolamine 11 per cent and glutelin 12 per cent (Chouhan *et al.*, 1986).

Analysed fruits, flowers and buds of *C. decidua* yielded 14 per cent surface wax (w/w) and consisted of a mixture of compounds, mainly straight chain saturated hydrocarbons and ketones with C 28 to C 32 chain lengths associated with N- and S- containing oils. Seeds contained 1.7 per cent sugar and 8.6 per cent protein with 20 per cent oil and 14 per cent oil in flowers (Sushila-Rai and Rai, 1987). Seeds of *C. decidua* contain 20.3 per cent oil with 68.6 per cent of unsaturated fatty acids and 31.4 per cent of saturated acids (Rai and Shekhawat, 2000).

The seeds contain glucocapparin from which the mustard oil methyl isothiocyanate is released when the plant is crushed (Gupta *et al.*, 1989).

Extraction and isolation of 15 natural products from *C. decidua*, which are also used as emergency famine foods was reported by Rai (1987). On the basis of spectral and chemical data studies, two new spermidine alkaloids 14-N-acetyl-isocodonocarpine and 15-N-acetyl-capparisine were isolated from root bark of *C. decidua* (Ahmad *et al.*, 1992) and two compounds n-nonacosane and n-hentriacontane were isolated from the flowers (Garg *et al.*, 1993).

Uses

Green or dried leaves of *C. decidua* are used as diet supplement for goats, sheeps, camels and other animals during scarcity period of grass. Young green fruits are an important ingredient of the famous "Panch koot" mixtures of dry vegetables of Rajasthan that includes kair fruits, kumat seeds, dry kachri (*Cucumis*), sangri (Khejari pods) and kamal dandi (lotus roots) (Hocking, 1993). The green immature fruits are considered good for antihelminthic, laxative, asthma, constipation, coughs, hysteria, worms and other psychological problems (Ghazanfar, 1994). Bark has an acrid, hot taste, analgesic, diaphoretic, akheteric, laxative, antihelminthic, good for cough and asthma, ulcers and boils, vomiting, piles and all inflammations. The fruit has a sharp hot taste astringent to the bowels, destroys foul breath, biliousness and urinary purulent discharges good in cardiac troubles (Ayurveda). In Punjab the top shoots and young leaves are made into a powder and used as blister. They are also used as antidote to poison and also in afflictions of the joints. The fresh young leaves are crushed and soaked in water. The water is strained off. The residium is dried and allowed to solidify. A tiny piece of it is eaten with butter and gives relief from pains of bruise after a fall.

Dietary fibre content of *C. decidua* varied from 38.5 to 55.7 per cent. Hemicellulose in *C. decidua* given at 10 per cent of the diet to rats induced a greater resistance to hyperlipaemia than cellulose and has most pronounced hypocholesterolaemic effect, which operated through increased faecal excretion of cholesterol as well as bile acids (Agrawal and Chauhan, 1988).

C. decidua has been reported to have diuretic properties and antidiabetic properties. *C. decidua* helps in controlling wind erosion in sandy areas, reduction of alkalinity and increase of organic carbon and available N, P and K and is found to be the best species for shelterbelts to check the movement of sand and its morphometry plays an important role in sand dune stabilisation in the Thar desert of India (Pandey and Rokad, 1992). Ethnobotanical expeditions from western Maharashtra revealed the use of root extracts of *C. decidua* in fisheries for catching predatory and weed fishes that compete with cultivated carp. Flower buds are also used as potherbs.

Quantitative analysis of fuelwood properties like calorific value, density, silica, carbon, ash-biomass ratio, moisture, volatile matter and fuelwood index of *C. decidua* revealed its best fuel wood characters (Jain, 1994). Estimation of herbage production under canopy cover of *C. decidua* was greater as compared to that in open field and is thus a suitable species for use as woody component in silvipastoral systems.

This widely distributed drought-hardy shrub is providing livelihood to the inhabitants of the region who collect the fruits from naturally occurring shrubs and use them for vegetable and pickles. Its commercialisation and planting on farm boundaries will provide a dense fence. As the fruits are produced and collected during the hot months when the rural people have hardly any other agricultural activity, it can supplement the income and provide sustainability to the system

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***Acacia jacquemontii* Benth - A Potential Multipurpose Shrub**

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Acacia jacquemontii Benth. belongs to Mimosaceae family. Locally it is known by various names like Bu-banwali, banwali, bouli, gulli bouli in Rajasthan; Ratabauli in Gujarat; and baul, bamul, kihar in Panjab. Much branched bushy shrub. Leaves are bipinnate, stipular spines white at maturity; leaflets 8-10 pairs. Flowers 10-12 mm in dia, pale yellow, in axillary fascicled heads. Calyx Complanate, 1-13 mm long, corolla 1-1.8 mm long lobes ovate oblong, acute pods long flat straight. Seeds 5-8/pod flowers in Dec-Feb and pods mature in March-June.

It form very gregarious formation on sand dunes and sandy plains. Its density increases on high dunes. It is found in India (Gujarat, Punjab, Rajasthan, Delhi, Saurashtra) and Pakistan. In Rajasthan; it is widely distributed in sandy habitat in Pali, river beds, oren and gauchar in Jodhpur, sand dunes bordering Pakistan in Jaisalmer, high dunes in Bikaner, Hanumangarh and Ganganagar, scattered on farm boundries in Nagaur and Sikar; and on dunes and wasteland in Churu and Jhunjhunu districts of western Rajasthan.

Acacia jacquemontii is a less known multipurpose species. Its unique sand binding ability due to profuse root system makes it potential species for sand dunes stabilization. Due to multi-stem growth character, it yields small poles that are used for making frames of thatched houses and huts. Its young shoots/branches are used for making baskets, granaries and other household articles (Prasad *et al.*, 2004). The wood is good fuel and yields good quality charcoal which is used in making gun powder. On burning, the wood gives out intense heat and therefore, preferred by gold, silver and iron smiths (Bhandari, 1990). The plant yields 100-150g/ plant edible gum which is highly priced in pharmaceuticals. The tender green branches and leaves are used as fodder and provide good browse for camel. The dried thorny branches are used as fence. The bark is used in small sized tanneries, imparting brown or black

color to the leather. It has tan and non tan ratio of 1:7.

Present Status of Research

Despite its paramount importance, it remained unattended by the scientific community and no efforts have been made to harness potential of this plant species. Poor natural regeneration and its continuous extraction by local people from natural stands have threatened the existence of this precious species. Further, to maintain bio-diversity and ecological balance, it has been emphasized worldwide by the plant scientists and foresters to give special attention to less exploited indigenous species having high potential from societal and ecological point of view. Taking consideration of these backgrounds, studies on *A. jacquemontii* were initiated at CAZRI, RRS, Jaisalmer, with main objective to standardize propagation and silvicultural techniques for multiplication of this species in hot arid region. The paper deals with the present status of research conducted on *Acacia jacquemontii* and future thrust areas to harness full potential of this species.

Pod and Seed Characteristics

To assess and examine pod and seed characteristics, a natural stand of *A. jacquemontii* having 15 plants spread over about 1 ha area was identified and selected at village Murhar in Jaisalmer district of western Rajasthan. The selected stand was regularly visited to record observations on flowering and pod formation. When seeds matured, pods were collected and seeds separated. Observations on pod length, width, weight and numbers of grains per pod were recorded from a sample of 20 pods. Similarly, observations on seed size and weight were recorded.

Flowering in *A. jacquemontii* initiated in mid February and pods matured in last week of April. Pods are pinkish white in colour with prominent pink colored lining and have pointed ends (1.0 mm). Different characteristics of pod and seed have been given in table 1. The length, width, weight and number of grain per pod varied from 5.2 to 10.0 cm, 1.0 to 1.7 cm, 0.22 to 0.60g

and 4.0 to 8.0 with mean values of 7.24, 1.54, 0.36, and 5.4, respectively. The seed size and its weight varied from 5.5 to 7.5 mm and 0.03 to 0.06 g, respectively. The mean weight of 100 seed was found to be 4.93g.

Table 1. Pod and seed characteristics of *A. jacquemontii*

Characteristics	Mean	Range
<i>Pod characteristics</i>		
Length (cm)	7.24±2.80	5.20-10.0
Width (cm)	1.54±0.36	1.0-1.7
Weight/pod (g)	0.36±0.020	0.22-0.60
Number of grain/pod	5.4±0.29	4.0-8.0
<i>Seed characteristics</i>		
Size (dia in mm)	6.65±0.15	5.5-7.5
Weight/grain (g)	0.045 ±12	0.030-0.060
Weight per 100 seeds (g)	4.93±0.31	4.04-5.43

The observations on pod and seed characteristics of *A. jacquemontii* are agreeable with the findings reported by Bhandari (1990) in Jodhpur district of western Rajasthan. Little delay in initiation of flowering in Jaisalmer in comparison to Jodhpur may be due to the locality factor as the annual precipitation of Jodhpur is much higher than that of Jaisalmer.

Seed Germination Behavior and Seed Treatment

Seed germination trials were conducted to study the effect of pre-sowing treatments (T_1 : soaking seeds in cold water for 12 hrs, T_2 : Soaking seed in hot water at 80°C for 2 hrs and T_3 : untreated seeds; and size of seeds (large and small) on germinating behavior of *A. jacquemontii* seeds. Findings revealed significant effect of pre-sowing treatments and size of seeds on germination (Table 2), time for earliest germination and germination energy values (Table 3). Large seed germinated at faster rate and gave better germination percentage than the small sized seeds. Seed treated with cold water (T_1) gave better result. Like germination, root development (enlargement of radical) was effected significantly by pre-sowing treatments (Table 4). The size of seed had no effected on root development. Seed treated with cold water (T_1) showed maximum root development while untreated seed the least. For obtaining better germination of *A. jacquemontii* seeds it is suggested to use only healthy and bigger size seeds and soak them in cold water for 12 hour before sowing (Mertia and Prasad, 2004a).

Table 2. Effect of pre-sowing treatments and seed size on germination of *A. jacquemontii* seeds

Treatments	Per cent germination after hours of seed setting			
	8	16	24	32
Pre-sowing treatments				
T_1	35.0	83.5	85.8	100.0
T_2	0	62.7	77.8	80.0
T_3	0	13.3	47.5	75.8
LSD (P<0.05)	8.386	7.116	9.334	3.880
Seed size				
Large	11.1	75.6	77.6	100.0
Small	12.2	30.7	63.0	77.2
LSD (P<0.05)	NS	5.810	7.621	3.197

T_1 = Soaking seeds in cold water for 12 hours.

T_2 = Soaking seeds in hot water (80°C) for 2 hours.

T_3 = Untreated seeds (control).

Table 3. Effect of pre-sowing treatments and seed size on germination behavior of *A. jacquemontii*

Observation	T_1		T_2		T_3	
	Large	Small	Large	Small	Large	Small
Time for earliest germination (hours)	8	8	16	16	16	24
Germination after 32 hours of seed Setting (%)	100	100	100	60	100	71.6
Germination energy	67.7	36.7	100	30.4	67.7	61.7
	*(16)	(20)	(16)	(24)	(32)	(24)

*Figures in parentheses indicate time in hours taken to attain peak rate of germination

Table 4. Effect of pre-sowing treatments and seed size on root development in *A. jacquemontii*

Treatments	Root development/radical enlargement (cm) after hours of seed setting			
	27	30	33	36
Pre-sowing treatments				
T_1	1.30	1.43	1.63	1.83
T_2	0.60	1.00	1.25	1.43
T_3	1.17	0.20	0.33	0.830
LSD (P<0.05)	0.63	0.812	0.97	NS
Seed size				
Large	0.89	1.09	1.35	1.72
Small	0.52	0.67	0.82	1.01
LSD (P<0.05)	NS	NS	NS	NS

Keeping aside pre-sowing treatments of seeds, the reason for better germination observed in large seeds than small seeds could be attributed to larger embryo or

gametophytic tissues and bigger cotyledons (Farmer, 1980). Poor rate of germination observed in smaller seeds could be attributed to their less ability to imbibe water. Pre-sowing treatment of seeds with cold water (T_1) appears to be the best as compared to other treatments. The results of this study corroborate with the finding of Mertia and Kunhamu (2000) who reported highest seed germination and germination energy for seeds of *Salvadora oleoides* treated with cold water. However, time reportedly been taken by *S. oleoides* seeds to attain peak rate of germination was more than the time taken by *A. jacquemontii* for attaining its peak rate of germination. The faster and higher radical enlargement or root development showed by large seeds in initial hours after emergence appears to be due to larger cotyledons (Farmer, 1980). The pace of radical enlargement in large seed slowed down and became at par with small seeds after 12 hours of emergence because of diminishing support of stored energy of larger cotyledons.

Seed germination and seedling growth in nursery

For standardization of nursery techniques for seed germination and seedling growth, a nursery trial was conducted at CAZRI, RRS, Jaisalmer using two seed size viz. large (>6.5mm dia) and small (<6.5mm dia) and four sowing depths viz. D_1 : 0.5cm, D_2 : 1.0cm, D_3 : 1.5cm and D_4 : 2.0cm.

Data on seed germination have revealed that sowing depth as well as seed size had affected percentage germination significantly (Table 5). The rate of germination was also affected significantly with size and sowing depth of seeds. Irrespective of seed size, large seed sown at 0.5cm and 1.0cm depths (D_1 & D_2) attained peak rate of germination after 36 hours of sowing whereas seed sown at 1.5cm & 2.0cm depth (D_3 & D_4) could attain similar pace of germination after 60 to 72 hours. In fact no germination was recorded upto 48 hours when seed was sown at 2.0cm depth (D_4). Maximum germination (100%) was obtained when seed was sown at D_1 (0.5cm) depth, which was at par with germination (91.7%) obtained at D_2 (1.0cm). Germination obtained at D_3 (1.5cm) and D_4 (2.0cm) depths were statistically at par. Irrespective of sowing depth large seed gave 100 per cent germination as compared to 84.8% obtained in small seeds.

Data on seedling growth (height and number of leaves per seedling) recorded at 7, 14, 30 and 60 days

after sowing have been given in table 6. It revealed that the depth of sowing influenced plant height significantly in early days up to 14 days of their growth and thereafter seedling grew steadily irrespective of depth of sowing. At 14 days, maximum plant height was obtained by seedling emerged out of sowing at depth of D_1 (0.5cm) followed by D_2 (1.0cm), D_3 (1.5cm) and D_4 (2.0cm). However, size of seed influence growth of seedling upto 30 days and thereafter its effect was neutralized. On an average, height of seedling emerged from large seeds was higher than those of small seeds. Unlike plant height, number of leaves per plants had no significant bearing on seed size and sowing depths (Table 6).

Table 5. Effect of sowing depth and seed size on germination of *A. jacquemontii* in nursery

Treatments	Germination (%) after hours of seed sowing				
	36	48	60	72	84
Sowing depth (cm)					
D_1 (0.5)	76.7	81.7	100.0	100.0	100.0
D_2 (1.0)	50.0	50.0	91.7	91.7	91.7
D_3 (1.5)	10.0	11.6	80.0	90.0	90.0
D_4 (2.0)	0	0	10.0	75.0	88.0
LSD (P<0.05)	9.99	9.35	9.98	11.45	5.59
Seed size					
Large	45.0	45.8	80.0	96.7	100.0
Small	23.3	25.8	60.8	81.7	84.8
LSD (P<0.05)	7.07	6.61	7.07	8.09	3.95

Better germination and vigorous seedling growth from large seeds are attributed to larger embryo or gametophytic tissue and larger cotyledons (Farmer, 1980; Daleep *et al.*, 1993). Higher germination with heavy seeds of various trees have been reported by Singh *et al.*, (1973); Manga and Sen (1995) and Negi and Todaria (1997). The increased germination of *Hardwickia binata* (Ponnammal *et al.*, 1993) and *Abies pindrow* (Singh and Sah, 1992) have been found with increase in seed size. Sowing of seeds at increasing depths have been reported to cause less or delayed germination (Chandra and Atma Ram, 1980). Our findings on germination of *Acacia jacquemontii* seeds in respect to seed size and sowing depth are in concurrence with earlier reports on seed germination of *Pinus* (Singh *et al.*, 1973) and *P. juliflora* (Mutha *et al.*, 1995). Growth of seedling of *A. jacquemontii* was influenced with seed size and sowing depth only in initial stage upto 30 days and thereafter, they grew steadily

Table 6. Effect of sowing depth and seed size on seedling growth of *A. jacquemontii* in nursery

Treatments	Seedling height (cm) days after sowing				Number of leaves /plant days after sowing			
	7	14	30	60	7	14	30	60
Sowing depth (cm)								
D ₁ (0.5)	9.6	11.0	17.9	27.6	2.3	3.0	5.5	7.9
D ₂ (1.0)	7.4	9.4	17.9	28.6	2.0	3.4	4.7	8.2
D ₃ (1.5)	7.2	9.4	19.9	27.5	2.2	2.7	6.1	8.6
D ₄ (2.0)	6.7	8.7	18.1	27.7	2.0	3.7	6.7	9.0
LSD (P <0.05)	1.21	1.59	NS	NS	NS	NS	NS	NS
Seed size								
Large	8.4	10.3	19.2	29.0	2.1	3.4	5.8	8.5
Small	7.0	8.9	17.7	26.7	2.2	3.1	5.8	8.4
LSD (P <0.05)	0.36	1.21	1.28	NS	NS	NS	NS	NS

irrespective of seed size or sowing depth (Mertia *et al.*, 2004). It appears that initial advantage of seed size has been compounded with other factors such as greater soil resistance and specific characters of the species (Pathak *et al.*, 1980).

Field Performance and Growth Behavior

When planted out in field, *A. jacquemontii* grew fast and showed its multi-stem growth character after one year of planting (Mertia and Prasad, 2004b). The multi-stem growth character of this species helps it to bind sand/soil more efficiently. Data on performance and growth behavior of *A. jacquemontii* in field have been given in table 7. Site conditions had significantly contributed in the growth of the plant. Highest growth was obtained in deep soil whereas it was least in shallow soils.

Table 7. Growth characteristics of *A. jacquemontii* after four years of planting in field

Soil Site Conditions (Depth in cm)	Plant Height (cm)	Crown Diameter (cm)	No. of Shoots/ plant	Shoot Dia. Collar Dia. (mm)
Shallow (<50 cm)	163	220	8	12.41
Medium (50-100 cm)	248	309	12	15.58
Deep (>100 cm)	393	532	28	23.41

Biomass yield

More biomass was obtained when it is grown in deep soil as compared to shallow soils (Table 8) Poor biomass yield in shallow soils indicate that it grows well in deep sandy soils.

Table 8. Biomass yield of *A. jacquemontii* after planting in field

Soil Site Conditions (Depth in cm)	Biomass yield (kg/plant)			
	Hard wood	Twigs/	Leaves	Total
Shallow (<50 cm)	-	4.0	0.5	4.5
Medium (50-100 cm)	9.0	7.0	2.5	18.5
Deep (>100 cm)	80.0	69.0	14.5	163.5

Future Research Needs

For harnessing maximum potential of the species, further investigations are required on its sand binding ability, root growth pattern, browse and wood quality in plantation area. The quantification of gum production and methods to improve its quality need further experimentation. Silvicultural operation like pruning, felling pattern of coppicing, etc. need to be standardized.

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***Opuntia ficus-indica* - A Multipurpose Underexploited Arid Shrub**

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Opuntia species are members of the cactus family (Cactaceae) and are commonly referred as tuna cactus, barbary fig or prickly pear cactus. *Opuntia ficus-indica* grows well in dry climate. Basically a native of Mexico and the region around it, the cactus has by now found a foothold in most parts of the world, though it has been commercially exploited only in a few countries like Mexico, Brazil, Argentina, France, South Africa, Italy and the US. Plantation of spineless cactus in hot deserts and drought-prone areas can serve as reserve feed to animals at maintenance level and an alternate source of human food in the highly rainfall deficient years. *Opuntia ficus-indica* is thus an under-appreciated plant species that can play an important role in drought proofing and livelihood security in dry areas. Very little attempt has been made to grow it on a plantation scale in India where it is commonly referred as *Nagpani* or *Thor*. It generally grows wild or as bio-fence in dry areas.

Spineless cactus was introduced at CAZRI Jodhpur in 1970s. The spineless cactus (*Opuntia ficus indica*) has oblong to elliptic joints, yellow flowers, pale, green, red and yellow fruits and is not affected by wild cochineal insect (*Dactylopius* spp.) under Indian conditions. It is highly drought-resistant and can grow in areas of 200 mm rainfall on deep sandy soils and also in areas with 120 to 150 mm annual rainfall if supplemental run-off is available. Fronds of the cactus are succulent and palatable.

Different parts of the cactus can be used as fruit and vegetable for human consumption, fodder for cattle, and raw material for various industries to prepare natural dyes, adhesives and glues, pharma products for treating blood sugar and various other disorders and cosmetics like shampoo, cream, soap and body lotion.

Establishment Techniques

An elaborate technique for raising plantation of this cactus was developed at CAZRI so as to provide rapid growth, use the limited water supply effectively and also to keep wind erosion of the sandy soils to a minimum (Shankar and Saxena, 1976). According to them in areas receiving only 150 to 250 mm annual precipitation the plantation have to be located in water channels and valleys. Small earth dams (*nadis*) are built to keep water from flowing away.

Fronds of the cactus are plucked at the joint and the cut end of the frond is dribbled in the sandy soil up to a quarter of the total length of the frond. Before planting, soil treatment with pesticides is essential to avoid microbial and fungal infection at the cut ends. Plant to plant and row-to-row distance of 3 m is recommended for the areas to be brought permanently under plantation. The above spacing may be reduced to 1 m for short-term plantation. Around the base of each planted frond a crescent shaped ridge slightly raised towards the slope gradient serves as a micro-catchment accumulating and supplying more moisture for rapid growth. With this technique nearly 95 per cent survival of the planted fronds has been achieved on the flat alluvial plain at Jodhpur (Shankar and Saxena, 1976). Erect planting keeping 1/3rd portion of frond above the ground and 2/3rd burying in the soil found better than flat planting at Karnal and Jhansi (Singh *et al.*, 2001; Singh 2003) Similarly, growth performance was also better on ridges than on flat surface. February-March is the ideal period for planting. It may also be planted after the withdrawal of monsoon especially during October but February planting gets better growth period. After passing through a dormant phase in the ensuing winter, the cactus sends out secondary and tertiary fronds and flowers during March-April. This is followed by another spurt of vegetative growth in the following monsoon season (Shankar and Saxena, 1976).

Forage Yield

Yields ranging from 10 to 30 t/ha of green fodder have been obtained in Mediterranean areas where rainfall amounts to 350 to 450 mm. Green fodder yield of 12.5 t/ha has been reported from southern part of India. Harvesting is done by plucking the fronds at each joint from the branches and the main stem. The mature fronds at the base of the main stem are left undisturbed for further regeneration during the ensuing spring season. When the fronds achieve the full growth, these are plucked, chaffed and fed to animals.

In 1975 with exceptionally high rainfall (600 mm) at Jodhpur, 3-4 years old plants having 5 to 7 mother fronds at the base, produced 10 to 21 new fronds within a period of six months (July-December). The green weight

of newly developed fronds in this period ranged from 95 to 454 g/frond, whereas one to two years' matured fronds weighted 995 to 1958 g/frond. When computed on single plant basis the green forage yield of three year old shrub works out to be nearly 30 t/ha. Single frond weighing 270 g each when placed for rooting in 23 cm size earthen pots produced a new frond weighing 125 g within a period of 150 days with 25 g of root biomass (Shankar and Saxena, 1976).

At CAZRI, Jodhpur three new accessions, received from Burbank (USA) faced four consecutive years of drought by 1982 and even then gave 6.0t/ha aboveground biomass production of fronds in 2 m x 2 m spacing (Anonymous, 1982). During 1883 when there were normal rains, the plantation of *Opuntia ficus-indica* grew very well after sustaining four years of drought and aboveground biomass production of fronds was 28.5 t/ha. During summer months, when there was acute shortage of water, this plantation became the target of avian fauna, especially the parrots (Anonymous, 1983).

Nutritive Value

The green forage has 6.8% protein and phosphorus (0.16%) and, therefore, needs addition of supplementary protein which may come from dry feed (straw, hay or browse). The leaves of *Ziziphus* spp. (*ber* or *bordi*) which is locally known as *pala* in Western Rajasthan is rich in protein (>14%) and so when mixed with chaffed cactus will balance the nutritive value. The cactus fodder, when fed alone, however, provides the near maintenance diet as its protein value borders the minimum protein level (7%) recommended for normal maintenance of animals.

Ripe fruits of this cactus can be eaten. Fruits are delicious and used in the preparation of sweets and fermented liquors and have also been tried as a source of industrial alcohol in Mexico. Fruit juice contains ascorbic acid (40 mg/100 g), carotene (9 mg/100g), citric acid (0.8%), pectic substances and gum. The seeds are nutritious (12.06% protein) and may, therefore, be used as animal feed after grinding. The oil extracted from the seeds is semi-drying in character and yields 13.3 per cent saturated fatty acids. A mucilage or gum with excellent adhesive properties can be extracted from joints and other parts of the plant by pressing or boiling or soaking the plant material in water and then straining it for the gum to ooze out. The gum is soluble in water but swells to a jelly like mass. The gum obtained from the fruits contains bassorin with an acid character and no hydrolysis yields pentoses and the gum obtained from the flowers contains mannose and galactose.

Feeding Value

Considering that the feed reserve should be 30 per cent of the animals' total requirement, the normal production (green fodder yield) is sufficient for the maintenance of 8 to 24 sheep in drier (150 to 350 mm annual precipitation) areas. This, of course, is the ideal feeding balance. But the scarcity balance during periods of famine may include dry feed (straw, hay or browse) to the tune of 10 per cent of the cactus consumed. With dry matter component in their diet, animals can consume cactus fodder to the tune of at least 10 per cent of their body weight. That is, a sheep weighing 45 kg can eat 4.5 kg of cactus fodder. Addition of dry feed is essential to avoid diarrhoea. But this cactus can be fed alone for 6 to 10 week without danger (Shankar and Saxena, 1976).

Current Status

Attention to its real commercial potential was redrawn around 1990 with the introduction of a few US clones (varieties) at the Nimbkar Agricultural Research Institute at Phalton (Maharashtra) and the Karnal farm of the Central Soil Salinity Research Institute (CSSRI) (Singh and Felker, 1995).

Five distinct clones have now been identified for commercial cultivation for different end-uses. These include clone 1270 (fruit-cum-forage), clones 1271, 1280 and 1287 (fruit) and clone 1308 (vegetable). Except 1287, all other clones are virtually thornless. In clone 1287, the thorns (spines) have to be burnt before consumption by humans or animals. These accessions have been introduced at other institutions like National Research Centre for Agroforestry, Jhansi, Central Arid Zone Research Institute, Jodhpur, Central Institute of Arid Horticulture, Bikaner and many other places in the country.

This plant is deemed an ideal source of fodder in arid regions because its vegetative portion (cladode) retains its green colour, vitamin A content and other quality characteristics even during long storage periods. Besides being palatable, it is relished as fodder by cattle, sheep and goats.

The fruits of the cactus, though not commercialised in India, is considered a table delicacy in several European countries. Mexico has exploited these fruits the most as money-spinners in the domestic and export markets. Besides, direct consumption, these relatively small fruit, weighing between 110 gm and 160 gm each, are used for making mock-gherkins, salad

dishes, jams, syrups, alcoholic drinks and juices.

Charles E. Russell, of Texas A & I University, has studied some of spineless cacti and other varieties as animal fodder in arid regions of Texas, Mexico, and Chile. The pads can be the important source of food and water for range animals during times of drought or hardship. According to Russell, the pads are a highly-prized commodity in the dairy industry of Mexico. When fed to dairy stock, the pads impart a distinctive flavor to the milk and butter, and these products are highly desired locally.

In pre-Columbian times, the culture of the cactus-eating cochineal insect was of great value to the Aztecs who used it for the manufacture of the royal red robes of Aztec emperors. In the sixteenth century the Spanish conquerors shipped the platyopuntias, to the Mediterranean and then to the Canary Islands for raising the cochineal insect for production of the dye.

Today the dye mainly provides the carmine stain used in preparing microscope slides. The carminic acid from the cochineal insect is also used as a pH indicator, and as a natural colouring in foods, soft drinks and cosmetics.

Research Needs

- Collection of cactus germplasm available in different parts of India and establishment of repository.
- Introduction of promising exotic germplasm accessions for fruit, forage, vegetable and dye (Cochineal) traits from Mexico, Brazil, Argentina, USA, South Africa, Italy, etc.
- Evaluation of germplasm for different traits on different locations in arid and semi-arid region including its potential as live fence.

- Standardization of agrotechniques and integration of cactus with other trees, shrubs and crops.
- Post harvest handling and value addition.

Raising plantation of this cactus in the hot desert and drought-prone areas will serve as an insurance against erratic rainfall conditions leading to normal crop failures, by way of providing reserve feed of maintenance level to the animals and will also help to reduce the large-scale animal movement and causality during famine. Raising it on farm boundaries will provide the much-needed fence to check biotic interference.

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Shrubs for Arid Land Management

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Arid lands are spread over 31.7 m ha hot and 7.0 m ha cold geographical regions in India. Overexploitation of these fragile ecosystems, erratic rainfall, extremes of temperatures, high wind velocity and frequent droughts in hot arid region cause degradation due to wind and water erosion. Vegetation cover comprising of perennial grasses, shrubs and a few scattered trees are primary defence mechanism against water and wind in these ecosystems. However, high population of 107 human and 137 animals per sq. km in western part of Rajasthan has caused degradation of vegetation cover thus exaggerating desertification process. The situation is alike in other hot and cold regions.

Amongst the vegetation, shrubs are the hardest species to withstand adversities of nature and protect land while providing multitude of products like food, fodder, aromatic and medicinal plants. Rangelands in hyper arid and arid situations are supplemented with shrub species and enrich their productivity. There has been emphasis on arid shrubs for systematic investigations and their integration in farming system mode. These shrubs have to be utilized for conservation and production in view of sustainable arid land management.

Despite great emphasis on arid shrubs, the non-organized marketing chain and lack of knowledge for their value addition limits their recognition in unit factor productivity. An understanding of actual needs, export potential, post harvest technology and value addition while development of marketing chain may help the desert farmers for their livelihood under adverse situations.

Management of vegetation close to land surface plays an important role in controlling erosion due to wind and water. The types of this vegetation on different habitats and efforts to use them in arid land management are discussed in this paper.

Vegetation types

Vegetation on different habitats can be described in three rainfall zones : Less than 200 mm, 200-300 mm and 300-400 mm. Two very basic habitats in each zone are sandy and gravelly / rocky (Pediments). There are distinct shrubs, grasses and trees on these habitats as the rainfall increases from the west to the east. Physiognomically,

the vegetation in the low rainfall zone is a shrub savanna with large sprawling tussocky grasslands of *Lasiurus indicus* - *Panicum turgidum* with 5-14 per cent cover and sparingly distributed shrubs with a few, occasional trees. Gravelly rocky pediments in the low rainfall zone are devoid of tussocky grasses, instead they support stoloniferous grasses of *Eleusine compressa* and *Dactyloctenium indicum*, both excellent soil binders. The shrubs of *Capparis* - *Euphorbia caducifolia* with *Mytenus emarginatus* and *Salvadora oleoides* put together rarely exceed a density of 400/ha. In the rainfall zone of 200-300 mm, sandy habitats have same shrubs but here *A. jacquemontii* starts gaining dominance and *Calligonum* becoming less and less until it disappears in higher rainfall zone. Grass cover changes to species of *Cenchrus* and with *P. cineraria*, *Tecomella undulata* gains dominance. Here the trees are more uniform, though clumped in favourable locations like in Nagaur. Deep alluvial plains have *Capparis* - *Ziziphus* - *Calotropis* shrub cover which often appears distinct on grazinglands. *Cenchrus setigerus* with *Eleusine compressa* predominate as grass cover, while *Salvadora oleoides* in pure patches and in association with *P. cineraria* occupy this zone. For different rainfall zones, specific shrub, grass and tree cover are given in Table 1.

Degradation of Vegetation

Anthropogenic pressure degrades the plant cover of each habitat; the severity being directly proportional to degradation. With increasing degradation, tree, shrub and grass cover degrade giving way to species of lower successional status. Ultimately, land can be totally barren. Such different states of land degradation call for site specific problem solving approach. However in all such efforts, the ultimate aim is to telescope succession so as to achieve best possible plant cover in as short period as possible. Providing adequate and suitable plant cover to land surface ultimately prevents erosion of soil due to both water and wind. We discuss below some of these approaches using shrub vegetation with grasses for better land management.

Impact of Degradation

The lower rainfall in arid areas compared with that in humid climates does not mean a corresponding low level of soil

Table 1. Vegetation types on different habitats

Rainfall Zone	Habitat	Shrubs	Grasses	Trees	Region
< 200	Sandy (Plains, hummocks dunes)	<i>Calligonum polygonoides</i> , <i>Acacia jacquemontii</i>	<i>Lasiurus indicus</i> , <i>Panicum turgidum</i>	<i>Prosopis cineraria</i>	Jaisalmer, western Bikaner, Western most Barmer
	Gravelly/ Rocky (Plains, slopes)	<i>Capparis decidua</i> , <i>Euphorbia caducifolia</i>	<i>Eleusine compressa</i> , <i>Dactyloctenium indicum</i>	<i>Salvadora oleoides</i> , <i>Maytenus emarginatus</i>	
200-300	Sandy (Hummocky, dunes)	<i>Acacia jacquemontii</i> , <i>Calligonum polygonoides</i>	<i>Cenchrus ciliaris</i> , <i>Cenchrus setigerus</i>	<i>Prosopis cineraria</i> , <i>Tecomella undulata</i>	Barmer, western Jodhpur, Central Bikaner, Ganganager and western Hanumangarh
	Alluvial plains (Plains, slope)	<i>Capparis decidua</i> , <i>Ziziphus nummularia</i> , <i>Calotropis procera</i>	<i>C. setigerus</i> , <i>E. compressa</i>	<i>Prosopis cineraria</i> , <i>Salvadora oleoides</i>	
300-400	Alluviums	<i>Ziziphus nummularia</i> , <i>Crotalaria burhia</i>	<i>C. setigerus</i> , <i>Dichanthium annulatum</i>	<i>Prosopis cineraria</i> , <i>A. nilotica</i>	Jalore, Pali, northern Jodhpur, Nagaur, Churu, Hanumangarh
	Pediments/ Piedmonts	<i>Grewia tenax</i> , <i>Commiphora wightii</i>	<i>Sehima nervosum</i> , <i>Eremopogon foveolatus</i>	<i>Acacia senegal</i> , <i>Anogeissus pendala</i>	Pali, Jodhpur, Jalore, Nagaur

Source: Kumar (1994)

erosion by water. Indeed rainfall erosion can be higher in arid areas than in any other climatic zone as sandy terrains are more susceptible to detachment. This is partly because the rainfall of arid areas has a high proportion of convective thunderstorm rain of high intensity and high erosive power. Biological measures like vegetative barrier, windbreak/shelter belt and stubble mulching are very effective for moisture conservation and controlling soil erosion due to both wind and water.

Vegetative Measures for Management of Degraded Land

Contour vegetative barriers for sloping land

Contour vegetative barriers are hedgerows of perennial grasses or shrubs planted at a regular interval on contours for conserving soil and water in sloping lands. Suitable grass species are grown along contours at suitable vertical interval to intercept part of runoff and to control erosion in

agricultural fields having flat to slight undulating topography. The contour vegetative barrier moderates the velocity of overland flow and traps silt at low cost, and augment production of food, fuel and fodder or fibre from lands by growing suitable vegetation species. In recent years, contour vegetative barriers have found acceptability among the farmers as these are cheaper over mechanical measures and are protective while being productive. Contour vegetative barriers can be easily established across a wide spectrum of soil-climatic conditions. Selection of species depends upon purpose of barrier, site-specific conditions, particularly soil and climatic variables. The spacing between plant-to-plant and row-to-row are governed by vegetation species to be planted as barrier. In general the plant-to-plant spacing of 20 to 30 cm at predetermined or 50 to 100 cm vertical interval between the barriers has been found effective for soil and water conservation. Generally, paired row of barrier

planted in staggered form across the slope proves more effective.

Generally, dominant grass or shrub species of the region should be preferred for vegetative barrier. Among grasses *Cenchrus ciliaris*, *Cenchrus setigerus*, *Saccharum bengalense*, *Vetiveria zizanioides*, *Lasiurus indicus*, *Panicum antidotale* and *Panicum turgidum* can be effectively used for soil and water conservation in arid areas. Shrubs like *Leptadenia pyrotechnica*, *Ipomoea carnea* and *Euphorbia antisyphilitica* can also provide good protection against water and wind erosion. Contour vegetative barriers of *Cymbopogon jwarancusa*, *Cenchrus ciliaris* and *Cenchrus setigerus* transplanted 0.30 m apart on contours at 0.6 to 1.0 m vertical interval in sandy loam soil of Jodhpur (Rajasthan) have performed well and formed effective barriers in reducing soil erosion and increasing soil moisture storage. In a study conducted during 1992-1994 at 19 farmers field near Jodhpur rooted slips of local eight species of perennial grasses (*Cenchrus ciliaris*, *Cenchrus setigerus*, *Cymbopogon jwarancusa*, *Lasiurus indicus*, *Panicum antidotale*, *Panicum turgidum*, *Saccharum bengalense* and *Vetiveria zizanioides*) and seedling of six species of shrubs (*Agave americana*, *Aloe barbadensis*, *Barleria prionitis*, *Euphorbia antisyphilitica*, *Ipomoea carnea* and *Leptadenia pyrotechnica*) were transplanted at 1 m vertical interval on contours across the slope. Result indicated that perennial grass species performed the best and formed effective barrier against soil erosion. Runoff volume and specific peak discharge were reduced by 28 to 97 per cent and 22 to 96 per cent respectively (Sharma *et al.*, 1999).

In another study conducted at Kalyanpur (Distt. Barmer) during 1998, vegetative barrier of *Lasiurus indicus*, *Saccharum munja* and *Cassia angustifolia* were established at horizontal interval of 30 m. The moisture data revealed 36.5 per cent, 72 per cent and 54.2 per cent higher moisture storage as compared to control in *Cassia angustifolia*, *Lasiurus indicus* and *Saccharum munja* respectively (Gupta and Rathore, 2002).

Wind strip cropping

Strips of perennial grasses of *Lasiurus indicus* and *Ricinus communis* established at right angle to the direction of winds reduced the impact and threshold velocity of wind to the minimum and thus checked soil erosion by wind and increased the crop production (Mishra, 1964). In another study (Gupta and Agrawal, 1980) it has been found that a 18-20 years old cover of such perennial grasses as *Lasiurus indicus*, *Cenchrus*

biflorus and *Panicum turgidum* at Bikaner completely checked the movement of sand.

Catchment development

Presence of trees, shrubs and grasses in catchment area helps in various ways for resource conservation. In a study conducted at Jhanwar watershed (1988-2005), three sub-catchments of 8.8, 9.2 and 12.0 ha were planted with local tree species along with some engineering measures like anicut, loose stone checkdams and protection were provided for biotic interference. Results indicated that due to increased vegetation in catchments along with other conservation measures, soil erosion reduced from 10.27, 19.62 and 30.14 tons yr⁻¹ (at beginning of project in year 1988) to 1.4, 1.4 and 1.8 tons yr⁻¹ in the year 2003 (Bhati and Goyal, 2003). The increased vegetation along with other measures also helped in recharge of ground water from 0.33m to 0.75m year⁻¹ depending upon the nature and amount of rainfall. Beside soil and water conservation, increased vegetation also helped in environmental improvement. In general, the ambient atmospheric temperature inside the watershed area was reduced by 4-6°C; moisture availability was increased by 45-65 per cent and soil productivity was raised by 35-40 per cent.

Sand dune stabilization

Sand dune fixation is necessary to prevent the movement of sand long enough to enable either natural or planted vegetation to become established. The technique of dune fixation is, therefore, based on the principle of reducing the threshold velocity of wind at the dune surface by establishing a pre-planting mechanical system. Sand dune fixation is a unique sector of soil conservation with specific techniques, due to the difficult conditions, instability of the soil, the abrasive action of the sand grains and the low or practically non-availability of plant nutrients.

Mechanical barriers for protecting the establishment of plants are required in most of the locations. This may be done by low fences, made of dry reeds and mulching with vegetation wastes. Locally available brushwood such as *Crotalaria burhia*, *Leptadenia pyrotechnia*, *Ziziphus nummularia*, *Calligonum polygonoides*, *Lasiurus indicus*, *Panicum turgidum*, *Erianthus munja* can be used to bury vertically downwards in lines 2m to 3m apart on windward slope of a dune in arid areas. In case where prevailing wind blows only from one direction or from opposite directions, mechanical barriers can be established on parallel lines. However, when winds blow from different directions, a checkerboard

system should be resorted. The distance between the parallel strips as well as the size of the checkerboard differs according to wind speed, the steepness of slopes and form of dunes. As a thumb rule, fences or micro-windbreaks should be closer together on the top and on windward slope of dunes and spaced wider on low dunes and depression. This has to be accompanied by seeding of grasses and the planting of bushes and trees, which are adjusted to the low fertility level, the mechanical abrasion of moving sand and the low water availability. Complete protection has to be provided, even after fixation by vegetative cover. Slight disturbances such as the creation of footpaths or wheel tracks may start new sand movement. The following trees/shrub species are recommended for sand dune stabilization in arid areas.

Trees : *Acacia tortilis*, *Acacia nubica*, *Prosopis juliflora*, *Calligonum polygonoides*, *Zizyphus nummularia* etc.

Grasses : *Lasiurus indicus*, *Cenchrus ciliaris* and *Panicum turgidum*

Creepers : *Citrullus colocynthis*

Role of Shrubs in Enhancing Production Potential

Shrubs and trees for fodder and fuelwood have also been experimented at CAZRI, Jodhpur. Shankarnarayan (1984) opined that in many parts of arid regions probably more animals feed on shrubs and trees than on grasses and pasture legumes. Leaf fodder of some of the shrubs like *Zizyphus* species is almost as nutritious as that of leguminous fodder crops. Shrubs also provide fair amount of fuelwood to the inhabitants of arid regions. Fuelwood and leaf fodder production from various native shrubs species in 300 mm rainfall situation is given in Table 2.

Table 2. Fuelwood (dry) and leaf / pod fodder production from shrub species in 300 mm rainfall zone in arid zone western Rajasthan.

Species	Fuelwood (kg shrub ⁻¹ year ⁻¹)	Leaf / pod fodder (kg shrub ⁻¹ year ⁻¹)
<i>Acacia jaquemontii</i>	2.50	1.26
<i>A. senegal</i>	8.15	3.32
<i>Bellenites egyptica</i>	6.28	0.40
<i>Calligonum polygonoides</i>	7.90	1.40
<i>Calotropis procera</i>	5.11	-
<i>Capparis decidua</i>	3.00	1.10
<i>Prosopis juliflora</i>	11.50*	6.55*
<i>Zizyphus nummularia</i>	8.95*	4.25***
<i>Z. rotundifolia</i>	7.40	7.40

* Production per thicket

** Pod fodder per thicket

*** Leaf fodder per thicket

In an improved silvi-pasture with *Dichrostachys nutans* as shrub component (hedge row plantation) and *Cenchrus ciliaris* and chick pea as herbaceous fodder component, appreciable amount of nutritious leaf fodder and fuel was obtained from the shrubs in 400 mm rainfall zone (Sharma, 2004) (Table 3). Thus shrubs can play vital role in leaf fodder production in arid areas if they are managed appropriately.

Table 3. Production of leaf fodder and fuelwood from *Dichrostachys nutans* after four years of initial establishment in 5 x 1 m spacing.

Production	Leaf fodder (kg)	Fuelwood (kg)
Average plant ⁻¹ year ⁻¹	1.27	4.02
Average ha ⁻¹ year ⁻¹	2540.00	8040.00

The shrubby thickets of *Prosopis juliflora* found to be very useful in stabilizing sand dunes, the dominant land formation of arid western Rajasthan. The dunes devoid of any vegetation cover are highly wind erosion prone. Besides, stabilizing the dunes shrubby thickets of *P. juliflora* gave substantial fuelwood yield in different rainfall situations (Kaul, 1985) (Table 4). Similarly, Muthana (1981) reported that shrubby thickets of *Zizyphus nummularia* produce leaf fodder to the tune of 1.7 q/ha in alluvial plains with total annual rainfall between 250 - 300 mm.

Resource Conservation Aspects

Larger parts of hot Indian arid zone are affected by severe wind erosion, particularly during summer months, when dry and barren soils are exposed to strong wind regime. The primary cause of drifting sand is wind itself. At 25-30 km hour⁻¹ wind speed the eddies generally have an upward velocity of 5-7 km hr⁻¹ resulting in vertical movement of dust. The lack of protective vegetative cover and fine and coarse texture of soil are other causes of wind erosion. Measurement of dust blowing from soil surface on a stormy day vary from 50-420 kg ha⁻¹ in Jodhpur region, while in Jaisalmer region, where wind velocity is generally high, the average soil loss is 511 kg ha⁻¹.

Soil loss through wind erosion can be minimized by (i) reducing field widths, (ii) providing vegetative cover, (iii) utilizing stable soil aggregates or clods for wind resistance, (iv) constructing ridges or contours and (v) levelling land surface. Amongst various conservation practices special emphasis is placed on field wind breaks

Table 4. Average fuelwood yield (kg thicket⁻¹) by way of partial cutting of shrubby thickets of *P. juliflora* on stabilized sand dunes at different locations.

Age of thicket (years)	Location				
	Jhunjhunu (395 mm)*	Churu (350 mm)	Bikaner (287 mm)	Gadra Road (285 mm)	Sardarshahar (286 mm)
4	-	-	15.1	15.5	41.9
5	-	-	23.9	41.7	36.7
6	-	-	-	43.8	36.2
7	78.8	-	-	-	38.2
8	193.3	47.5	-	-	49.8
9	136.9	-	-	-	54.4

* Values in parentheses are average total rainfall of particular location

or shelterbelts. Depending on wind velocity shelterbelt design, type and lay out differs from site to site. The shape of shelterbelt should be pyramidal in structure, i.e., tallest trees should be in centre followed by flank rows of medium height trees and lateral rows should be of bushy plants or shrubs. Thus, shrubs play special role in creation of shelterbelts. Shrubs like *Prosopis juliflora*, *Ziziphus species*, *Calligonum polygonoides*, *Acacia Senegal*, *A. bivenosa* and *Colophospermum mopane* are very suitable for outer rows of shelterbelt, if it is a three row shelterbelt and in lateral rows if the shelterbelt is of five rows.

A three rows shelterbelt in which *P. juliflora* shrubby thicket was used as outer rows with central row of *Albizzia lebbek* reduced wind speed from 12 per cent at 10H (height) distance from shelterbelt to 33 per cent at 2H distance during summer season (Gupta *et al.*, 1984). In monsoon season the wind speed reduced to the tune of 21 per cent at 10H distance to 38 per cent at 2H distance. The shelterbelt plantation brought about 50 per cent reduction in wind erosion, which ultimately reduced the nutrient losses from the soil. In bare soil the nitrogen loss in peak summer period (66 days, April-June) was 191 g ha⁻¹ while in *P. juliflora* - *A. lebbek* sheltered area it was 123.0 g ha⁻¹. The loss of phosphorus during same period from bare soil was 101 g ha⁻¹, while in the same shelterbelt area the loss was 65.0 g ha⁻¹. The loss of potassium was accounted to be 1039.0 g ha⁻¹ bare soil and in Shelterbelt protected area, it was only 664.4 g ha⁻¹. Mann (1985) carried out an objective evaluation of *Prosopis juliflora* wind breaks and found its effectiveness index 8.6 during summer months and 13.2 during monsoon season. Thus, in monsoon season the effectiveness index of the *P. juliflora* wind breaks increased by 53 per cent.

Thus, shrubs are not only an essential component of vegetation in all the rainfall regions and on different land uses and landforms imparting ecological stability, but these are also source of a variety of products and services to mankind. Recognising their importance, shrubs alongwith grasses have been tried in large number of land management problems, with success. But in-depth studies are required for quantification of cause and effect relationship on one hand and impact assessment of shrubs on the other. In doing so, blending social needs with ecological requirements in the overall context of economic gain would call for innovative and imaginative research programs for the overall benefit of desert dwellers.

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Role of Shrubs in Wind Erosion Control

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Wind erosion is a major problem in the sandy tracts of arid regions, affecting human habitations, transportation networks, canals, other infrastructural facilities and agricultural activities. In the Thar Desert of Rajasthan, where sandy terrain occupies more than 70 per cent area, and wind velocity is moderate to high during the summer months, potentials for wind erosion is also high. Vegetation cover helps to reduce the impact of wind on sandy terrain, but there is no simple relationship between rainfall amount, vegetation cover and sand mobility (Ash and Wasson, 1983). Several other related aspects need consideration for appreciating the contribution of plant cover in control of wind erosion. This article provides a short review of our understanding of the role of vegetation in controlling wind erosion.

Major Plant Communities in Sandy Habitats of Indian Part of Thar Desert

Thar Desert in Rajasthan is dominated by monsoon winds, and receives average annual rainfall ranging from ~500 mm along the Aravalli hill ranges in the eastern fringe to ~100 mm along the border with Pakistan in the west. Over the centuries this rainfall has helped to establish and nurture a range of natural vegetation in the region, including trees, shrubs and grasses. While trees are dominant in the eastern part, receiving 300 mm or more rainfall annually, shrubs and grasses are dominant in the western part receiving 100-300 mm rainfall.

Saxena (1977, 1992) and Kumar (1997) summarized the dominant plant communities in the region. In the very dry western part, where the average annual rainfall is less than 200 mm, *Calligonum polygonoides* is the major shrub of the sandy habitat, especially on sand dunes, along with *Haloxylon salicornicum*, *Leptadenia pyrotechnica* and *Citrullus colocynthis* as major associates in the Jaisalmer-Bikaner tract, and *Clerodendrum phlomoides*, *Acacia jacquemontii* and *Aerva pseudotomentosa* in Barmer tract. *Ziziphus nummularia*, *Salvadora oleoides* and *Capparis decidua* dominate the sand sheeted shallow colluvial plains. *Lasiurus sindicus* and *Panicum turgidum* are the dominant grasses. Trees are rare, and usually consist of *Acacia senegal*, *Tecomella undulata* and *Prosopis cineraria*. In the 200-350 mm rainfall zone, especially between Barmer, Phalodi, Bikaner and Jodhpur, the

dominant plants of the sandy habitat are *Z. nummularia*, *S. oleoides* and *C. decidua*, along with associates like *A. jacquemontii*, *Calotropis procera* and *Tephrosia purpuria* (Saxena and Singh, 1976; Saxena, 1977). *Eleusine compressa*, *Aristida* spp. and *Cenchrus* spp. are the major grasses. In the sandy habitat of Bikaner-Churu-Nagaur tract, where the average annual rainfall is 250-400 mm, *C. polygonoides* and *L. pyrotechnica* are dominant shrubs, along with *Aerva persica*, *A. pseudotomentosa*, *Crotalaria burhia*, *C. procera* and *C. colocynthis*. Further east, in the Jhunjhunu-Sikar-Ajmer tract, where the average annual rainfall is >400 mm, the sandy habitat has a dominance of trees like *Prosopis cineraria* and *Acacia nilotica*, the major associates being *A. senegal*, *A. cupressiformis*, *Z. nummularia*, *Ailanthus excelsa* and *Sacchurum munja*.

Estimates of Wind Erosion from Bare and Vegetated Sandy Surfaces

Plant cover has always been found to be an effective means of arresting wind erosion. Ramakrishna *et al.* (1990) found that during periods of severe gusty winds over a semi-stabilized parabolic sand dune at Shergarh (high wind erosivity zone) the peak rates of erosion of sand grains up to -1 phi (0.2 mm) size were approximately 46 kg m⁻² h⁻¹. Sand movement from a barchan (a mobile crescentic dune without any vegetation) nearby was ~43% more than that from the parabolic dune.

During the sandstorms in April-June 1979, soil loss from a bare sandy plain at Bikaner - was recorded as 1449 t ha⁻¹, whereas the nearby cultivated fields with a cover of 45 cm high pearl millet stubbles lost 22 t ha⁻¹ (Gupta and Aggarwal, 1980). Long stubbles of small grain crops have generally been found to be more effective than an equal quantity of short stubble (Gupta, 1993).

During a 20-day period of sandstorm in June-July 1985, a loss of 2630 to 3160 t ha⁻¹ of sandy soil was measured in the fields that were discploughed with tractor in the western Rajasthan. The land lying fallow for a year or more and having 2 to 4 per cent vegetation cover, lost 127 to 320 t ha⁻¹ of soil, while the pastures with 8 to 12 per cent vegetation cover

remained substantially less eroded. Degraded pastures experienced a loss of 217 to 683 t ha⁻¹ of soil (Dhir *et al.*, 1992; Table 1).

Table 1. Estimated wind erosion during a sandstorm in 1985

Land use/ management	Number of sites	Mean soil loss (t ha ⁻¹)	
		Range	Mean
Cultivated			
Long fallow	12	124-320	207
Untilled since previous crop	16	220-377	283
Tilled	11	756-1180	932
Disc ploughed	3	2630-3160	2837
Pastureland			
Undegraded	6	<100	<100
Degraded	9	217-683	472

The clearing of ground flora, including clumps of *Lasiurus syndicus* grass from a sandy plain at Chandan, led to the loss of 15 to 18 cm of soil (3128 to 3754 t ha⁻¹) during the same period (Kar, 1988, 1994).

Factors Influencing Ability of Vegetation to Arrest Aeolian Sand Transport

Influence of vegetation on aeolian sand transport depends on (a) the attributes of vegetation, and (b) nature and environment of the sandy terrain that influences the effectiveness of vegetation. Attributes of vegetation that are usually found to influence sand transport rates are density of plant, plant type and species composition, and status of plants at site (e.g., height, crown, foliage density, etc.). Factors influencing the effectiveness of a given plant community are usually wind regime, wind strength, terrain type, sediment supply and human and livestock pressures (e.g., through grazing, fuel wood collection, etc.). Plant density and plant shape are the two most important attributes that influence arresting of sand.

Although some estimates are available on the control of vegetation on wind erosion, there is now growing evidence that different properties of a plant cover have different influences on erosion. Morgan (1990) calculated the drag exerted by single plant rows or barriers of up to ~0.4 m height to evaluate the influence of various vegetation properties on wind erosion. The most sensitive parameters were found to be the projected foliage area facing the wind, leaf area density and across-wind leaf alignment when the erosion was detachment-limited.

Small changes in biomass and plant height had little effect on predicted soil loss. It was found that a greater density of leaf area, aligned downwind, lead to a greater contact length between the leaf surface and the air stream, and resulted in a higher drag coefficient. Therefore, the wind erosion increased (Morgan, 1990).

In other words, a blanket statement that vegetation cover decreases wind erosion needs a proper review. Several studies have emphasized on the sand trapping efficiency of the vegetation and the role of vegetation in the growth and evolution of sand dunes (see e.g., Tsoar and Moller, 1986; Thomas and Tsoar, 1990; Hesp and Thom, 1990; Wiggs *et al.*, 1995, 1996).

Buckley (1987) found that a 4-8 per cent cover of erect and spreading plant type can reduce sand transport by about 30 to 50 per cent of that on bare sand, assuming a wind speed of 10 m s⁻¹ (i.e., 36 km h⁻¹). If the plant cover is increased to 17 per cent, then the sand transport rate is decreased by 84 per cent. With an average wind velocity of 15 m s⁻¹, the 17 per cent plant cover can reduce sand transport to 22 per cent of that under bare sand condition. The equation that determines the sand transport was found to be (Buckley, 1987):

$$q = B\{V(1-kC) - V_t\}^3$$

where, q is rate of aeolian sand transport (g cm⁻¹ s⁻¹)

B is Bagnold's (1941) factor: $\{0.174/\log(z/k)\}^3$
*C_s v(d/D)p/g

V is wind velocity

k is a constant

C is plant cover; and

V_t is threshold wind velocity.

Ash and Wasson (1983) have rightly pointed out, over a sand dune sand movement can occur with up to 35 per cent of the surface area sheltered by plants, especially near the dune crests, because of higher wind speed at the crest.

Several other attributes of a plant cover, including canopy height and cover, root distribution pattern, etc., can influence the effectiveness of protection provided by shrubs and grasses. For example, bushes of *Calligonum polygonoides*, despite having a poor canopy structure, are good sand binders because of a network of horizontally spreading, near-surface root system that arrests the sand effectively, even during strong wind.

The clumpy nature of small shrubs is a major problem in wind erosion control. During a high wind regime, erosion is enhanced around the individual clumps (or the roughness elements), leading to scouring around the plants. Lee and Soliman (1977) determined from a wind tunnel experiment the flow regimes associated with three different roughness element densities (corresponding to three different vegetation cover densities). Wolfe and Nickling (1993) summarized the finding as follows.

An isolated roughness flow occurs when the plant spacing to height ratio (S_p/h) is more than 3.5 and plant cover (C) is less than 16 per cent. As S_p/h decreases to 3.5-2.25 and C increases to 16-40 per cent, the regime grades into wake interference flow, and when S_p/h is less than 2.25 and C >40 per cent, it changes to skimming flow. Net deposition should increase in direct proportion to the change from isolated roughness flow to a wake-interference and a skimming flow. Much of the natural rangelands of Jaisalmer region should experience the first two kinds of flow, while the last one is expected in research plots, which give emphasis on increasing the plant cover.

In the shrub-dominated degraded shallow sandy plains of our desert, C is usually <8 per cent, and the under-storey is almost non-existent. The medium-tall shrubs, therefore, encourage isolated roughness flow. At places where sand thickness increases to >1 m and degradation is less, wake interference flow results in a closer spacing of the shrub-coppice dunes, or the nebkhas (e.g., in the protected grazing lands). Shrub-coppice dunes are also numerous along the boundaries of the crop fields in the sand-dominated plains in the central and western parts of the Thar, where the dunes occur in a linear fashion, controlled by a linear array of planted shrubs along field boundaries, and mostly joined by a transverse ridge. Ultimately such dunes on field boundaries evolve as either network dunes or as sand streaks. In all the above cases horse-shoe vortices start developing on the windward side of individual shrubs, resulting in erosion, while captive flow in the wake region leads to sand deposition. Simultaneously, the porous plant architecture allows sieving of sand through the shrub to create a linear arm downwind. In the case of a good, porous barrier like that of *C. decidua*, the sand is trapped within the bush and is then transmitted slowly downwind.

Many of the coppice dunes along the boundaries of crop fields develop at the expense of sediments within the crop fields immediate upwind of the dunes. As the

individual fields upwind are ploughed before the rains, the loose sand is picked up during strong wind and is trapped by the shrub. After the sand storms, farmers try to retrieve part of the lost sand from the coppice dunes.

As the coppice dunes gradually grow, the crop fields suffer net erosion. Eventually the fields assume a saucer to bowl shape, depending on the amount of deflation. There are many examples of such saucer-shaped crop fields in the desert, with high deflation (Kar, 1988).

Plant species like the digitating *Capparis decidua*, have a symbiotic relationship with the sand dunes (Saxena, 1977). The plants are fast colonizer of the newly developed sandy hummocks, and multiply to spread themselves as the hummocks grow in size. Some ground-hugging shrubs like *Prosopis juliflora* have also been found to arrest sand movement and encourage sand deposition.

Apart from the above, smaller shrubs like *Haloxylon salicornicum*, *Crotalaria burhia* and *Aerva pseudotomentosa* have been found to form low sand mounds during periods of strong wind, but such mounds seldom grow beyond 1.5 m height, and disappear in the surrounding sand sheet deposits once the variable low wind sets in. By contrast, trees provide a lesser protection to the sandy soil and are expected to result in wake interference flow and consequent erosion. Trees planted in rows encourage faster wind along the corridors between the rows and, hence, faster erosion of sand. However, trees are good as wind breaks.

Conclusion

We conclude from this short review that vegetation plays a crucial role in aeolian sand activity, especially during the periods of strong wind. Although it is customary to believe that vegetation stabilizes the sandy surface, our review suggests that small shrubs and grasses perform better than trees in arresting sand, but the density of the plants, association of the different plant species in an area, characteristics of the individual plants (including leaf geometry, root density and architecture, etc.), as well as terrain and wind conditions determine the efficacy or otherwise of the shrub cover in arresting sand.

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Shrub based Agroforestry for Arid Regions of India

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The climate of arid zones plays a dominant role in structuring its physical as well as biotic environment. The shrubs growing in this region contains sufficient amount of nutrients to be considered as livestock feed. It is evident from the existing native vegetation of arid zone, that shrubs are capable of withstanding the harshness of the arid climate as well as heavy grazing pressure. Certain shrubs possess morphological and physiological elasticity in relation to drought. Fodder shrubs possess a definite potential for resolving climatic, biological, social, and economic constraints encountered in arid and semiarid areas.

Network research carried out in India revealed that alternative land use involving perennials (tree/crop, grass shrub or a combination of both) has advantages and can conserve natural resources and increase productivity. Some of the advantages of planting them in arid region are as follows:

- Provide permanent vegetative cover to the soil or land surface and thus substantially control erosion caused by both water and wind.
- Improve the microclimate for crop growth.
- Provide nutritious green fodder, which is in short supply to support livestock.
- Protect the environment and upgrade soil quality through their deep root system.
- Enhance organic matter by recycling biomass into the soil.
- Reduce runoff, surface evaporation and weed growth and improve water use efficiency when lopping from the shrubs is spread on the soil surface for recycling.
- Provide fuel wood and minor forest products.
- Support the development of soil microbe, and
- One of the most important advantage of growing shrubs is that they generate much needed cash when aromatic and industrial value shrubs are grown.

Some valuable shrubs for agroforestry system include *Dichrostachys cinerea*, *Jatropha curcas*, *Simmondsia chinensis*, *Euphorbia caducifolia*, *Opuntia spp*, *Calligonum polygonoides*, *Ziziphus nummularia*, *Lawsonia inermis* and *Carissa carandus*. These shrubs can be used as biofence or grown as strips along with crops or can form an integral part of silvi-pastoral systems.

Arid Zone Agroforestry with Shrubs

In combined production systems, agriculture, livestock production, forestry, and combinations thereof are practiced on the same piece of land, either in rotation, simultaneously, or spatially. Such combinations, also called "agroforestry", can involve agricultural crop production or animal husbandry, within which shrubs play a significant role in arid region. Most of shrubs are drought resistant, they are still able to provide fuel, fodder, fruits and other products when the crops fail, as frequent droughts are a common phenomenon in the hot arid region. Thus shrubs have a very important place in the life of man in arid regions of India. They are directly related to the livelihood of inhabitants and also provide the important service of climate moderation in many forms in an inhospitable environment. These extensive agroforestry systems of arid regions of India are living systems, evolved through interaction of so many environmental, biological, social, economic, and cultural factors. Woody components (i.e., trees or shrubs) in the agroforestry systems supply a considerable amount of subsidy for the sustainable operation of specific systems in the form of fuel wood, fodder, minor timber, fruits and many other edibles.

Several agroforestry systems are suitable for arid and semi-arid regions. The most common agroforestry system is Sivipastoral followed by energy plantation and boundary planting especially of shelterbelts, windbreaks and hedges together with scattered trees in agricultural / cultivated fields, constituting an Agrisilviculture system. This is followed by boundary plantation of all species for shelter.

Silvipastoral System

In simple words the term silvipasture denotes "silvi" means trees and pasture means "grasses" or "grass +legume mixtures". But in real sense it is an ideal combination of grasses, legumes and trees for optimizing land productivity, conserving plants, soils and nutrients and producing forage, fuel wood, timber, etc. on sustainable basis (Rai *et al.*, 1999). Thus this involves replantation, substitution or intervention in the existing vegetation by desirable species (Deb Roy and Pathak., 1974). Recently Nair, 1993 defined that silvipastoral systems are land use systems in which trees and/or shrubs are combined with livestock and pasture for forage and fuel wood production on the same unit of land. Within this broad category, several types of systems and practices can be identified depending on the role of tree/shrub component, viz. cut and carry system, live fence post, browsing and grazing. Trees and shrubs in the silvipastoral system often contribute substantial amount of leaf fodder especially in arid and semi-arid region during lean periods through lopping/pruning of shrubs.

Studies conducted at Fatehpur Shekhawati revealed that maximum biomass of 3.9 t/ha was obtained with *Dichrostachys cinerea* + *Cenchrus ciliaris* silvipastoral system, (Rai and Handa, 2004). Similarly studies conducted in red gravelly soils at Jhansi (Rai *et al.*, 2000) reported that on an average biomass of 2.1 t/ha/year was obtained at 10 years rotation from *D. cinerea* (Table 1).

Table 1. Growth and production of 10 year old *D. cinerea*

Growth parameter	Value
Height (m)	4.5(0.45)
Diameter at breast ht. (cm)	5.0(0.5)
Canopy (m)	3.7(0.37)
Dry leaf Fodder (t/ha)	1.00(4.3)
Fuel wood (t/ha)	8.38(39.9%)
Bole (t/ha)	11.64(55.4%)
Total biomass (t/ha)	21.02
Productivity (t/ha/yr)	2.10

Figures in parenthesis denote mean annual increment for growth parameters and % value in case of yield in various parts of shrub.

Another Study conducted at NRCAF Jhansi in medium black soils revealed that on an average, the dry leaf fodder and fuel wood production recorded with *D. cinerea* under silvipasture system was 0.32 and 1.68 kg/shrub/year. Total dry biomass recorded with this species was 16.2 kg/shrub at 8 yrs of age. Thus, it showed a production rate of 2.02 kg/shrub/year (Rai, 1999). Leaf fodder obtained from *Z. nummularia* ranged from 105 kg/ha (at 11% density) to 150 kg/ha (at 18% density) on the basis of annual lopping (Kaul and Ganguli, 1963). They also suggested 14 per cent density of *Z. nummularia* was quite good for optimum production of leaf fodder (125 kg/ha). Roy *et al.* (1987) reported that biomass production of 14.0 kg/tree in a six year old *D. cinerea* under silvipastoral system giving an average production of 1.2 t/ha/yr.

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Ornamental Shrubs in the Arid Zone

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Shrubs of aesthetic value have abundant colors, shapes, sizes and adaptability. Though not truly desertic in origin, many shrubs from sub humid region have been adapted and naturalized in arid conditions. A wide range of such ornamental shrubs have been evaluated for over three decades in the Botanical garden of CAZRI, Jodhpur. Their package of practices required for their multiplication, plantation maintenance and after care have been standardized. The criteria for evaluating these species have been as follows:

- Drought hardy
- Tolerant to continuous hot winds and dust storm
- Tolerant to frost
- Disease resistant
- Rapid growth
- Attractive flowers and fragrance
- Lustrous foliage
- Well developed root system
- Aesthetically attractive

The results of aforesaid long term study constitute present paper which describes the group of selected shrubs for this region. It is important to mention that all these shrubs require irrigation at varying interval and due care to achieve desired results. We have included following three groups into broader framework of ornamental shrubs:

1. Shrubs
2. Creepers , climbers and lianas
3. Hedges

Ornamental shrubs

These could be grown as row, in a landscape or in a corner as shrubbery both individually and in clusters. Some of these remain evergreen with irrigation while other could be deciduous. Amongst 35 varieties of *Bougainvillea* as evergreen shrubs tried in the Botanical garden, those assuming robust growth and bright colors are Marypalmer, Thimma, shubra and multibract Million Dollar group. Other hardy shrubs are *Lantana* (Many colours), Gudhal, Kaner,

Gulnar and Pilakaner. *Bougainvillea* are the first choice as they flower for ten months. Shrubs giving continuous flowering include *Rusellia*, *Tabernemontana*, *Gulnar*, *Gultara*, *Kaner* and *Peelakaner*. Sweet scented shrubs having fragrant flowers include, *Raibel*, *Mogra*, *Ratrani* and *Din ka Raja*. Flower and foliage features as well as period and method of multiplication of these shrubs are given in Table 1.

Hedge Plants

Due to their multistemmed habit, shrubs make excellent hedges and fences (Table 2). The height of hedge can be maintained as commensurate with hedge material. Hedge shrubs can be categorized into low, medium and high shrubs. Hedges of *Barleria*, *Clerodendrum inerme*, *Cassia auriculata* and *Clerodendrum aculeatum* look excellent when maintained at smaller height say up to 70-90 cm. *Kaner*, *Mehndi*, *Lantana* and *Dodonea viscosa* make good hedge from 100-150 cm. *Bougainvillea*, *Pithecellobium dulce*, *P. juliflora* and *Parkinsonia aculeata* are tall hedges up to 250 cm. These make excellent screen against hot winds and sand storms.

Shrubby Climbers

Climbers (Table 3) are used as divider screens, covering ugly corners or providing green look to walls. Some of these have shown vigorous growth if irrigated frequently e.g. *Railway creeper*, *Ghavbel*, *Chameli*, *Juhi*, *woodrose* and *Antigonon leptopus*. Many have ornamental foliage like *Asparagus*, *Monstera*, *Pothos*. Flowers of *Quisqualis indica* (Jhumki lata) and *Clitoria jacquemontea* have attractive looks and colours. These can be used to provide shade to green houses, parking spaces and verandahs especially in south west corners.

Conclusion

Evidently these shrubs and climbers provide not only aesthetic look but also ameliorate environment. When *Bougainvilleas* were first introduced to urban elite of Jodhpur, it was accepted with hesitation in early seventies and there was only one private nursery providing these plants. After thirty years now, the greening of Jodhpur by planting these ornamentals in their residences is a delight to eye. In view of their multicolour eye catching appearance and long period of flowering, Maharaja of

Table 1: Ornamental shrubs suiting to arid areas

Botanical name	Local name	Flower characteristic	Foliage features	Multiplication method	Period of multiplication	Remarks
<i>Bauhinia variegata</i>	Kachnar	Large, red pink & white	Bifid leaves	Seed	July-Aug.	Leafless when in flower
<i>B. acuminata</i>	Kanchan	Yellow	Bifid leaves	Seed	Oct.-Feb.	Very hardy
<i>Cassalpinia pulcherrima</i>	Gul-tura	Yellow, orange and deep chocolate	Fine leaves	Seed	July-Oct.-Feb.	Flowers 3 times in a year
<i>Cestrum diurnum</i>	Din-ka-Raja	Sweet smelling, small	Shining	Vegetative	July-Aug.	Flowers day time
<i>C. nocturnum</i>	Rat-Rani	Strong smelling	Shining	Vegetative	July-Aug.	Flower night time
<i>Cassia auriculata</i>	Anwal	Yellow	Light green	Seed	Mar.&Sept.	Good for dry areas, drought hardy
<i>Bougainvillea spectabilis</i>	Boganbel	White,red,pink,yellow,orange Mauve etc.	Deep green	Vegetative	Feb.-Aug.	8-10 months flowering
<i>Dombeya aliporensis</i>	Wedding flower	Light pink, Mauve & white	Ear shape, rough	Vegetative	March-April	Flowers develop in cluster
<i>Erythrina indica</i>	Rangan	Orange, red and large	-do-, smooth	Seed	July-Oct.-Feb.	Leafless at flowering
<i>Hibiscus-species</i>	Gudhal	Light red, deep red, white, pink, etc.	Shining	Vegetative	Major part of years	Deep green foliage
<i>Lagerstroemia indica</i>	Sawni	Red, pink, white & mauve	Small, shining	Vegetative	July-August	Need more water
<i>Lantana camara</i>	Jhurmuta	Yellow, orange, white	Rough, bad smelling	Vegetative	Feb.-July	Good for low & medium hedge, yellow most attractive
<i>Murraya exotica</i>	Kamini	White	Shining leaves	Vegetative	July-Aug. Nov.-Dec.	Susceptible to hot wind
<i>Nerium oleander</i>	Kaner	White, pink, red	Green shining	Vegetative	Feb.-Aug.	Very hardy, non palatable
<i>Nyctanthes arborescens</i>	Harsingar	Orange, white	Rough	Seed	July-Oct.	Flowers makes carpet in morning
<i>Punica granatum</i>	Gulnar	Red	Smooth	Vegetative	July-Feb.	Compact multibract flowers
<i>Plumeria acutifolia</i>	Nagchampa	Yellow & Red, yellow white	Large, smooth	Vegetative	July-Feb.	Weak against wind
<i>Russelia juncea</i>	Rasellia	Red-tubular	Needle shaped	Vegetative	July	Flowers major part of the year
<i>Tabernaemontana coronaria</i>	Chandni	White	Shining	Vegetative	Major part of year	Drought hardy
<i>Thevetia nerifolia</i>	Pela-kanar	Yellow, orange	Shining and narrow	Seed	Feb.-Aug.	Drought hardy & unpalatable

Table 2. Hedge plants suiting arid conditions

Botanical name	Local name	Suitable height (cm)	Flowering	Method of multiplication	Period of multiplication	Remarks
<i>Clerodendrum phlomoides</i>	Arni	100-150	White	Vegetative	Monsoon	Very hardy, field planting
<i>C. inerme</i>	Choti Arni	80-100	White Shining	Vegetative	Monsoon	Less hardy
<i>C. aculeatum</i>	Jhurmutta	80-100	White small	Vegetative	Monsoon	Hardy
<i>Barlaria cristata</i>	Jhati, Vajradanti	60-80	Yellow & white thorny	Veg. & seed	Monsoon	Very hardy
<i>Bougainvillea spectabilis</i>	Boganbel	90-120	Several colour	Vegetative	Feb-monsoon	Very hardy
<i>Cassia auriculata</i>	Anwal	80-100	Yellow	Seed	Monsoon	Very hardy-suiting field
<i>Dodonea viscosa</i>	Rellia	80-100	White, leaf shining	Seed	Monsoon	Hardy, susceptible to root disease
<i>Nerium oleander</i>	Kaneer	100-150	Pink, red-white	Vegetative	Monsoon	Very hardy, non-palatable
<i>Lawsonia inermis</i>	Menhdi	100-120	Pinkish, yellow	Vegetative	Monsoon	Very hardy, non-palatable
<i>Pithecellobium dulce</i>	Jangaljelebi	120-180	White, creamy	Seed	Monsoon	Hardy
<i>Lantana camara</i>	Jhurmuta	60-150	Several colour	Vegetative	Monsoon	Hardy, yellow most attractive
<i>Prosopis juliflora</i>	Vilayati babool	150-200	Cream colour	Seed	Feb.-July	Very hardy
<i>Parkinsonia aculeata</i>	Parkinsonya	100-180	Yellow	Seed	Feb.-July	Very hardy
<i>Tecoma stans</i>	Peelia	150-180	Yellow	Seed	Monsoon	Need more water

Jodhpur (Shri Gaje Singh Ji) requested CAZRI to make a plan for The Ummed Bhawan Palace and provide various coloured Bougainvillea and necessary guidance. Now it is an excellent attraction for world tourist to enjoy its flowering during November and March. Military, Air force and B.S.F. area in Jodhpur have now adopted all the ornamental shrub material from CAZRI. They have followed faithfully the technical guidance with the result that these provide a unique look to their areas with green and ornamental foliage. All these efforts have absolutely changed the desertic outlook of Jodhpur town to a pleasing look and cool ambiance.

National Highway Authority of India (NHAI) is planting these shrubs (drought hardy, non-palatable) as wind screen with in the divider lane and the performance of these shrubs is just exemplary. They not only stop erosion of soil of divider lane but also help to screen strong focused light of vehicles passing across each other in both lanes. With such diversified uses, these have become a source of employment, too. Today, Jodhpur town itself has over two dozens nurseries providing these saplings and earning handsome income. Thus, there is a need to promote their large scale urban green lots as well as fine tune their plantation protocols to ameliorate environment and earn a part of livelihood.

Table 3. Suitable creepers/climbers for screening the windward face in arid areas

Local name	Flower colour	Growth characteristic	Period of Flowering	Method multiplication	Period of multiplication	Remarks
Ghavbel (<i>Argyrea nervosa</i>)	Mauve	Heavy climber	March	Seed	July	Evergreen
Hukkabel (<i>Aristolochia grandiflora</i>)	Dull purple	Fast growing	March	Seed	July	Evergreen
Satawar (<i>Asparagus racemosus</i>)	White, small	Good growth	Dec.-Feb.	Seed	July	Winter leafless
Aparajita (<i>Clitoria ternatea</i>)	-do-, Blue	Good growth	Dec.-Feb.	Seed	July	-
Railway creeper (<i>Ipomoea palmata</i>)	Blue, white	Good growth	Dec.-Feb.	Seed & Vegetative	July	Good for screen
Juhee (<i>Jasminum auriculatum</i>)	White, scented	Good growth	April-Aug.	Vegetative	July	Hardy, attractive
Chameli (<i>J. grandiflorum</i>)	White, scented	Good growth	Sept.-Feb.	Vegetative	July	Hardy, attractive
Jhumkilata (<i>Quisqualis indica</i>)	Red, White & scented	Vigorous to Moderate	June-Oct.	Vegetative	July	Winter deciduous
Mogra-Motia raibel (<i>Jasminum officinale</i>)	White, scented	Moderate	April-June	Vegetative	Monsoon	Much prefer household low shrub

Few Economic Shrubs and Their Commercialization

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The arid region of India is spread in 38.7 m hectares area, out of which 31.7 m ha is under hot arid zone and 7.0 m ha under cold arid zone. The hot arid region occupies major part of the north western India (28.57 m ha) and occurs in small pockets (3.13 m ha) in south India. The north western region occurs between 22° 30' to 32° 05' N and from 68° 05' to 75° 45' E covering western part of Rajasthan (19.6 m ha 69%), Gujarat (6.22 m ha 21%) and south western parts of Haryana and Punjab (2.75 m ha 10%).

In terms of the standard climatic types tropical climate viz., sub humid, arid and semi-arid are spread over different regions of Gujarat state. The regions in the extreme north comprising of the district of Kutchh and western part of Banaskantha and Mehsana, the northern fringe of Saurashtra and its western part have arid climate.

The arid and semi-arid regions generally have hostile environmental conditions such as low and erratic rainfall, intense solar radiation and high wind velocity, the soils are immature, structureless and very coarse in

texture with low water holding capacity and poor nutrient status posing problems of low and unstable crop production. Therefore, there is a need of tree resources, shrubs in particular for supplementation of income through supply of food, fodder, fuel, small timber and as soil cover to check soil degradation and generation of employment for rural masses.

The presence of shrubs in arid ecosystem beyond tree limit also signifies its importance in sustainable livelihood in arid areas. However, wild nature of shrubs and over exploitation to meet the demand of food, fodder and fuel made their existence difficult. To make rural livelihood more sustainable, there is a need to domesticate shrubs and their commercial exploitation in arid agroforestry.

There are number of shrubs having economic importance in arid ecosystem. (Jadeja *et al.*, 1999) Local people use these shrubs in one way or the other. Some of these yield products of economic value (Table 1).

Table 1. Important shrubs of arid region and their products of economic value

Sr. No.	Local name	Botanical name	Product of economic value
1.	Mehndi,	<i>Lawsonia inermis</i>	Leaves containing orange natural dye
2.	Guggal,	<i>Commiphora wightii</i>	Gum oleo-resin from stem
3.	Senna,	<i>Cassia angustifolia</i>	Foliage containing sennocide
4.	Kair,	<i>Capparis decidua</i>	Fruits for vegetable and pickle
5.	Karonda,	<i>Carissa carandas</i>	Fruits
6.	Jharberi,	<i>Ziziphus nummularia</i>	Fruits, fodder and biofencing
7.	Aswangandha,	<i>Withania somnifera</i>	Roots
8.	Ketki,	<i>Agave cantala</i>	Fibre and biofencing
9.	Kuwarpatha,	<i>Aloe barbadensis</i>	Leaf jelly as medicine and leaf as vegetable
10.	Phog,	<i>Calligonum polygonoides</i>	Quality fuel wood and flowers as food
11.	Lana,	<i>Haloxylon salicornicum</i>	Fodder for sheep and goats
12.	Gangani,	<i>Grewia tenax</i>	Fruits, seeds and bark
13.	Akra and	<i>Calotropis procera</i>	Fibre
14.	Kheep	<i>Leptadenia pyrotechnica</i>	Hut making and fibre

The shrubs having economic value and can be exploited on commercial basis are described below:

Mehndi (*Lawsonia inermis*)

Henna (*Lawsonia inermis*) popularly known as mehndi belonging to family Lythraceae, is a white or pink flowered and highly branched perennial shrub which survive up to 40-50 years. It grows well in open places and forests in drier parts of the country ranging from Rajasthan to South India. It grows well under diverse soil conditions ranging from sandy soils, stony soils to wastelands that are not suitable for cultivation of any other crop.

Mehndi leaves contain lawsone (2-hydroxy-1,4 naphthoquinine) a pleasant orange natural dye, which is used to color palms, nails, feet, silk, hairs and wool. With the growing fear of carcinogenic effects of synthetic dyes, the use of mehndi as hair dye is increasing day by day. Mehndi is also an effective treatment for conditioning hair and as a powerful anti-dandruff agent which accelerates hair growth. Hence, to meet its ever increasing demand from Europe, USA, Egypt, Middle East, there is an urgent need to bring more and more marginal and wasteland under mehndi cultivation.

Mehndi is cultivated in over 34000 hectares mostly in and around Sojat area of Pali district of Rajasthan adjoining to Gujarat. In arid regions of Rajasthan where mehndi is cultivated, rainfall is low as well as erratic, soils are salt affected, sandy to sandy loam with poor water holding capacity, the underground water is brackish and not fit for irrigation hampering economic cultivation of arable crops. Under the situation, farmers cultivate mehndi as a rainfed plantation crop and earn around Rs. 36000 per ha, which is lucrative enterprise from a poor resource base.

In Gujarat, northern part of Banaskantha district and north-west Gujarat, i.e. Kutchh district have similar situation posing problems of low and unstable crop yields. Majority of Kutchh region also faces problems of soil salinity and saline sodic underground water, which further aggravates the problem. Under the situations which are more or less akin to arid western Rajasthan, cultivation of mehndi as a rainfed plantation crop will not only improve economic condition of the farmers but also improve/maintain soil fertility by controlling soil erosion through wind and water. Thus introduction of mehndi as a plantation crop has a great potential in arid and semi-arid region of Gujarat (Jaimini *et. al.*, 2005)

The plants can be propagated either by cuttings or seed. However, for high foliage yield and superior leaf

quality and colour, seed propagation is preferred. Approximately two-month old seedlings are transplanted in the field following 60 cm x 30 cm spacing on setting of monsoon. Generally organic manures are not applied to avoid incidences of termite attack. Mehndi does not require any fertilizer or irrigation for growth, infact the colour intensity decreases if irrigation are given at frequent intervals. The incidence of pest and disease is minimum in mehndi. However, application of haptachlor (5%) dust/chlorpyriphos 20% EC may be given if termite problem is noticed.

Mehndi gives economic yields from the second year onwards. Farmers can get one or two cuts in a year, i.e. November-December and April-May. In agroforestry system plant should be cut at 0.5 m height and in sole plantation at 10-15 cm height and dried in shade, the leaves are separated and suitably packed for marketing.

Cost of cultivation is initially high for the first year but quite low in subsequent years. It yields 2500 kg dry leaves in second year and 3200 kg or more after third year. A farmer can fetch a net profit upto Rs. 36000 per ha at current minimum price of Rs. 20 per kg dry leaves in Sojat market yard.

Guggal (*Commiphora wightii*)

Guggal is a small tree or shrub of family Burseraceae. The branches are crooked, knotty, aromatic and end in sharp spines. It has wide adaptability and can grow in arid region under varying conditions due to presence of small, leathery leaves and thick bark covered with a white waxy coat over the stem.

The gum of guggal is an important ingredient of large number of potential Ayurvedic formulations. The gum oleo-resin extracted from the plant is well known for its anti-rheumatic, anti-cholesterolaemic and anti-inflammatory actions. The warm dry climate is good for high yield of oleo-gum-resin.

Commercial cultivation of guggal is not common. It is widely distributed in Gujarat and Rajasthan extending from extreme desert areas in northwestern region to rocky tracts of the Aravalis and also in Kutchh region of Gujarat.

It can be propagated by seed and vegetatively through stem cutting. Propagation through seed is not common because of very poor germination. Studies conducted at SDAU, Sardarkrushinagar has indicated more success when semi hardwood cuttings were treated with 800 ppm IBA. The university has also identified fast growing plus shrub of guggal collected from Kutchh.

For its commercial cultivation one year old plants raised from vegetative propagation are planted at 3 x 3 m spacing in a pit of 30 cm³ filled with FYM and top soil mixed with chlorpyrifos to prevent termite attack. Its cultivation as biofence is more remunerative as compared to block plantation. The plantation is made in July on onset of monsoon.

The plants are ready for tapping after 8-10 years. Tapping is done by making a shallow incision on the main trunk bark near to ground. Usually the incision is made after November but before April. The resin is collected at an interval of 10-15 days. On an average a plant yields about 400-600 g of gum resin having market price of Rs. 100-120/kg.

Senna (*Cassia angustifolia*)

Senna (*Cassia angustifolia*) belonging to family Caesalpiniaceae called, as Sonamukhi in Rajasthan and Mindhiaval in Gujarat is a perennial shrub cultivated in the drought tracts of Rajasthan, Gujarat and in southern region of Tamil Nadu. Senna holds a lot of promise as an ideal drought tolerant herbal plant of arid region, which can be raised throughout the year. In India, it is cultivated in 3000 hectares and 5000 tonnes of dried leaves and seeds are harvested annually. India holds 17th place in global herbal market and earns Rs. 50 million annually through the export of dry leaves, seeds and fruits. France, Belgium, Srilanka, Switzerland, Japan and European countries are the major consumer of senna. It has vast potential in export due to its medicinal values.

The chief constituents of its leaves and seeds are glycosides of derivatives of anthracene named as Sennocide A and Sennocide B is used as Siddha and Ayurvedic medicine. Sennocide content in senna ranges from 2.5 - 4.0 per cent. The medicine prepared from Senna cures cough, jaundice, stomach and skin diseases. Senna pods are used as laxative and considered to be more certain than the leaves and to cause less griping.

The local variety 'Tiruneveli' is cultivated in rainfed arid/ semi-arid tracts of Gujarat and Rajasthan. SDAU, Sardarkrushinagar has developed a Senna composite having more foliage and high number of pods which are rich in sennocide content.

The plant is a small shrub, about 1 m in height with pale substrate or obtusely angled, erect or ascending branches. The compound leaves are generally yellowish-green.

The plant grows well in all sort of soils, even it grows well in saline and alkaline soils. The pH range for better growth is between 7.0 and 8.5 with adequate drainage. Senna is mainly cultivated as a sole crop. However, it can be incorporated profitably in agroforestry systems to fetch additional income and to improve soil fertility.

The plant is propagated through seed. The seed rate per hectare is 25 kg for rainfed and 15 kg for irrigated crop. Sowing is done from 15th July to 15th September. Seeds are soaked in water for 12 hrs and dried under shade for an hour before sowing.

The matured leaves, pods and whole plant are the major yielding components in Senna. The total crop duration is about 150 - 160 days. The first harvest is practiced for leaves. The well matured dark greenish leaves are manually collected at three months after sowing. Second harvest is done at 30 days interval from the first harvest. This time the 75% matured pods are harvested. The last harvest is done by removing of the whole plants and kept for drying.

In arid areas the economics of this crop is much better than other crops. The total cost of cultivation of this crop is around Rs. 12000/- in irrigated and in rainfed it may around Rs. 7000/- per ha. The market rate of dried leaves varies from Rs. 10-15 per kg and for the pod it varies from Rs. 20-25 per kg. The Senna grower can get Rs. 15000 per ha from irrigated crop and expect around Rs. 10000 per ha from rainfed crop.

Kair (*Capparis decidua*)

Kair (*Capparis decidua*) belonging to family Capparidaceae is a leafless shrub found as wild in arid and semi-arid regions of India. It is an important indigenous fruit of Rajasthan and Gujarat. It is also found in dry regions of Haryana, Punjab, Madhaya Pradesh, Uttar Pradesh and Deccan Peninsula.

Kair is most suited on wasteland or neglected sites where a few species can grow. It is shrub with many dense thorny branches, leaves are very small caducous. Its immature fruits are used as vegetable and in pickle making. Ripe fruits are edible and liked much by children. Fruits have medicinal value in cardiac improvement and billousness. Bark is used in cough, asthma, inflammation and rheumatism.

Kair can easily be grown in various types of wastelands but its root development is better in sandy soils. It can tolerate salinity to a greater extent.

There is no named improved variety but large variation in fruit size, pulp content, and its sweetness, seed size and spineness has been observed during a survey conducted under NATP on arid region shrubs.

Kair is mainly propagated by seeds and root suckers. Propagation by semi-hardwood and hardwood cuttings is also possible. Rooting in cuttings can be enhanced with the treatment of IBA at 1000 ppm. Rainy season is the best period for Kair propagation.

One year old seedlings are planted in the pits of 60 cm³ size filled with a mixture of soil and FYM (50:50). The distance of planting may be kept 3 m both ways. The planting is done in the beginning of monsoon.

Planting of Kair on field boundaries as a biofence is more remunerative than the sole raising because it will protect arable crop besides giving fruits and fuelwood on lopping.

Kair shrubs raised from seeds start bearing 7-8 years after planting, where as vegetatively propagated shrub start fruiting after 4-5 years. The main season of flowering is spring i.e. March-April. The green immature fruits become ready for harvesting in May-June. A 10-year old Kair shrub yields about 5-7 kg fruits.

Karonda (*Carissa carandus*)

Karonda is an evergreen spiny shrub of family Apocynaceae. Due to its hardy habit, it can be grown on a wide range of soils in tropical and subtropical climate. It also grows well on wasteland of dry areas.

Karonda leaves are thick dark green in colour. It posses strong axillary spines which are often forked. The flowers are white and fragrant. The fruits are small berry like, sub-acidic and sweet when ripe and rich in ascorbic acid and minerals. Its ripen fruits are eaten where as unripen fruits are used as vegetable and for making chutney, tarts, pickle and jelly. Karonda is best suited as a live protective hedge due to the presence of axillary spines and formation of profuse leaves on crowded branches.

On the basis of fruit colour, Karonda can be classified as green fruited, pink fruited or white fruited. However, the differences are not much in shape and size of fruits from all the three varieties. Karonda can be easily propagated by seed and to raise seedlings, the fresh seeds are sown in the nursery in the month of August or September. Under good management, seedlings become ready in 6-8 months for plantation. Propagation of Karonda

is also possible through hardwood cutting and inarching. Softwood grafting is also successful in Karonda and is very useful technique for *in-situ* propagation in arid areas. Air layering is quite successful in Karonda. It is done in the beginning of monsoon. Rooted layers are obtained after 3 - 4 months of layering.

For plantation, the pits of 30 - 45 cm³ are dug and filled with organic manure and soil in the ratio of 1:1. The planting distance in hedge/fence is recommended at 1 to 1.5 m and regular planting at 2 m both ways. The best time for planting is the beginning of monsoon.

Karonda starts bearing flowers and fruits from third year of its planting. The plant starts bearing flower in the month of February and ripe fruits are available in the month of August. However, unripe fruits are available from May onward. About 10-15 kg and 4-5 kg fruits per plant are obtained under good management and wastelands, respectively.

Jharberi (*Ziziphus nummularia*)

Jharber or Chniber (*Ziziphus nummularia*) belonging to family Rhamnaceae is a thorny, bushy shrub armed with twin stipular spines. It is the most hardy fruit/fodder shrub of arid region. It is always a bush usually 1.8 - 2.4 m high, forming irregular rounded masses of spines, with numerous clustered stems, and suckers thrown up from the roots. Leaves are oblong, elliptical and prominently three nerved. Flowers 10 - 20, greenish yellow occurring in axillary cymes. Fruits 8.3 mm in diameter, red, glabrous, shining when ripe.

Ziziphus nummularia is common throughout north-west India and in other parts of south India. It is mainly found in the dry arid region of Punjab, Rajasthan and Gujarat. The shrub exhibits xerophytic characteristics and goes to dormant condition during summer. Its tap root system is extensive and grows deep into the soil with in a short period enabling it to draw water from deep soil. Leaf scales on buds, thick cuticle, sunken stomata on leaves and presence of thorns help in reducing water losses from plant system. It can also tolerate saline and alkaline soil conditions. Therefore, it grows extensively on wide variety of neglected soil and best suited for planting in arid wasteland where other plant species cannot survive easily. The shrub coppices and suckers well. Flowering take place during summer and fruits are formed soon after flowering. The fruit which are small and dark red to brown in color are available in winter season.

Different plant parts of *Ziziphus* species have medicinal value. In Ayurveda its roots and leaves are used to cure *kapha*, biliousness and headache. The roots are also used for treatment of fever, wounds and ulcers. The bark cures boils and is useful in the treatment of dysentery and diarrhoea. In Yunani system, the roots and bark are tonics, leaves are anthelmintic and useful in stomatitis, gum bleeding, wounds syphilitic ulcers, asthma and lever complaints. The flowers are used a collyriun in eye treatment. The leaf decoction is used as a hipbath for joint pain and as a gargle for sorthroat and bleeding gum.

The leaves of *Ziziphus nummularia* are a rich source of protein and minerals. It is a popular fodder shrub in arid region since it grows and regenerate very quickly even under stress condition. A Jharberi shrub easily provides 2.5 to 3.0 kg air dried leaves (pala) per year. Palatability of air dried leaves for both sheep and goat is higher than that of the leaves of Khejri (*Prosopis cineraria*) which is a prominent fodder tree of the Thar Desert. Jharberi shrubs are commonly used as live fencing. Cut branches are often used as a protective fencing material around agricultural field. Further, in inter specific hybridization, *Ziziphus nummularia* could be an excellent donor parent to introduce drought tolerance, early fruit maturity and dwarf tree stature.

Besides, above described shrubs, other shrubs viz., Kuwarpatha, Aswangandha, Ketki, Phog, Lana, Gangani, Kheep and Akra also have importance in arid ecosystem, but very little information is available on their phenology, reproductive biology, productivity etc. Therefore, there is a need to collect information on above aspects for domestication and commercialization of these unexploited shrubs.

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Distribution and Ethnobotany of Shrubs of Arid Gujarat

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The arid region of Gujarat has hostile environmental conditions such as low and erratic rainfall, intense solar radiation and high wind velocity. The forest cover is extremely low (3.34%). The soils are coarse textured, salt affected with low water holding capacity and poor nutrient status. In this fragile ecosystem a large number of shrubs exist which are important in sustaining livelihood in these areas. These natural shrubs occurring here meet the demand of food, fodder and fuel. Some of the important shrubs of arid region of Gujarat are: Guggal (*Commiphora wightii*), Kair (*Capparis decidua*), Jharberi (*Ziziphus nummularia*), Bawli (*Acacia jacquemontii*), Kheep (*Leptadenia pyrotechnica*), Akra (*Calotropis procera*, *C. gigantea*), Senna (*Cassia angustifolia*), Awal (*Cassia auriculata*), Ketki (*Agave americana*), Mehndi (*Lawsonia inermis*) and Ratan Jot (*Jatropha curcas*) (Jadeja *et al.*, 1999). A brief description of these important shrubs is as under:

Guggal [*Commiphora wightii* (Arn.) Bhandari]

(Burseraceae)

Flowering season : March-May, Fruiting season : June-July,

Guggulu (Sanskrit), Gugal (Hindi, Gujarati), Indian Bdellium (English)

Found in Central Gujarat (Mahi ravines near Vasad), North Gujarat (Idar, Pahada, Mahudi), Saurashtra and Kutch, common in the last two zones.

Grows in sandy and stony areas. A deciduous, bushy shrub. Bark peeling off in flakes. Young parts glandular pubescent; branches crooked and knotty. Leaflets 1.2-2.4 x 0.9-1.7 cm, obovate. Flowers red in fascicled cymes at end of branches. Drupes 0.4 - 0.8 cm across, ovoid, shortly beaked, deep-red, 2-6 valved, pyrenes ovate, acute.

Source of Indian Bedellium, a gum-resin, used as an incense, fixative in perfumery and in medicine as an astringent antiseptic, anti-arthritic used as stomachic and for muscular rheumatism. It stimulates appetite and acts as a diaphoretic, diuretic, expectorant and uterine stimulant.

Kair [*Capparis decidua* (Forsk.) Edgew.]

(Capparaceae)

Flowering Fruiting season : February-September (Occasionally whole year)

Karira, Gudhapatra (Sanskrit), Karer (Hindi), Ker, Kerdo (Gujarati)

Common, scattered or subgregarious in scrub forests and dry open wastelands throughout the state. A densely branching, glabrous, almost leafless shrub or small tree. Leaves scanty, small, caducous found only on young shoots. Flowers red or scarlet, in small corymbs. Fruit 0.8 - 1.5 cm, almost spherical, smooth, glabrous, green when young and red when ripe.

The wood is light yellow to pale brown, moderately hard and heavy, used for knees of boats, axles of cart-wheels and tool-handles.

The flowers are eaten as vegetables, flower buds used as a pot-herb. Fruits are pickled, useful in cardiac troubles and biliousness. The bark is acrid, laxative, diaphoretic, anthelmintic and useful for cough, asthma and inflammations.

Jharberi [*Ziziphus nummularia* Burm. f.]

(Rhamnaceae)

Flowering and Fruiting season : July-January;

Bhukamataka, Sukshamphala (Sanskrit), Jhariberi, Jhadiaber (Hindi), Chanibor, Chania bor, Pali, Palia (Gujarati), Wild jujube (English).

Common throughout the state, in open grass lands, fields and waste lands, especially in arid and semi-arid regions.

An armed shrub with zigzag branches. Bark grey or pale-brown, smooth. Leaves alternate, broadly ovate to orbicular. Flowers greenish-yellow or creamy-white, in axillary fascicles. Drupes 0.5-0.8 cm across, globose, smooth, deep-red when ripe.

The fruit is eaten; ripe fruits sold in market upto April. The branches are used for fencing. Tender parts grazed by animals but later only sheep and goats are

able to browse on it. Leaves stored as 'Pala' for use as fodder. Leaves used in scabies and other cutaneous diseases. Dried leaves are burnt and smoke inhaled for cough and cold. Fruits are cooling and astringent, used in bilious affections. Wood affords high quality charcoal and fuel.

Bawli [*Acacia jacquemontii* Benth.]

(Mimosaceae)

Flowering season : April, Fruiting season : May-June
Bawli (Hindi), Ratobaval (Gujarati)

A bushy thorny shrub with smooth brown branches, leaves 2-pinnate; stipular spines white, straight, 2-5 cm long, connate at the base; flowers yellow, sweet scented in axillary, small globose heads. Found in drier areas of Gujarat.

The branches are lopped for fodder; the bark is used for tanning. Wood is whitish-yellow, yields gunpower charcoal. Plant may be used as a sand binder in arid zones.

Kheep [*Leptadenia pyrotechnica* (Forsk.) Decne.]

(Asclepiadaceae)

Flowering season : October-January, Fruiting season :
March-May

Kheep (Hindi), Khip, Ranser (Gujarati)

Found in Bharuch in Mahi ravines, Chhotaudepur, Panchamahals, North Gujarat, Saurashtra and Kutch.

A bushy shrub. Leaves when present 4.5-8.5 x 0.2-0.3 cm, narrowly linear or linear-lanceolate, sessile. Flowers greenish-yellow, in axillary fascicles. Follicles 7.5-14 cm long, ovate-conical to ovate-lanceolate, glabrous.

Yields a fibre used for ropes, also suitable for paper manufacture. Plant used as fodder, also employed for thatching. Tuberous roots consumed as a vegetable.

Akra [*Calotropis gigantea* (Linn.) R. Br.]

(Asclepiadaceae)

Flowering season : Throughout the year, Fruiting season :
March-July

Arka, Mandara (Sanskrit), Ak (Hindi), Moto Akado (Gujarati)

Throughout common in wastelands and in open forest and in dry regions. There are two varieties found one with purple flowers and another with white flowers.

A tall shrub; with milky latex, abundant; bark ash coloured, shallowly longitudinally fissured, spongy young branches covered with white cotton hairs. Leaves sessile to subsessile, thick, glaucous-green. Flowers 2-4 cm across, in terminal and lateral umbellate cymes. Fruit a follicle, paired, 7-10 x 3-5 cm glaucous-green cottony pubescent.

Bark yields a fibre which is white, silky, strong and durable, used for fishing-nets and lines, bow strings and twine. The floss from the seeds used for stuffing mattresses, pillows etc. Root bark is similar to ipecac in action. In paste form applied in elephantiasis. Preparations of roots and leaves as powder, balms, enemas and ghee or clarified butter used against abdominal tumours; extracts anticancer. Plant useful for indigenous medicines for a number of diseases like small pox, ailments of spleen, leg and chest pains, boils, muscular pain, rheumatism, epilepsy, tongue paralysis, tetanus, syphilis, carbuncle, convulsions, postnatal complaints, scabies, ringworm, cholera, neuralgia, pneumonia, bite of jackal or dog, rabies, etc.

Akra [*Calotropis procera* (Ait.) R.Br.]

(Asclepiadaceae)

Flowering season : Throughout the year, Fruiting season :
January-July

Alarka (Sanskrit), Akra, Akada (Hindi), Ankdo, Nano Ankdo, Rato Ankdo (Gujarati)

A shrub common in wastelands and open forests.

A small shrub ; very similar to *Calotropis gigantea* but differs in the structure and size of coronal lobes with reference to the gynostemium. Leaves decussate, smaller, ovate-oblong, elliptic or obovate, abruptly acuminate, cottony-hairy when young only. Flowers purple spotted, pink and scented. The petals of this species are erect unlike *Calotropis gigantea*. Root bark useful for treating chronic cases of dyspepsia, flatulence, constipation, loss of appetite, indigestion and mucus in stool. Plant used in spleen complaints, rheumatism, hemiplegia, epilepsy, smallpox, etc. Plant anticancer, latex and leaves nematocidal.

Senna [*Cassia angustifolia*]

(Caesalpiaceae)

Flowering and Fruiting season : Throughout the year
Sonamukhi (Hindi), Mindhiawal (Gujarati)

Common throughout wastelands in Kutch.

The plant is a small shrub, about 1 m in height with pale subterrate or obtusely angled, erect or ascending branches. The compound leaves are generally yellowish green.

The plant grows well in all sort of soils, even it grows well in saline and alkaline soils. The pH range for better growth is between 7.0 and 8.5 with adequate drainage. Senna is mainly cultivated as a sole crop. However, it can be incorporated profitably in agroforestry systems to fetch additional income and to improve soil fertility.

The chief constituents of its leaves and pods are glycosides derivatives of anthracene named as Sennocide A and Sennocide B. It is used in Siddha and Ayurvedic medicine. Sennocide content in senna ranges from 2.5-4.0 per cent. The medicine prepared from Senna cures cough, jaundice, stomach and skin diseases. Senna pods are used as laxative and considered to be more certain than the leaves and to cause less griping. Recently this plant has gained importance due to its domestication, large scale cultivation because of its export potential.

Awal [*Cassia auriculata* Linn.]

(Caesalpiaceae)

Flowering and Fruiting season : Throughout the year

Tarwar (Hindi), Awal, Awar (Gujarati), The Tanner's cassia Avaram (English)

Throughout in wastelands and roadside in green areas in arid and semi-arid regions.

An erect, 1-2 m tall, bushy shrub, branching from base. Leaves pinnately compound with large auricled stipule, glabrous above pubescent beneath. Flowers large, yellow with orange veins. Pod flat thin papery depressed between the seeds.

This plant was commercially planted in Madras, Mysore and Hyderabad for bark used in tanning. The bark is astringent and the leaves and fruits are anthelmintic. The root is used in treatment of skin diseases.

Ketki [*Agave americana* Linn.]

(Agavaceae)

Flowering season : Once in life cycle

Kalakantala (Sanskrit), Bans Keora (Hindi), Ketki

(Gujarati), American Aloe, Century plant (English)

A spiny perennial shrub; it is a short stemmed half-woody plant, bearing a rosette of long, erect, spiny pointed, fleshy, fibrous leaves, leaf margins spiny. Agave flowers only once during their life and the flowering stem (scape) arises from the centre of the rosette of leaves as a thick pole, which rapidly grows to a height of 7-10 m. They die after fruiting. The scape bears white flowers in bunches, some of which develops into bulbils by which vegetative propagation takes place.

Agaves were introduced in India by Portuguese in 15th century and naturalized throughout India. In Gujarat mainly used as live hedge fencing to forest boundaries and agricultural fields.

Agave fibres are one of the important hard fibres, mostly used for making ropes, cordage and twine, the shorter fibres and istles used for making brush and mops. Leaf juice used for warts, cancerous ulcers, and putrid tumours. Various plant parts used for ascites, dropsy anascarca, venereal sores, syphilis and dysentery.

On cutting off the young flowering scape a large quantity of juice is obtained which on fermenting yields pulque, the national drink of Mexico; the distilled spirit is known as mescal.

Ratan Jot [*Jatropha curcas* Linn.]

(Euphorbiaceae)

Flowering season : October, Fruiting season : Cold season

Kananaeranda, Parvataranda (Sanskrit), Bagbherenda, Jangli arandi, Safedrand (Hindi), Ratan Jot, Muglai erando, Vilayati erandi, Jamal gota (Gujarati), Physic Nut, Purging Nut (English)

Medium sized shrub, which can grow any where on gravelly, sandy and saline soils. Occurs in semi-wild condition. It is a cross pollinated species because of its monoecious nature.

Cultivated as a hedge plant. Naturalized in many parts, as a road side weed and in open sandy soil. A large soft wooded, deciduous shrub with greenish-yellow, smooth bark, oblong with scars of fallen leaves; leaves 4.5-18 x 4.8-17.5 cm, broadly ovate or nearly orbicular, entire or shallowly 3-5 lobed, glabrous. Flowers in 6-8.5 cm long, terminal or extra axillary, paniculate cymes. Capsule 1-2.5 cm, in diameter, globose or broadly ovoid, yellow, smooth.

The seed contains 30-35 per cent curcas oil, a powerful purgative: also used for manufacturing candles, soaps and varnishes; illumination (burns without soot) and lubrication and in wool industry. Recently this plant has gained industrial importance due to its scope as an important bio-diesel plant, which could be of great significance in rejuvenating the nation's economy. The oil is used in sciatica, dropsy and paralysis and externally for skin troubles and rheumatism. Also abortifacient. Latex dries to a bright reddish-brown brittle substance, resembling shellac and used as marking ink. Bark yields a dark blue dye used for dyeing cloth, fishing nets, and lines; also contains tannin. Juice of the plant useful in scabies, eczema and ringworm.

These shrubs and many more in arid region of Gujarat not only possess economic value but are the integral part of the arid ecosystem. They possess high growth rate, resistance to biotic and abiotic stresses, conserve soil and moisture, improve soil productivity and have potentiality to provide products useful to the inhabitants of the arid region. A large number of shrubs are being overexploited and are at the verge of extinction. Conservation of biodiversity of the arid zone shrubs needs prime attention.

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Economic Shrubs of Banni Region of Arid Gujarat

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The Gujarat state occupies about 20% of the arid regions of the country. In the state, Kachchh with 45652 Km² fall totally in the arid land. Banni with 3847 ha. area is located on the northern border of Kachchh district, (23° 19' to 23° 52' N latitude and 68° 56' to 70° 32' E longitude). It is about 60 Km from Bhuj. The plains of Banni represent an embayment between the Kachchh mainland, uplift in the south, the Panchham uplift in the north and the Waged and Beal uplift in the east. Banni plains form a low soil table rising 3 to 10 m above the level of the Great Rann, and the entire area is more or less flat without any gradient. The southern part of Banni is an intervening stretch of salty waste, known as little Rann of Banni, which separates the Banni from the Kachchh mainland. According to Singh and Kumar (1998) the area can be divided in three parts as east, west and central Banni. The climate of the Banni is arid. The total annual rainfall, occur through south-west monsoon between June and September, is very low (the annual average rainfall in the area is 317 mm per year) with a coefficient of variation of 65 percent. Therefore, droughts are a recurring phenomenon in Banni (Rao *et al.*, 1999).

The soils of Banni are inherently saline and consist of recent alluvium mixed at places with aeolian sandy deposit and the entire area has deep to very deep clayey and coarse textured soils in discontinuous patches. The salinity of the soil is highly variable from 1.0 to over 15.0 M mhos/cm and the pH ranges between 6.5 and 8.5. Kanzaria (1999) based on material contents divided the soil region into four textural groups (Table 1). Moderately fine textured soil with 59.4 percent area occupy first rank followed by 25.2, 9.9 and 5.5 percent areas under medium, fine and coarsed textured soils, respectively.

Table 1. Soil texture of Banni region

S. No.	Textural class	Area (ha)
1.	Coarse textured soils (Sand to loamy sand)	16279
2.	Medium textured soil (sandy loam to loam)	74530
3.	Moderately fine textured soils (clay loam to silty clay loam)	175897
4.	Fine textured soils (clay to silty clay)	29444
Total		296450

The region use to be one of the prominent grassland and also harbour a number of trees and shrubs (Shah, 1978) but with the introduction of *P. juliflora* in sixties, grasses as well as tree and shrub species have reduced and are replaced by *P. juliflora* in almost entire area. The ground stratum is composed of approximately 34 species of grasses of which many are rich in animal nutrition and few are edible for human beings. The number of grass species reported by various agencies include; 22 grass species by Banni Development Agency, an additional 11 species by Indian Council of Agricultural Research (ICAR, 1977) and 1 species by Kadikar (1994). Among the grass species, few are perennial, which include; *Eragrostis tenella*, *Dichanthium annulatum*, *Urochodra setulosa*, *Desmostachia bipinnata*, *Cenchrus ciliaris*, *Cenchrus setigerus*, *Sporobolus helvolus* and *Sporobolus diandrus*. The survival of these species during the hot summer is due to deep rooting and formation of rhizomatous, underground growth, which enables them to tide over the inhospitable situations.

The shrub and tree mainly composed of *Prosopis cineraria*, *Acacia nilotica*, *Acacia leucophloea*, *Acacia senegal*, *Salvadora persica*, *Salvadora oleoides*, *Capparis decidua*, *Tamarix* sp. *Prosopis juliflora* etc. (Annon, 1999). A few of them are seen even today in wilderness as well as near human settlements but most of them have been, in due course of time, are replaced by *P. juliflora*. Further, the tree species like *Azadirachta indica* and other plant species such as, *Ziziphus zozoba* and *Calatropis procera* are also found in the area. Although, the information on grasses of the region, their production potential and usefulness is studied to a large extent such information on trees and shrubs found in the area are not well documented. Trees and shrubs growing in the region and surrounding areas contain certain products of economic value (CSIR, 1986). The shrubs found in the area possess products of edible (Vyas, 2001; 2004); medicinal (Vyas, 2002; Nair and Mahanan, 1998) and industrial value (Vyas and Purbey, 1998) besides the common uses as fodder and fuel wood. The information on the usefulness of these shrubs has been described in this report, however a cautious scientific exploitation is recommended looking to fragile ediphic and environmental conditions of the region.

Agave americana Linn. (Agavaceae)

A spiny perennial shrub with very short stem bearing a rosette of long erect, pointed, fleshy, fibrous leaves, leaf margin spiny. Flower and fruit only once in life and die after fruiting. Flower white in bunches on long flowering stem. Some flower develop into bulbils for vegetative propagation of plant.

Uses : Used as live hedge fencing to forest boundaries and agricultural fields. Fiber extracted from leaves is used to make rope, cordage and twine. Leaf juice used for warts, cancerous ulcers and putrid tumours. Plant used for treatment of venereal sores, syphilis and dysentery.

Ammannia baccifera L. (Lythraceae)

A glabrous, erect, branching small shrub. Plants found only in banni region. Leaves opposite or alternate; oblong or elliptical; Flower and fruit in July Oct. Inflorescence short axillary cymes. Flower red in colour. Plant contains 89.9 mg/ 100g vitamin C.

Uses : Leaves laxative also used in treatment of rheumatic pains, fever and also in external remedy of ringworm and skin affections. Plant possess anti-typhoid and anti tubercular characters. Rhizomes are used to cure urenary calculi.

Calotropis procera (Ait) R.Br. (Asclepidaceae)

A very common in the region. Plants are small branched shrubs having milky latex; bark ash coloured. Young branches are covered with white cottony hairs. Leaves decussate, opposite, ovate oblong, elliptic or obvate, acuminate. Inflorescence terminal and lateral umbellate cymose. Flower pedicilate, purple, scented. Petals erect. Fruit follicle, green in colour. Flower round the year, fruit in January to July.

Uses : Root bark used to treat dyspepsia, loss of appetite, indigestion and mucus in stool. Stem bark yield strong durable fiber, used to make fishing lines and nets. Leaves and latex antitermite, nematicidal. Whole plant used against cancer, spleen problems, rheumatism, epilepsy and small pox.

Capparis decidua (Forsk) Edgew. (Capparaceae)

A well branched, glabrous, leaf less shrub found in the entire drylands of Gujarat. Plants generally fruit and flower during February and September. Stem modified to phyllocladé, Flower red in small corymbs. Fruit smooth glabrous, spherical, green when young red on maturity. Wood yellowish, hard and heavy.

Uses : Wood is used for making knees of boats, axels of

cartwheel and tool handles. Flowers and unripe fruit are cooked as vegetables; unripe fruit are pickled also. Fruit are used in Indian system of medicine to treat cardiac troubles. Stem bark is useful in cough, asthma and inflammation.

Capparis spinosa Linn. (Capparaceae)

A small, armed, prostrate shrub found on rocky, hilly localities and old walls. Stem has characters similar to *C. decidua*. Leaves long, orbicular, ovate or obovate petiolate. Flower solitary, axillary, white. Fruit berry, obvate, veined red when ripe. Plant flower and fruit in Oct. Dec., Frs. : Jan. April.

Uses : Flower buds and unripe fruit pickled. The bark is useful in diseases like rheumatism, paralysis, toothache and infection of spleen and liver.

Cassia auriculata Linn. (Caesalpiniaceae)

An erect bushy shrub having branching from base. Leaves pinnately compound with large auricled stipule. Flower large, yellow. Fruit pod, depressed between the seeds. The plant has flowering and fruiting all over year.

Uses : Bark is used in tanning and is anti helmintic; Leaves and fruits are also antihelmintic. Root is used in treating skin diseases.

Euphorbia caducifolia, Linn. (Euphorbiaceae)

A pale green, dense, dendroid, fleshy shrub with branching from base. Stem and branches cylindrical having olivergent stipular spines. Leaves variable in size, shape and form, fleshy palegreen caducus. Involucre generally solitary on short fleshy peduncle usually centrally male, peripheral hermiphrodite; Female flower pedunculate; fruit capsule trilocular, seed 3 round, one in each locule, globose, smooth. Plant produce flower and fruits between Jan. Feb. and Feb April respectively.

Uses : The milky juice used as a cure for treatment of cough, skin diseases, leaves are eaten raw or as vegetable. Dry stem used as fuel. Planted on field margins as hedge.

Euphorbia neriifolia. Hook. f. (Euphorbiaceae)

An erect deciduous shrub, young branches angled with stipular black thron, leaves crowded at top of stem, straight, glabrous, sub fleshy, stipulate, Inflorescence few flowered cymes in the axil of stipule. Capsule deep red or pale brown, smooth, glabrous. Fls: November April; Frs: Summer season.

Uses : Latex used to remove warts and cutaneous eruptions, as purgative and expectorant. Dried stem used as fuel.

***Jatropha gossipifolia* Linn. (Euphorbiaceae)**

A large bushy gregarious shrub with 3-5 lobed palmately compound leaves. Which are shiny brown first and later turn to green, petiole and leaf blade covered with glandular hairs; flower dark red in cormbose cymes; fruit capsular, long, truncate at both ends; seed greyish red. Flower and fruit during rains.

Uses : Planted as ornamental shrub in garden. The stem bark contain alkaloid "jatrophine" having properties similar to quinine. The root bark and leaf decoction is used against, leprosy, ache and venereal diseases respectively. Leaves are applied to cure carbuncles, eczema and itches. They are also used in intermittent fever. Seed contains 25-30 % oil of industrial use.

***Leptadenia pyrotechnica* (Forsk.) Decene. (Asclepidaceae)**

A rare often leafless much branched shrub; stem modified to phylloclade, leaves linear or linear lanceolate when present, long, glabrous; flowers yellow in small umbellate cyme; fruit follicles, long. Flower and fruit Oct. Jan.; March May.

Uses : Yield fiber, which is used for ropes and in paper industry. Whole plant used as fodder and also in thatching. Roots used as vegetable by villagers.

***Opuntia elatior* Mill. (Cactaceae)**

Plant grown as live hedge on farm boundaries. A bushy shrubs with succulent jointed stem having straight spines, often leafless, flate, obovate, glaucous-green. Flower yellow or pale-pink, solitary on free margin of joints. Fruit berry; red. Plant flower and fruit between from December to May.

Uses : Plant after removal of spines fed to camel. Fruits eaten as " Prickly pear" and to treat whooping cough.

***Suaeda fruticosa* Frosk. ea. Scop. (Chenopodiaceae)**

A small sub-erect, perennial shrub. Leaves succulent, sessile; flower foetid, red in leafy spikes; fruit turbinate utricle, membranous spongy; seeds black, beaked, shining.

Uses : Plant is used as fodder by camel and goat. The meshed leaves are used mixed with oil to cure sores of back of camels and poultice for the eye. The dried plants are used as fuel. A crude carbonate of soda called " Sajji" is prepared from ash of whole plant.

***Withania somnifera* (L.) Dunal (Solanaceae)**

An erect branched under shrub, stem covered with minute stellate tomentum; leaves ovate; flower solitary axillary, greenish or lurid yellow; fruit berry, orange coloured enclosed in persistent calyx. Plant flower in November-April and berries ripen in January-May.

Uses : Plant form an important drug in Aurvedic system of medicine. Root decotion is used in hiccups, female disorders, cough, rheumatism and dropsy. It is also used in the treatment of inflammation, ulcers and scabies when applied locally. Leaves are given in fever.

***Ziziphus jujuba* Mill. (Rhamnaceae)**

A spiny deciduous shrub, leaves alternate, ovate to lanceolate. apex obtuse; base oblique, margin serrulate, inflorescence an axillary cyme; flower greenish yellow, complete. Fruit drupe ovate, dark reddish brown. Fls Frs : July-January.

Uses : Used against poor apitite, general fatigues, constipation, pulpitational insomnia, besides fruits being eaten after ripe. Wood used as fuel.

***Ziziphus nummularia* Burmf. (Rhamnaceae)**

A common armed shrub with zigzag branches. Bark gray pale brown, smooth. Leaves alternate broadly ovate. Flower greyish yellow in fascicles. Fruit deep red, globose, smooth. Plant produce flower and fruit from July to January.

Uses : Wood used as fuel and in charcoal making. Leaves are fed to sheep and goat as fodder, also used to treat cutaneous diseases. The smoke of burning leaves cure cough and cold. Branches used to fence any area. Fruits are eaten when ripe.

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Micropropagation of Shrubs of Arid Regions

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Plants have always been, and will continue to be, of vital importance for humankind. They are an essential source of food, feed, raw materials, energy and recreation. Shrubs provide valuable ecosystem services and produce biomass in fragile ecosystems of The Indian Thar Desert and the Aravallies. Several shrubs/woody shrubs have evolved under the environmental conditions of these regions. Many of these shrubs tolerate biotic and abiotic stresses. These are not only botanical curiosities but also sources of biomass, phyto-chemicals used for human and animal health, genes and metabolic products for prospecting. The nature and biological diversities of these hardy shrubs should be studied thoroughly in order to optimize their utilization to sustain life and ecosystem. There is need for characterization, and conservation and propagation of germplasms of these species using conventional and non conventional methods of plant breeding. With the diminishing availability of farming land, climatic changes, and the threat of declining water resources the task is to keep the system alive/productive to meet the growing demand of products based on 'functional' plants. Future-oriented, knowledge-based and value-added agriculture/forestry will have to become reality.

Plant biotechnology is a field of scientific research in which rapid advances have been made in the recent past. This appears to offer potential tools/methods for future development. Numerous opportunities for using biotechnology in plant breeding have been identified. Modern plant biotechnology is largely based on two key technologies: the ability to regenerate plants from single cell(s)/protoplast(s) or pieces of tissues, and the isolation, cloning and transfer of gene(s)/DNA. These are being exploited throughout the world for amelioration and utilization of plant resources.

Micropropagation is a sophisticated technique for the rapid multiplication of plants. It is the art and science of plant multiplication *in vitro*. It has a great commercial potential due to speed of propagation, high plant quality plant and the ability to produce disease-free plants.

The process of micropropagation include many steps: (i) selection of source plant to be cloned/mass multiplied, (ii) care and management of stock plant, (iii) establishment of cultures on culture media under aseptic conditions and multiplication of cultures, (iv) rooting of micropropagated shoots/propagules, (v) acclimations, and (vi) field evaluation. However, micropropagation is usually done by hand which makes the process cost-intensive and tedious for the worker especially because it requires a sterile work-place. Micropropagation has a great potential of cloning of genetically improved/selected genotypes for raising, new plantation. Recent experiments on photosynthesis *in vitro* have changed our approaches to micropropagation. Novel *in vitro* propagation system, where plants are capable of photosynthesis, have been proposed and implemented in research laboratories. Japanese workers led by Dr. Kozai have established leading role in this area of plant research.

At the Department of Botany, JNV University, Jodhpur, we have been working on development of micropropagation methods for cloning and conservation of germplasms of trees species, shrubs, threatened and rare plants including medicinal plants of the arid and semi-arid regions. Attempts have been made for generation know-how for *in vitro* culture of *Balanites aegyptiaca*, *Calligonum polygonoides*, *Capparis decidua*, *Capparis spinosa*, *Celastrus paniculatus*, *Citrus limon*, *Clerodendrum phlomidis*, *Commiphora mukul*, *Commiphora wrightii*, *Crotalaria burhia*, *Dendrocalamus strictus*, *Ephedra foliata*, *Glossonema varians*, *Glycyrrhiza glabra*, *Haloxylon salicornicum*, *Jatropha curcus*, *Lawsonia inermis*, *Leptadenia* spp, *Lycium barbarum*, *Maerua oblongifolia*, *Maytenus emarginata*, *Pedaliium murex*, *Phyllanthus emblica*, *Plumbago zeylanica*, *Psoralea corylifolia*, *Pueraria tuberosa*, *Punica granatum*, *Rauvolfia serpentina*, *Salvadora oleoides*, *Salvadora persica*, *Sarcostemma acidium*, *Simmondsia chinensis*, *Tallinum portulacifolium*, *Tinospora cordifolia*, *Vitex negundo*, *Withania coagulans*, *Withania sominifera* and *Ziziphus* spp.

Efficient protocols for cloning of *Capparis decidua*, *Celastrus paniculatus*, *Citrus limon*, *Clerodendrum phlomidis*, *Ephedra foliata*, *Glossonema varians*, *Glycyrrhiza glabra*, *Lawsonia inermis*, *Leptadenia* spp, *Maerua oblongifolia*, *Maytenus emarginata*, *Pedaliium murex*, *Phyllanthus emblica*, *Plumbago zeylanica*, *Psoralea corylifolia*, *Pueraria tuberosa*, *Punica granatum*, *Rauvolfia serpentina*, *Salvadora oleoides*, *Salvadora persica*, *Simmondsia chinensis*, *Talinum portulacifolium*, *Tinospora cordifolia*, *Vitex negundo* and *Ziziphus* spp. have been defined. Methods for *ex vitro* rooting of cloned

shoots has provided better opportunities for use of these methods for clonal selection and propagation of *Capparis decidua*, *Celastrus paniculatus*, *Citrus limon*, *Clerodendrum phlomidis*, *Lawsonia inermis*, *Leptadenia* spp, *Maytenus emarginata*, *Pedaliium murex*, *Plumbago zeylanica*, *Psoralea corylifolia*, *Pueraria tuberosa*, *Punica granatum*, *Rauvolfia serpentina*, *Salvadora oleoides*, *Salvadora persica*, *Simmondsia chinensis*, *Vitex negundo* and *Ziziphus* spp. Research on defining protocols for cloning of other species is in progress.

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Distribution, Propagation And Bioeconomic Importance of Shrubs in Cold Desert Regions of India

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Cold desert regions in India lie in the Trans-Himalayan Zone covering around two per cent of the total geographical area of the country. It encompasses mainly Leh and Kargil districts of Jammu and Kashmir and Lahaul and Spiti district with some parts of Chamba and Kinnaur districts of Himachal Pradesh. Occupying one-third of the total area in these states, the cold desert has profound bearing on the socio-economic and environmental needs of a large number of mountain people. The economic growth of these areas is hampered due to a variety of biotic, abiotic, ecophysiological and socio-political factors. The inaccessibility, harsh and inhospitable climatic conditions further jeopardise the endeavours for eco-restoration and economic development.

The region has quite distinctive climatic characteristics from that of hot desert areas, oftenly called as Deserts of Dryness. It is characterised by great extremes of heat and cold coupled with excessive dryness. High evapotranspiration rate, scanty precipitation that too in the form of snowfall, high wind velocity, high influx of radiation and shorter growing period prevail in the area. The soils are immature, sandy in texture with low nutrient content and waterholding capacity.

The vegetation in the cold arid region varies from semi-desert to desert type depending upon the prevailing bio-climate. It is subjected to harsh climatic conditions, not suitable for normal plant life. The preponderance of scanty rainfall, extreme variations in temperature, strong dusty winds alongwith poor soil conditions make the plant life extremely difficult. The plants normally tend to become prostrate, thick woolly, cushion forming, bushy, hardy and spiny with long roots and small leaves (Chowdhery and Rao, 2000). The shrubs as such form the dominant component of vegetation with few tree species that too with stunted growth growing along the water courses. On barren hill slopes, no tree species exist in this region except for a few indigenous shrub species. These shrubs due to low nutritional requirements

and an efficient use of nutrients absorbed make them useful not only for arresting desertification and restoring the ecological balance in the region but also for meeting the local demands for fuel, fodder, fruit, food, fibre and traditional medicines.

Realising the importance for greening of cold desert, the respective State Governments took many initiatives in the past for launching massive afforestation programmes but the main stress was on introduction of trees that too growing outside this zone - eventually showing little success. The shrub component was either totally overlooked or attracted little attention. Instead, the shrubs of genera like *Hippophae*, *Ephedra*, *Artemisia*, *Juniperus*, *Salix*, *Rosa webbiana*, *Elaeagnus*, *Caragana*, *Capparis spinosa* and *Colutea nepalensis* which form the dominant vegetation layer in the region and are very useful to the people from ecological and bio-economic considerations should have been given major importance. This manuscript provides a brief description of the cold desert, its vegetation particularly shrubs, their propagation and bio-economic importance.

Cold Desert in India

The cold desert in India extends over approximately 103,115 sq. km area that entails 87,780 sq. km in Jammu and Kashmir, 13,835 sq. km in Himachal Pradesh and 1500 sq. km in Uttranchal (Aswal & Mehrotra, 1994). Thus implies that the bulk of Indian cold desert lies in Leh and Kargil districts of Ladakh region of J&K, Lahaul and Spiti district, as well as some parts of Chamba and Kinnaur district of Himachal Pradesh. The whole region has a general aspect of highest elevation on the earth and extreme barren topography. The population density is very low and habitations are concentrated only along the water courses.

The climate is characterised by low rainfall, long freezing winters (-40° to -20°C), high summer temperatures (upto 40°C), low related humidity during active growing period, heavy influx of IR and UV radiations, thin air with reduced oxygen levels, large diurnal variations in temperatures (0° to 40°C), high wind velocity (40 to 60

km/hr), high ET rates, short growing season and coarse highly porous immature sandy soils. The main source of moisture is snowfall which normally starts in mid September and ends in April.

The vegetation in the cold desert is scanty and xeric. The mountain slopes are generally bereft of vegetation except few alpine shrubs and grasses. The shrubs show wide distribution while tree species occur mainly along the water channels/courses where soil is deep and moisture is available for major parts of the year. Table 1 presents the list of important shrubs and trees, indigenous and introduced, which hold special significance to the local populace of cold desert.

Cold Desert of Jammu and Kashmir

The cold desert in Jammu and Kashmir is restricted to Ladakh region located between 32° - 36° N latitude and 76° - 79° E longitude. The topography of the area is quite rugged with rocky terrain, rough and stony mountainous peaks reaching 4000 to 5000 m above msl with sandy desert valleys and some fresh water bodies. In Leh and Kargil, the valleys are quite wide, open and extend for considerable lengths. Six major rivers - Indus, Syele, Zanskar, Nubra, Laru and Drass traverse through the area. The parent rock is marine in origin comprising mostly conglomerates of limestone. Rocks of southern strata are composed of granite, mica and schist.

The climate of Ladakh is temperate arctic in nature which is extremely dry and cold. In winters the frozen rivers form natural roads. There is burning heat during the day time in summer with most piercing cold during the night. At regular intervals between 1200 to 1800 hr, strong whirl and violent gusts of wind sweep through Ladakh region.

Natural vegetation is mostly consisting of *Juniperus wallichiana*, *J. communis*, *J. macropoda*, *Caragana* spp., *Potentilla* spp., *Myricaria* spp., *Hippophae rhamnoides*, *H. salicifolia*, *Primula* spp., *Saxifraga* spp., *Arenaria* spp., *Draba* spp. and *Koleresia dutheii*, etc., excepting at Kargil and Drass hills where a cover of *Juniperus*, *Rosa* spp., *Caragana* spp., *Rhododendron* and *Betula utilis* are found. In addition, manmade forests are found along the river banks, rivulets and nallas comprising mostly species of *Populus*, *Salix*, *Hippophae* and *Myricaria*. Most of the vegetation is used for meeting fuel, fodder, fruit and fibre needs beside its utilization for medicinal value. A traditional medicinal system based on local herbs and shrubs called EMCHI is mostly predominant in large parts of the area. Rural people are also engaged in collection of minor forest produce (medicinal value). Some of the plants collected are *Physochlaina praealta* (Langtang), *Ephedra* spp (Sapat) and *Podophyllum* spp (Modi).

Cold desert of Himachal Pradesh

Cold desert in Himachal Pradesh is spread over in the districts of Lahaul and Spiti, parts of Kinnaur (Sumdo side) and Pir Panjal in Chamba. These areas have very difficult terrains with ice fields, perpetual snow covered peaks and hostile climate. The cold desert in Himachal Pradesh covers 35 per cent of its geographical area.

The district of Lahaul and Spiti is situated in west of the Greater Himalayan Range between 30°, 41' and 30°, 59' N latitude and 76°, 46', 29" and 78°, 41', 34" E longitude. Lahaul and Spiti district comprises mainly of two different valleys viz., Lahaul and Spiti. Physically,

Table 1. Important shrubs and trees, indigenous and introduced, in cold desert of India

Use	Species
Fuel	<i>Hippophae</i> , <i>rhamnoides</i> , <i>H. tibetiana</i> , <i>H. salicifolia</i> , <i>Juniperus communis</i> , <i>Juniperus macropoda</i> , <i>Populus candicans</i> , <i>P. ciliata</i> , <i>P. alba</i> , <i>P. deltoides</i> , <i>P. euphratica</i> , <i>P. nigr.</i> , <i>P. pamirica</i> , <i>Prunus amygdalus</i> , <i>Salix angustifolia</i> , <i>S. caesia</i> , <i>S. daphnoides</i> , <i>S. elegans</i> , <i>S. fragilis</i> , <i>S. hastata</i> , <i>S. karelinii</i> , <i>S. flabellaris</i> , <i>S. oxycarpa</i> , <i>S. pschnostachya</i> , <i>S. sclerophylla</i> , <i>S. sericocarpa</i> , <i>S. tetrasperma</i>
Fodder	<i>Populus candicans</i> , <i>P. alba</i> , <i>Robinia pseudacacia</i> , <i>Salix alba</i> , <i>S. angustifolia</i> , <i>S. caesia</i> , <i>S. daphnoides</i> , <i>S. elegans</i> , <i>S. flabellaris</i> , <i>S. fragilis</i> , <i>S. hastata</i> , <i>S. karelinii</i> , <i>S. oxycarpa</i> , <i>S. sclerophylla</i> , <i>S. sericocarpa</i> , <i>S. pschnostachya</i> , <i>S. tetrasperma</i>
Food/Fruit	<i>Juglans regia</i> , <i>Pinus gerardiana</i> , <i>Prunus amygdalus</i> , <i>Hippophae</i> species, <i>Prunus armeniaca</i>
Soil Conservation/ Stablization	<i>Hippophae rhamnoides</i> , <i>H. tibetiana</i> , <i>H. salicifolia</i> , <i>Populus alba</i> , <i>P. candicans</i> , <i>P. ciliata</i> , <i>P. trichocarpa</i> , <i>Rosa wbbiana</i> , <i>Salix alba</i> , <i>S. fragilis</i> , <i>Colutea nepalensis</i> , <i>Artemisia</i> sp., <i>Ribes orientale</i> , <i>Capparis spinosa</i> , <i>Ephedra gerardiana</i>

Lahaul valley is narrow, too steep and studded with green patches of Poplars, Willows and Conifers while Spiti valley is completely rugged without any greenery worth the name with broad sandy valley and high peaks with an average elevation of 6000 m asl. Cold desert area in Kinnaur district falls adjacent to the eastern part of Spiti (Sumdo). Pir Panjal ranges in Chamba district are located south-west of Lahaul. Sumdo area in Kinnaur is comprised of broad enchanting sandy valley surrounded with high mountain peaks. The Pir Panjal ranges possess perpetual snow cover with steep, rocky and gorgeous slopes.

Lahaul valley has two very fast flowing rivers - Chandra and Bhaga which amalgamate at Tindi to form Chandra Bhaga (Chenab). In Spiti valley, Spiti is the main river that amalgamates into Sutlej flowing through Kinnaur. Geology comprises of gneiss and schistone rocks; slates, quartzite, sandstones, dolomite, limestone, shales etc.

Climate in this region can be broadly categorised into spring, summer, autumn and winter seasons. Lahaul valley and Pir Panjal experience heavy snowfall in winters (6-7 months) while Spiti has very less precipitation during winters also. This lowers the temperature to -40°C. However, a temperature of -20°C is normally experienced. Summers are very hot and dry, associated within strong winds (40 to 60 km/hr) causing dust storms. Large diurnal temperature variations occur especially during summer.

Natural vegetation cover of the entire area is quite sparse. However, Lahaul valley and Pir Panjal areas still possess some forests on alluvial deposits, while in Spiti and Sumdo area, old trees can be counted on fingers. The overall vegetation consists of few tree species namely *Junipers*, *Birch*, *Poplars* and *Willows*. Common shrub species are *Hippophae*, *Artemisia*, *Rosa*, *Myricaria*, *Astragalus*, *Caragana*, *Ephedra* and *Salix*. Herbacious elements found commonly growing are *Thymus*, *Medicago*, *Trifolium*, *Anemone*, *Potentilla*, *Epilobium*, *Verbena*, *Allium*, *Aconitum*, *Delphinium*, *Aquilegia*, *Primula*, *Geranium*, *Polygonum* and *Cannabis* with most of them being used for medicinal purposes. The distribution of these species depends more upon the

altitude, aspect and availability of moisture.

Potential Shrub Species

Shrubs owe much potential in cold desert with respect to its eco-restoration and upliftment of the economy of the tribal people. There is, however, need to create a database for the existing flora especially shrub species and explore possibilities for introduction of germplasm from similar areas in other countries. Table 2 summarises the information with regard to some important shrub species of cold desert.

The vegetation of cold desert has a repository of several economic species, many of which are little known. The region has a variety of medicinal plants, which are practiced in the AMCHI system of medicine. But, of late, the knowledge of these folk medicines is being eroded due to the increased use of synthetic drugs. Large number of medicinal plants are traditionally used in Ladakh for diseases like malaria, cancer and gastro-intestinal disorders.

The medicinal flora comprises of both herbacious and shrubby component. *Allium* spp., *Artemisia eu-chroma*, *Aquilegia fragrans*, *Astragalus* spp., *Artemisia* spp., *Betula jaquemontii*, *Carum carvi*, *Coridalis* spp., *Ephedra gerardiana*, *Gentiana kurroo*, *Hyoscyamus niger*, *Heracleum candicans*, *Juniperus communis*, *J. macropoda*, *Malva rotundifolia*, *Taraxacum officinale* etc. A brief description of some important medicinal plants is mentioned in Table 3.

Strategies for Promoting the Integration of Shrubs

Shrubs constitute an important and dominant vegetational layer in the Cold Desert areas of India. The shrubs show their occurrence in almost all niches of the desert while the tree species are mainly concentrated along the water courses/irrigational channels. The shrubs because of their low nutrient and water requirements, extensive root system, and multiple uses viz., excellent soil binder, fuelwood of high calorific value, fruit and medicines need to be given more preference while implementing afforestation programmes for ecological and bio-economic rehabilitation of the cold arid zone. Their integration in the different land use systems will also help promote diversification. Some of the points which need attention are:

Table 2. Distribution, phenology, regeneration and utilization (uses) of important shrubs of Indian cold desert

Species	Distribution	Phenology	Regeneration	Uses
1. <i>Juniperus</i> (Cupressaceae) A shrub or small evergreen conifer, circumpolar in Northern Hemisphere, the shrubby form is found from 3000 to 4000m and grows in exposed sites and on dry rocky slopes where precipitation in its natural habitat is in the range 350 to 750mm. Seeds are borne into one to three seeded berry like cones which require three years to mature. There are above 100,000 seeds per kg.				
1.1. <i>Juniperus communis</i> (Common Juniper)	Afghanistan to C.Nepal, N. Temperate zone. 1800-3600m. Drier areas.	A dense erect shrub upto 1.5m or at high altitudes a prostrate shrub. Leaves needle-like sharp-pointed, 6-13mm long, with a broad bluish-white band above, in whorls of 3. Male cones ovoid. Female cones blue-black when ripe, 6-8mm, seeds usually 3.	Regeneration through seed. Natural regeneration deficient. There is need to develop suitable seed pre-treatment techniques to secure optimum germination. The species is included in the endangered list.	Soil binder, wood is used as fuel. Oil from wood and leaves is used for manufacture of perfumes and medicines.
1.2 <i>J.macropoda</i> Boiss. Pencil cedar	Pakistan to Uttranchal, 2400-4300m, dry river valleys, gregarious, forming open forest in Lahaul	A tree upto 18m, very like <i>J.indica</i> , but fruit with 2 or more seeds, and with light open foliage with spreading sharp pointed leaves on lower branches and with scale like leaves on upper branches and branchlets. Lower leaves linear 8mm, scale leaves c. 1.5mm. Fruit bluish- black, resinous.	Regeneration through seed. Natural regeneration deficient. There is need to develop suitable seed pre-treatment techniques.	Wood most valuable for furniture, building and pencil making, also used for fuel and charcoal, good soil binder. Essential oil also useful for preparation of perfumes.
2. <i>Hippophae- Seabuckthorn</i> (Elaeagnaceae) A deciduous, somewhat spiny shrub or small tree. Flowers one-sexed, occurring on different plants, borne on previous year's shoots. Leaves 6mm or more broad with star-shaped hairs. Can resist low temperature upto-40°C, highly developed root system, ability to fix atmospheric N @ 180kg/ha/yr. high calorific value fuel wood 4500 cal/gm.				
2.1 <i>H.rhamnoides</i> L. subsp. <i>turkestanica</i> Rousi	Pakistan to H.P.widely distributed in cold desert regions of J& K and H.P. 2100-3600m. riversides. Planted as hedge in irrigated patches.	Usually dwarf much branched very thorny shrub to tree with scaly young twigs and with a silvery waxy covering to the older shoots. Leaves smaller and narrower and clothed beneath with silvery scales.	Regeneration by seed and vegetative methods. Flowering in spring. Seeds have no dormancy and remain viable for one year. Depulped seeds show higher and	Excellent soil binder due to well developed root system. Ability to fix N. Fruits very rich in nutrients and bioactive substances such as sugar, organic acids and vitamins.

		by 2-4mm broad, green above. Fruit 6mm, orange or red.	fast germination, 65-78% in 18-25 days in nursery. Cuttings of 20cm length show better survival and rooting success (Singh <i>et al.</i> , 1997). Cuttings treated with 0.4% IBA formulation gives best rooting of 86.7% and 33.3% during August and March, respectively (Naveen, 2002).	Vitamin-C content 5-100 times higher than any other fruit or vegetable (LuRong-Sen, 1990). Very good source of fire wood in cold desert with calorific value of wood 4100 cal/kg and biomass 34.27 t/ha (Singh <i>et al.</i> , 1991).
2.2 <i>H. salicifolia</i> D. Don	H.P. to S.E. Tibet. 2000-3500m. Colonize alluvial gravel, river side wet slips.	A deciduous thorny shrub or small tree upto 5m, with rusty scaly shoots and oblong-lanceolate leaves with dense stalkless clusters of yellowish brown male flowers, female flowers solitary on leafless stems. Leaves 3-7 by 6-8mm broad with star shaped hair beneath. Fruit c.7mm globular, orange or red, succulent.	Seeds and vegetative parts.	Excellent soil binder, fixes N, yields fuel wood, fruit rich in nutrients, bioactive substances and vitamin-C. Pulp and seed high medicinal value.
2.3 <i>H. tibetana</i> Schetr	H.P. to S.E. Tibet. N.W. China. 3300-4500m. Riversides, stony moraines, gregarious	A very dense much branched shrublet, with long stout terminal spines formed from the tips of old branches, small narrow-elliptical leaves, covered with rust coloured scales. Flowers stalkless, yellowish in clusters appearing on leafless stems. Leaves blunt 1.5-2cm by 2-5mm broad, numerous. Ripe fruit orange-red.	Seed and vegetative parts	Excellent soil binder, fix N, yields fuel wood, fruit rich in nutrients, bioactive substances and vitamin-C. Pulp and seed high medicinal value. Bark is reported to have tumour inhibiting activity.

<p>3. <i>Ephedra gerardiana</i> Wallich ex Stapf (Fam: Ephedraceae)</p>	<p>Afghanistan to Bhutan. 2400-5000m. Stony slopes, gravel terraces in drier areas of cold desert i.e. Ladakh and Spiti. Other species of the genus found in Spiti are <i>E. equisetina</i>, <i>E. intermedia</i> and <i>E. monosperma</i></p>	<p>A low growing rigid tufted shrub 30-60cm, with numerous densely clustered erect slender smooth green jointed, branches arising from a branched woody base. Male cones ovate, solitary or 2-3, with 4-8 flowers. Female cones usually solitary. Fruit ovoid 7-10mm, with fleshy red succulent bracts enclosing 1-2 seeds.</p>	<p>The natural regeneration is through seed and root suckers.</p>	<p>Goats and yaks feed on the branches during winter. Plant used medicinally, it yields the alkaloid ephedrine, a decoction of stems and roots is popular remedy for rheumatism and syphilis in Russia.</p>
<p>4. <i>Capparis spinosa</i> L. CAPER (Fam: Capparidaceae)</p>	<p>Afghanistan to E.Nepal. 2000-3000m. Stony slopes in dry valleys</p>	<p>A straggling spreading shrubby plant with two ranks of rounded rather leathery leaves with spiny branches and with large solitary axillary whitish to pinkish flowers with long purplish stamens and a longer stalked ovary. Flowers 3-8cm across, leaves variable, ovate to elliptic, 1-4 cm, mostly spine tipped. Fruits fleshy, oblong ellipsoid with red pulp and brown seeds.</p>	<p>Natural regeneration through seed mainly.</p>	<p>The flower buds are edible. The roots, leaves and bark are used medicinally. Important role in feed, fodder and soil and water conservation. The dry bark of the root is considered diuretic.</p>
<p>5. <i>Rosa webbiana</i> Wallich ex Royle (Fam: Rosaceae)</p>	<p>Pakistan to W.Nepal. 1500-4100m. Rocky slopes, naturally occurring in Lahaul and Spiti and parts of Ladakh regions and Kumaon, associated with <i>Juniperus macropoda</i>.</p>	<p>Common pink flowered rose of W.Himalaya. A deciduous shrub upto 2.5m with slender branches with straight prickles and leaves with small rounded leaflets and prickly leaf-stalks. Flowers 2.5-7cm across. Leaflets 5-9. Stems and leaves often turning bright pinkish, fruit-red/ ovoid to flask shaped. Flowers appear in June- July and seeds mature in Oct-November.</p>	<p>Natural regeneration through seed. Seed have seed coat dormancy. Maximum germination of 90% was recorded in seeds treated for 20 min. duration in conc sulphuric acid. Propagates well through shoot cutting and root suckers. (Singh et al.,1997)</p>	<p>Soil stabilizer binder, fruits are used as an application to wounds, sprain injuries and foul ulcers. Fruits are eaten and contain high content of Vitamin-C. Total biomass basis on dry matter was 5.42 kg/plant (Singh et.al, 1997). Used as fuel. Calorific value 3.8 kcal/g.</p>

<p>6. <i>Ribes orientale</i> Desf (Fam: Grossulariaceae)</p>	<p>Afghanistan to W.Nepal. Bhutan. S.W. China 2100-4000m stony slopes, rocks</p>	<p>A shrub 1-2m with glandular hairy twigs with small shallowly 3-5 lobed leaves, reddish purple unisexual flowers. Leaves 1.2-3.5 cm broad, rounded and kidney shaped. Berries globular, deep red, sparsely glandular hairy.</p>	<p>Regeneration through seeds</p>	<p>Soil stabilizer and important from medicinal point of view. Fruit is cooling, laxative and anydone.</p>
<p>7. <i>Elaeagnus parvifolia</i> Wallich ex Royle (Fam: Elaeagnaceae)</p>	<p>Afghanistan to S.W. China, 1500-3000m, common throughout Himalayas</p>	<p>A deciduous, somewhat spiny shrub, with oblong elliptic leaves, dull yellow white fragrant flowers appearing with young leaves. Flowers few, in axillary clusters. Leaves alternate, lateral shoots ending in a straight thorn, shrub upto 2m or more. Fruit ovoid, fleshy, edible, red, covered with silvery scales.</p>	<p>Regeneration through seed and root suckers.</p>	<p>A good soil binder, fodder and fuel wood.</p>
<p>8. <i>Colutea nepalensis</i> SIMS. (Fam: Leguminosae)</p>	<p>Important shrub of cold desert region of India, found in inner Himalayas from Afghanistan to Nepal between 2450-3450m elevation. Its associates are <i>Rosa webbiana</i>, <i>Ephedra gerardiana</i> and <i>Capparis spinosa</i>.</p>	<p>An erect, nearly glabrous shrub. Leaves odd pinnate 2-6cm, obovate, flowers yellow, often tinged with red. Calyx bell shaped. Ovary stalked, pubescent. Pod bladder like, ovoid, seeds many – kidney shaped.</p>	<p>Natural regeneration through seeds and root suckers. Germination upto 60% in nursery and 80% in lab. was recorded (Singh and Jishtu, 1997). Good coppicing capacity.</p>	<p>Provides effective soil cover. The contribution of above ground biomass is more to total biomass than root biomass. Very good fuel with calorific value 4000 to 4500 cal/g Biomass per plant is 5-7 kg. (Singh and Jishtu, 1997). Wood is used for preparing baskets and leaves as medicine.</p>

9. <i>Myricaria germanica</i> (L) Desv. (Fam: Tamaricaceae)	Pakistan to Kashmir, W. Asia, 1500-2100m. River sides, common and gregarious in Kashmir and H.P.	An erect shrub 1-2m. Flower spikes 10-20 cm or more long terminal and lateral with large reddish often quite papery bracts which are broadly trapezoid. Flowers pinkish-red, c.5mm. Spikes elongating in fruit. Leaves 2-3mm, densely clustered. Fruits 8 mm.	Regeneration by seed mainly.	Soil binder, fuel, medicinal value.
9.1 <i>M. elegans</i> Royle	Pakistan to Kashmir, 2700-4000m, stony slopes, common in Ladakh	An erect shrub 3-4 m with brown stems, leafy lateral branches, many long lateral spikes of white or pinkish-tinged flowers. Spikes upto 10 cm or more, petal 5mm, rounded, stalked. Leaves elliptic, 1-1.5cm. Fruit c.1cm, spindle shaped, glaucous.	Regeneration by seed mainly.	Soil binder, fuel, medicinal value.
10. <i>Artemisia</i> Wormwood (Fam: Asteraceae)	An erect annual or perennial. Leaves much dissected. Flower heads small, usually in branched leafy clusters. The species occurring in cold desert are <i>A. sieversiana</i> , <i>A. wallichiana</i> , <i>A. brevifolia</i> , and <i>A. dracuncululus</i> .			
10.1. <i>A. brevifolia</i>	Pakistan to W Nepal. Tibet 2100-4200 m. Dry stony slopes. Common in Ladakh and Lahaul & Spiti.	A much branched stiff, strongly aromatic, shrubby perennial with dissected pale grey to almost white leaves and with narrow branched spikes of axillary clusters of yellowish to reddish flower heads. Heads ovoid. Leaves ovate. Stem 15-40 cm.	Regeneration by seed and root suckers.	Soil binder, fuel and also used medicinally and for the production of santonin used internally against worms.
11. <i>Potentilla</i> (Fam: Rosaceae)	N. temperate region, mountainous regions. Shrubs or herbs, rarely annual, usually softly hairy. Leaves stalked, digitately compound, 3-5 leaflets or pinnately compound from 3 to numerous leaflets. Flowers usually yellow some white, purple or red. Petals 5, stamens numerous rarely 5-10, ovary solitary.			
12. <i>Caragana</i> (Fam: Leguminosae)	Spiny shrub, leaves pinnate, ending in a hardened spine. Pod oblong. Leaflets. crowded.			

12.1 <i>C. brevifolia</i> Komarov	Kashmir to Uttranchal. 3300-4500m. Alpine steppe country. Common in Ladakh	A densely branched, spreading or erect, very spiny shrub upto 60cm, with solitary yellow often orange- flushed flowers. Flowers larger upto 2cm, yellow streaked with red. Leaflets mostly 1cm. Pod 3 cm, hairless, leaves pinnate and flowers nearly stalkless.	Regeneration through seed and root suckers. Good coppicer.	Soil conservation and fuel wood.
12.2 <i>C. gerardiana</i>	Pakistan to C. Nepal, 3000- 4100m, dry open slopes.	A densely branched, very spiny shrub, 90- 120 cm, often forming tight clumps in dry arid areas, pinnate leaves and with almost stalkless, usually solitary yellow flowers. Flowers c.2cm. Leaflets 8-12 Spines 1-4 cm. Pod 1.2-2cm, with dense grey hairs.	Regeneration by seed and root suckers. Good coppicer.	used as mainly fire wood and soil binder.
13. <i>Astragalus</i> (Fam: Leguminosae)	Small spiny shrub or shrublets forming low clumps or mats. Common in drier areas. Distinguished from related genera by the tubular calyx with 5 short teeth or lobes, and by the pod which is often longitudinally divided into 2 chambers. Important species in cold arid region are : <i>A. grahamianus</i> Royle ex Benth: Pakistan to Uttranchal. 1500-3300m, open slopes, stony ground, common in Kashmir and Lahaul. <i>A. zanskarensis</i> Benth ex Bunge : Kashmir, 3000-4300m., stony slopes, common in Ladakh and Zaskar. <i>A. himalayanus</i> Klotzsoh : Pakistan to E.Nepal, 2400-4500m, open slopes, common in Kashmir.			
13.1 <i>A. candolleanus</i> Royle ex Benth	Pakistan to Nepal. 2700- 4500m. Alpine slopes, inner valleys of cold desert.	A low compact shrublet, with yellow flowers in dense stalkless clusters, pinnate leaves, long spines formed from the rachis of old leaves. Flowers 1.2- 2.5cm long. Leaves 5- 10 cm, with many oblong to ovate leaflets. Pod 1.5-2.5 cm with spreading silky hairs.	Regeneration by seed and root suckers.	Excellent soil binder, used for fuel wood.
14. <i>Lonicera</i> (Fam: Caprifoliaceae)	Flowers usually in stalked pairs, with ovaries often partly fused. Corolla-tube short or long, sometimes swollen at base. Fruit of 2 often fused berries. This genus has 25 species out of which major number is present in cold arid zones.			

14.1 <i>L. spinosa</i> WALP	Afghanistan to S.E.Tibet. Alpine slopes, drier areas, dominant with <i>Caragana</i> species in Ladakh, also present in HP.	A low somewhat spiny shrub forming dense mat, leaves hairless, margins incurved. Flower c.1cm long, pale pink, several to many in almost stalkless clusters. Leaves narrow oblong 5-13mm. Branchlets spiny, often glaucous.	Regeneration by seed.	Fuel wood, soil binder.
15. <i>Salix</i> (Fam: Salicaceae) Willow Family:	<p>An important and common genus throughout the N. Temperate Zone. Deciduous trees and shrubs, with simple usually alternate leaves. Flowers unisexual, on different plants, numerous and borne in catkins. Female flowers of 2 carpels with many ovules. Fruit a capsule, seeds with a tuft of white silky hairs which aids their dispersal. The different willow species found in cold desert are many but few are described as follows:</p> <p><i>S. karelinii</i> Turcz. A shrub upto 120cm, but sometime a small tree upto 5m. 2100-4500m, open slopes, stream sides, common and gregarious in drier parts of Kashmir.</p> <p><i>S. flabellaris</i> Anderson: Afghanistan to Uttranchal, 3000-4000m, alpine slopes.</p> <p><i>S. denticulata</i> (<i>S. elegans</i> Wallich-ex Anderson): A shrub upto 3m, or a small tree upto 5m, with narrow elliptic, finely toothed leaves 4-5 cm, bright green above. Catkins appearing with the leaves, male catkins on short leafy shoots, female catkins green, borne on leafy shoots. Fruiting catkins upto 8 cm, hairless.</p> <p>Larger arboreal species of willow are very important in the economy of people in dry inner areas and are planted along irrigation channels. They are used for fuel, baskets, building and even for fodder. The commonest species include <i>S. acmophylla</i>, <i>S. alba</i>, <i>S. excelsa</i>, <i>S. fragilis</i>, <i>S. babylonica</i>.</p>			
16. <i>Spiraea</i> spp (Fam: Rosaceae)	N. temperate and cold regions. Erect, unarmed shrub or perennial herb. Leaves simple and compound, stipules usually small and soon falling off. Flowers numerous, usually bisexual. Petal 5, orbicular. Stamen 20. Style short, stigma terminal, ovules 2 – several. Fruit 3-5 small, 2-to several seeded.			

- Screening of indigenous and exotic species for selection of suitable species for different niches.
- Develop appropriate techniques for Seed Technology i.e. seed collection, seed maturity indices, seed handling and seed storage as well as seed pre-treatments.
- Undertake studies to develop macro-propagation methods, particularly, in species where there is inadequate seed production, seeding after long time, low-seed viability, poor germination due to dormancy etc.
- Develop cost effective nursery production and plantation techniques.
- Legal ban on uprooting of shrubs for fuel wood/ medicinal purposes. This will be, however, possible only if we ensure ample supply of fuel wood to locals.
- Encourage people to grow shrubs around their habitations and also on bunds of armlands (Agri-silviculture system) or non-arable lands (silvi-pastoral system).
- Encourage local people to create plantations and educate them about the importance of "Greening of Cold Desert".
- Establish small fruit processing units especially for proper utilization of the fruits from Hippophae etc. on similar lines as prevalent in China.

Table 3: Important medicinal plants of cold desert

S. No.	Species	Family	Common name	Plant part used	Used in Disorder
1.	<i>Aconitum heterophyllum</i> Wall.ex Royle	Ranunculaceae	Atees	Roots	Diarrhoea, abdominal disorders and fever.
2.	<i>Artemisia maritima</i> L.	Asteraceae	Khamba	Unopened flower heads	Antiseptic, vermifuge used for wounds and cuts, anthelmintic.
3.	<i>Astragalus himalayanus</i> Klotz	Fabaceae	Sadnak	Roots	Chronic bronchitis, cough-colds, and decoction.
4.	<i>Capparis spinosa</i> L.	Capparidaceae	Kabra	Roots and Fruits	Root bark is used as an expectorant, tonic, anthelmintic, in splenic disorders and in rheumatism. Fruits are used in dismenorrhoea. Ripe fruits used in pickle.
5.	<i>Colchicum luteum</i> Baker	Liliaceae	Kapichum	Bulbs	Tonic, carminative, laxative, aphrodisiac, gout, rheumatism, liver and spleen disorders.
6.	<i>Ephedra gerardiana</i> Wall.ex Stapf	Ephedraceae	Taapat	Whole plant	Asthama, blood ailments, liver disorder. Ripe fruits are eaten.
7.	<i>Euphorbia tibetica</i> Boiss	Euphorbiaceae	Tharnu	Roots and Latex	As purgative, latex used in skin disorders.
8.	<i>Gentiana kurroo</i> Royle	Gentianaceae	Tikta	Whole plant	Decoction in fever, blood purifier, headache, cough and liver ailments.
9.	<i>Hippophae rhamnoides</i> L.	Elaeagnaceae	Seabuckthorn, Chharma	Fruits	bronchial asthma, liver ailments and skin disorders. Also helps in reducing high cholesterol level in the body and the ability to aid healing of wounds.
10.	<i>H.salicifolia</i> D.Don	Elaeagnaceae	Tarboo	Fruits and Bark	Bark used as an anticancer drug, ointment.
11.	<i>Juniperus communis</i> L.	Cupressaceae	Dhoop	Whole plant	It is called local Doctor in cold desert. Fruits are carminative, stimulant and diuretic.
12.	<i>J.recurva</i> Buch-Ham.	Cupressaceae	Dhoop	Whole plant	Fruit are carminative, stimulants and diuretic.
13.	<i>Myricaria germanica</i> (L.) Desv.	Tamaricaceae	Umbu	Leaves, Stem and Bark	Decoction is used as blood purifier.
14.	<i>Podophyllum hexandrum</i> Royle	Podophyllaceae	Rodhadri	Roots	Decoction in diarrhoea, liver ailment, purgative, vermifuge and anticancer.
15.	<i>Potentilla fruticosa</i> L.	Rosaceae	Sparg-Cha	leaves	It is used as substitute of tea in cold desert. It is also used as astringent, antispasmodic, in diarrhoea, kidney stones, arthritis and cramps.
16.	<i>Rosa webbiana</i> Royle	Rosaceae	Chua	Fruits	Headache and liver ailments. Ripe fruits are eaten.

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Ethnobotany of Shrubs of Cold Arid Zone in Western Himalaya

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The Hindu Kush Himalayan region has vast tract of well known cold arid zone and the significant part of this land is in Afghanistan, Pakistan, India, Nepal, Bhutan and China. In India, cold deserts occur in Ladakh region of Jammu and Kashmir, Spiti Valley of Lahaul-Spiti District and Pooh sub division of Kinnaur District of Himachal Pradesh and small portion on Uttar Kashi (Nilang Valley) and Chamoli district (Mana and Niti Valley beyond Malari) in Uttaranchal. The total area of cold desert in India is approximately 98660 sq. km. In Jammu and Kashmir, the area lies between 32°15'-37°20'N and 72°30'-80°15'E and covers approximately 82,665 sq. km. In Himachal Pradesh, the area lies between 31°10'-33°57'N and 76°46'-79°E and covers approximately 15,000 sq. km. In Uttaranchal, the area lies between 30°64'-31°46'N and 79°-80°E and covers approximately 1000 sq. km. Approximately 37,500 sq. km is under illegal occupation of Pakistan and China. These regions have distinctive characteristics from those of the hot deserts in that the precipitation is mostly in the form of snow and the areas are cut off from the main land for over five months in a year with the temperature going as low as (-) 40°C.

Climate and Vegetation

Cold arid zones are characterized by unique socio-economic and ecological components, inviting special conservation issues. Vegetation of these regions is shrubby with numerous seasonal herbs of medicinal and aromatic value. Fuel-wood and fodder are the main constraints and natural regeneration is poor. In addition, man made forests are also found along river banks and nallahs comprising mostly of Poplars, Willows, *Hippophae* and *Myricaria* species. The Lahaul Valley and Pir Panjal areas are still alluvial and possess some forests on deposits, while in Spiti and Sumdo areas, the old (monumental) trees can be counted on fingers.

In spite of the fact that the soils are rich in nutritive minerals, Ladakh is devoid of any forest due to extreme water shortage, temperature fluctuations and peculiar climatic conditions. Scarcity of water and poor sand soil binding capability do not allow any natural forest to develop. Since the growing season in Ladakh is very short, the new growth of each plant is very small. The most conspicuous character of the vegetation is the cushion like habit of plants with spinous tipped leaves. The

vegetation can be classified into alpine mesophytes, oasisitic vegetation and desert vegetation.

The vegetation of Lahaul-Spiti, Kinnaur and Garhwal Himalayas is quite similar to that of Ladakh region; although the three categories of vegetation i.e. mesophytes, oasisitic and desertic may not be clearly marked. The vegetation of these regions has its own peculiarities. Generally, the vegetation is of dry temperate to dry alpine type. The flora is of steppe type and is rich at the lower elevations. A remarkable feature of the vegetation of the Lahaul and Spiti valley is that the South and East facing hilly slopes are particularly devoid of any vegetation and the North and West facing slopes show growth of plants.

The flora of Western Himalaya in general is controlled broadly by altitude and climate and more significantly by soil drainage, aspect and micro-climate. The vegetation of the cold arid regions in the Trans-Himalayan zone consists of a highly specialized group of plants with metabolic and reproductive strategies suitable for maximizing their activity in specialized harsh climatic conditions like very scanty rainfall, extreme diurnal fluctuation of temperature, meagre humidity, heavy snowfall, ultraviolet radiation, soil textures, etc. The vegetation is not compact, but is very typical. The number of species decreases as one moves towards high cold arid regions due to harsh climatic factors.

The overall vegetation in the cold arid zone is sparse, discontinuous and scattered. The only green patches soothing to the eyes are available around the villages. Main species growing in these areas are: *Juniperus macropoda*, *J. recurva*, *J. communis*, *Betula jaquemontii*, *Pinus gerardiana*, *Populus balsamifera* *P. ciliata*, *P. nigra*, *P. alba*, *Salix fragilis*, *S. flabellaris*, *S. elegans* and *Fraxinus zanthoxyloides*. Shrubby element is mainly dominated by *Hippophae rhamnoides*, *H. salicifolia*, *H. tibetica*, *Myricaria germanica*, *M. elegans*, *Rosa webbiana*, *Capparis spinosa*, *Colutea multiflora*, *Cotoneaster microphyllus*, species of *Salix*, *Ribes*, *Berberis*, *Potentilla*, *Crataegus*, *Lonicera*, *Caragana*, *Astragalus* etc. *Ephedra gerardiana*, *E. intermedia* and *Artemisia brevifolia* are the commercial medicinal and aromatic species forming vast patches as low scrubs. *Arnebia euchroma*, *Allium* species, *Dactylorrhiza*

hatagirea, *Convolvulus arvensis*, *Heracleum candicans*, *Gentiana tianschanica*, *Gentianella* species etc. are the other valuable medicinal herbs commonly growing in the area. Many species like *Centaurea depressa*, *Lonicera spinosa*, *Arnebia euchroma*, *Allium rubellum*, *Hyssopus officinalis*, etc. are endemic to the area.

Since the soil substratum in the cold deserts is quite fragile, the continuous extraction of medicinal species for export, fodder and fuel for local consumption is causing further degradation of genetic resources. Shrubs growing in these areas are playing significant role in the soil stabilization, beside meeting the ever increasing demand of fuel and fodder. People of the area are heavily dependent upon the shrubby vegetation for meeting their multifarious needs. In this paper, the main shrubby species of these ecologically unique areas have been described briefly along with their habitat description flowering/fruitletting period, economic uses, keeping in view the socio-cultural settings and other interactions, the local inhabitants have with the surrounding floristic elements. The important shrubby species have been discussed here in an alphabetical order:

***Artemisia brevifolia* Wall. ex DC. Prodr. (Compositae)**

Local/Common name(s): Kirmala, Nurchar, Seinski, Bhurse

A stout, much branched, scrub like perennial and aromatic shrub found in Ladakh, Kinnaur and Lahaul-Spiti districts of Himachal Pradesh at the elevation of 2100-4200 m on dry slopes. It forms vast patches in Udaipur range in Lahaul and Spiti and Kaa slopes in Kinnaur.

It is, 1.0-1.5 m tall, having multiple branched root-stock with upright, round, grooved, paniculate branched stems. Leaves are slightly rolled at the edges, multifold and white felted beneath. Flowers- yellow to red brown in shortly pedicellated flowers heads.

Flowering and Fruiting: June to October

Chemical constituents: Plant yields an essential oil, santonin (0.5-1.0 %) and a bitter substance artimisin. Santonin obtained from the plant is used in bitter pills used in the treatment of hookworm infestation in tribal areas.

Uses: Dried immature leaves and flower heads constitute the drug, which is used for expelling worms from the stomach and used in fever, dropsy and as a stimulant. It is also used as an insecticide. The plant is also being investigated for anticancer properties. The aerial parts

are spread over the cattleshed surfaces to expell harmful insects and also as a mulch.

***Astragalus candolleanus* Royle ex Benth.**
(Leguminosae)

Local/Common name(s): Rudanti, Rudrawanti, Khilla

It is found from Pakistan to Nepal between 2700-4500 m. in alpine slopes, common in Lahaul-Spiti, Ladakh and some inner valleys of Nepal. It is a low, compact shrub having leaves with many, oblong to ovate leaflets. Rachis of old leaves becomes woody and spiny. Flowers are yellow in dense stalkless clusters, set among pinnate leaves. Calyx often reddish, densely silky haired.

Flowering and Fruiting: May-June

Uses: Root powder and decoction is used in tuberculosis, in skin diseases, cough and as blood purifier. The total plant with roots is collected and thatched on rooftops for being used as fuel during winters.

***Astragalus grahamianus* Royle ex Benth.**
(Leguminosae)

Local/Common name(s): Chhichhar, Khilla

A low, very spiny shrub, found in Pakistan, Uttar Pradesh in open slopes, stony ground, common in Ladakh and Lahaul-Spiti and sparsely found in Pooh division of Kinnaur between 1500-3500 m. Leaves are pinnately compound, 3.5-7.5cm. long, ending in spiny rachis; leaflets 8-14, obovate, obtuse, retuse, mucronate, glabrous above, pubescent beneath; stipules large, amplexicaule. Flowers usually 2, in the leaf axils. Corolla yellow. Pod oblong, appressly pubescent.

Flowering and Fruiting: May-August.

Uses: Used in fever and insanity.

***Astragalus zanskarensis* Benth ex. Bunge**
(Leguminosae)

Local/Common Name: Fatula

It is found in Kashmir along stony slopes; common in Ladakh and Zaskar. A spiny shrublet forming compact rounded clumps, but restricted to the dry areas of the North-West Himalaya. Flowers 1.8-2 cm long; standard longer than wings or keel; calyx densely silky-haired. Leaflet 20-26, oblong blunt 6-10 mm with short brown hairs.

Flowering and Fruiting: June-August.

Uses: Helps in soil/sand binding, fodder for browsing cattle; for thatching of muddy roofs and as fuel wood.

***Berberis jaeschkeana* Schneid in Bull Hebser
Boiss. (Berberidaceae)**

Local/Common name(s): Kashmal

It is a deciduous shrub upto 1.0 m tall, found between Pakistan to East Nepal, 2700-4000 m. in alpine meadows and frequent on dry slopes in Kinnaur in H.P. Stems are stout, angular at first, slightly reddish, yellow-brown at maturity; spines-3 fid. Leaves oblong-elliptic, sessile or sub-sessile. Flowers in umbels or sub-umbellate, 3-5 (-8)- flowered. Fruit oblong-ovoid.

Flowering and Fruiting: June-October

Chemical constituents: Roots contain berberine, berbericine, palmatine.

Uses: The ripe fruits are eaten and roots are used as remedy for eye troubles. Branches are often used as fuelwood.

***Capparis spinosa* L. (Capparaceae)**

Local/Common name(s): Rutokpa, Martokkpa, Kabra

It is a dominating, trailing shrub of the cold deserts. *Capparis spinosa* shows its presence with long green branches and thick woody roots even on very hot, dry rocks and steep hill slopes. It is found in North-West Himalayan regions of Kinnaur, Lahaul-Spiti and Ladakh etc. ascending to 3800m. It has variable leaves, orbicular or from broadly ovate to obovate retuse or sometimes acute, mucronate, entire, rounded or cuneate at the base, glabrous or more or less pubescent. Flowers are handsome with long purple stamens, solitary, axillary pedicels 2.5-5 cm long, thickened in fruit. Fruit 2.5-5 cm long, obovoid, ribbed red when ripe, seeds globose, smooth and brown embedded in red pulp.

Flowering and Fruiting: July-September

Chemical constituents: Flower buds contain glucoside, rutin and pentosans (4%) on dry weight basis. Seeds yield:- 34-36 per cent fatty oil, used as massage in rheumatic joints.

Uses: It is used as feed, fodder and for soil and water conservation. The root bark is bitter tonic, expectorant, anthelmintic and diuretic. Flower buds and fruits are considered appetizing and diuretic. Pickled flower buds are useful in scurvy. Bark is also used in affection of liver, rheumatism and paralysis. It is an ingredient of Liv-52. Unripe fruits are used as vegetable while the ripe fruits are edible. The oil extracted from the seeds is used as a massage to cure joint pains and swellings.

***Caragana brevispina* Royle (Leguminosae)**

Local/Common name(s): Satbargi, Nyamzo, Burkundu

An erect spiny shrub 2-3 m. found in Ladakh, Spiti and Pooch division between 2400-3200 m. in shrubberies and dry slopes. Flowers usually 2, yellow, often flushed with red, borne on a stalk upto 2 cm; bracts linear. Standard 2-2.5 cm long, rounded with reflexed sides, thicker and firmer than the wings and straight keel, calyx 7-9 mm, finely hairy, lobes short with awn-like tips. Leaflets 8-16, ovate to oblong, 8-20 mm, with a fine point, silky haired beneath. Old leaves hardening into long thick spines to 4 cm with small basal spines; young branches downy. Pod hairless, 4-5 cm.

Flowering and Fruiting: May-June

Uses: The young flowers are eaten by children. As extremely spiny and compact shrub, it helps in soil binding and nitrogen fixation, thus improving the soil health.

***Caragana gerardiana* Royle ex Benth
(Leguminosae)**

Local and Common name(s): Shinaluk, Jirral, Trama

It is found in inner North-west Himalyan regions of Kinnaur, Spiti, Garhwal and Kumaon. It is a shrub upto 120 cm tall, with young branches densely pubescent. Leaves are pinnate; rachis 1.2 - 4.0cm. long, persistent, spiny; leaflets 8-10, oblanceolate, acute, densely silky, pubescent on both sides. Flowers 1-2, sub-sessile, axillary yellow. Pods 1.5 -2.0 long, pubescent externally and woolly internally.

Flowering and Fruiting: May-August

Uses: Used as firewood in tree less country and is also browsed by sheep, goats and chigu. The entire shrub is removed from above the ground level and used for thatching of floors/roofs.

***Clematis vernayii* C. Fisher (Ranunculaceae)**

Local/Common name(s) : Emong

It is a climbing shrub, found growing on walls, field borders and slopes in various parts of Spiti, Pooch and Ladakh between 1800-4000 m. especially in irrigated land in dry Tibetan border areas. Flowers are dull reddish-yellow to yellowish green with broad, blunt, spreading petals to 3 cm long, which are densely hairy inside and hairless outside.

Flowering and Fruiting: July-August

Chemical Constituents: Aerial parts contain ranunculin and an aglycone.

Uses: Leaves and fruits are used in skin diseases.

***Colutea nepalensis* Sims. Bot. Mag. t.**

(Leguminosae)

Local/Common name(s): Bladder-Senna (Nepal), Braa (Ladakh)

Found in Arid valleys of inner Himalayas in Ladakh, Spiti, Kinnaur and Kumaon (2600-3500 m.). It is a shrub with smooth, reddish-brown bark and fascicled branchlets. Leaves are glabrous, common petiole is 5-10 cm. long; leaflets 7-9 oval or obovate, 0.6-1.25 cm. long; lateral nerves indistinct. Flowers large, greenish yellow, in slender, drooping racemes. Pod membranous, inflated, about 2 inch long, hairy.

Flowering and Fruiting: July-September

Uses: Leaves are purgative and seeds are emetic and often used as an adulterant of Senna.

***Cotoneaster microphyllus* Wall. ex Lindle**

(Rosaceae)

Local/Common name(s): Cunats, Pasarni, Khariz, Luni, Ghaduli, Bhedda

It is common in the Himalayas from Kashmir to Bhutan, 2300-3300m. It is an erect or prostrate evergreen shrub with a small, coriaceous glossy dark-green, obovate or cuneate-oblong leaves; solitary, large, showy white flowers; nearly 1.25 cm. across, and ovoid scarlet fruits (on ripening).

Flowering and fruiting: May-June

Chemical constituents: The plant contains HCN-glucoside. Leaves contains sorbitol and a cyanogenetic glucoside prulaurasin. The young twigs contain sorbitol and hydrocyanic acid.

Uses: Used for making baskets. The ripe fruits are edible. Its stolons are used as an astringent. Under the name of "Pasarni", the paste of the twigs is used in the treatment of 'Herpes' (Brahmasutri) in lower areas of Himachal Pradesh. It is also used as fuel wood.

***Crataegus songarica* C. Koch Syn. *C. oxyacantha* Linn. (Rosaceae)**

Local/Common name(s): Hawthorn, Ringo, Phindak, Patkhan, Ban-sanjji

A shrub or a small tree upto 8 m tall with greyish branches, found in Afghanistan to Uttar Pradesh between 1500-2700 m. near cultivated area; quite common in Kashmir and Chenab valleys. Leaves deeply and sharply lobed and the branches bear lax, flat topped clusters of white flowers. Flowers 1.5 cm across, long-stalked; calyx woolly-haired below. Leaves deeply cut to two-thirds of their width into parallel-sided lobes with coarse acute teeth; blade broadly ovate or rhombic in outline, 3-5 cm; leaf-stalk nearly as long. Fruit red, globular giving an appearance of miniature apple.

Flowering and Fruiting: May-September

Chemical constituents: (+) catechin, (-) epicatechin, apigenin and rutin have been detected by HPLC from leaf, bud and flowers of this shrub.

Uses: The ripe fruits are eaten by the local people and also cherished by birds. Brandis says that the fruits of Himalayan Hawthorn are better in quality than the European and the wood is used as fuel and timber by the local people. Fruits are reported to be useful for heart problems. Wood is considered good for walking sticks.

***Ephedra Gerardiana* Wall ex Stapf. (Ephedraceae)**

Local/Common name(s): Chhe, Chedang, Somlata

A low, rigid, dense, tufted shrub, 15 cm to 1.2 m tall, naturally growing in Spiti upto Rangrik, common on river beds and amongst boulders. Other species of this genus found in Spiti area are *Ephedra equistina*, *E. intermedia* and *E. monosperma*. Stem is woody, gnarled; branchlets are green, erect or articulately ascending, interposed, .3-3.8 cm long 1.3- 2 mm diameter. Male spikes ovate, solitary or 2-3 together, flowers 4-8, Female spike usually solitary, 1 to 2 flowered; Fruit 7.5 mm long, ovoid, red, sweet and edible.

Flowering and Fruiting: June to September

Chemical constituents: Total alkaloid (Ephedrine, the principle alkaloid and pseudo-ephedrine) content in Indian Ephedras varies from 0.28-2.79 per cent. It also contains ephedroxane, (-) epicatechol, (-) epicatechogallete and (-) ephigallocatechol isolated from shoots.

Uses: The decoction of whole plant is used for chronic bronchitis, pneumonia and asthma. The local people use the fresh branches as tooth brush. The plant is also used in religious ceremonies. The tincture is an excellent cardiac stimulant to toxic conditions of the heart. Since the species forms compact patches, it is a very good soil and sand binder for the fragile landmass of cold deserts.

***Hippophae rhamnoides* Linn. (Elaeagnaceae)**

Local/Common name(s): Chharma, Tirku, Seabuckthorn

A large, thorny shrub, sometimes a small tree, found in Afghanistan and inner arid tracts of the North-West Himalayas, chiefly in the moist gravelly streambeds (Lahaul, Ladakh, upper Kinnaur, Inner Kumaon, Tibet) between 2200m-3600m. and as high as 4500m., in Tibet. Cultivated as ornamental in Europe and at Kabul.

Its leaves are subcoriaceous, 1.25-5 cm. long, linear-lanceolate or oblanceolate, narrowed into short petioled branchlets, or undersurface of leaves densely clothed with silvery or rusty coloured, circular, irregularly indented scales, upper side of leaves with a few scales when young, glabrous and dull green afterwards. Fruit-fleshy, orange or bright scarlet when ripe, seeds dark, nearly black, shining, obovoid, slightly compressed, less than 1.25 mm. long; with a deep longitudinal furrow on one side and a slightly depressed line on the other side.

Flowering and Fruiting: June-September

Chemical constituents: Plant contains steroids, terpenoids, alkaloids and sugar. Isorhamnetin-3-b-D-glucoside, isorhamnetin 3-retinoside, isorhamnetin-3- β -D-glucosido-a-L rhamnoside, isorhamnetin-3- β -isophrosido-7-L rhamnoside and a new isorhamnetin tetraside containing glucose and rhamnose isolated from fruits.

Uses: Fruits are rich in Vitamin-C. Seeds yield fatty oil. Fruits are acidic and edible, used for preparation of Jelly, Syrup, Chutney and also used against pulmonary complaints. Leaves are browsed by sheep, goats and cattle, while the twigs and branches are used as fuelwood. Caloric value of its wood is exceptionally high. Various products have been prepared in China from its fruits like wine, syrup, squash, various cosmetics, anticancer and anti-oxidants. The DRDO has floated LEH BERRY (Juice) in the Indian market.

***Humulus lupulus* Linn. (Moraceae)**

Local/Common name(s): Hops

It is a scabrid or prickly, twining shrub, native to Europe, found under cultivation in Lahaul-Spiti for its fruiting heads commercially known as Hops. Leaves are broadly ovate, cordate at the base, usually deeply 3-5 lobed. Male panicle 7.5-10.0 mm across. Female inflorescence 12-15 mm across with yellow flowers.

Flowering and Fruiting: July to September

Chemical constituents: Hops contain an essential oil, a bitter substance, choline, asparagine and lupulin.

Uses: It is used in flavouring and preservation of beverages and as tonic; considered moderately narcotic and anti-bacterial.

***Juniperus communis* Linn. (Cupressaceae)**

Local/Common name(s): Dhoop, Hauber, Chhershup, Shukpa, Bethar, Thelu.

It is common on stony slopes, in dry temperate and alpine zones of Western Himalaya and found as a common associate of *Pinus wallichiana* forest in Pattan valley in Lahaul division. The shrub is more or less procumbent. Leaves are in the whorls of 3, linear or boat shaped sharply pointed, spreading nearly at right angles from the branchlets. Flowers dioecious, axillary. Fruit subglobose, blue-black, glaucous. Seeds 1-3.

Flower and Fruiting: June-October

Chemical constituents: Berries contain oxalic acid, essential oil (0.8-1.2%), resin (8%), juniperine (0.36%). Bark contain tannin. Fruits and roots yield dyes.

Uses: The wood is used as fuel and the roots are collected for the preparation of essence by the local people. Leaves are useful in sciatica and rheumatism. It is also used in curing dropsy and diseases of urinogenital tracts. The twigs are lopped and used in 'Havana' - a religious worship process and the branches are used as fuelwood in alpine pastures by Gaddies and Gujjars.

***Juniperus recurva* Buch-Ham. ex D Don (Cupressaceae)**

Local/Common Name(s): Hauber, Dhup, Bithar, Theleru, Shurr, Pama, Tupi

The shrub is distributed throughout the temperate and Alpine Himalayas and Assam between the altitudes of 2200m-4500m. It is found in the district of Shimla, Sirmour, Kangra, Chamba Kinnaur and Lahaul-Spiti in H.P., between the elevation of 3000-5000m.

It is a low spreading shrub with awl-shaped leaves, 6-8 mm long, in whorls of three. Growth rather lax; stem often brown with ultimate branches tall like and curving separately in various directions. Fruits purplish brown to black, shining when ripe, ovoid 8-13 mm., 1-seeded.

Flowering and Fruiting: June to September

Chemical constituents: Plant yields isocedric acid and 4-Ketoceryl. Leaves yields biflavonoides and essential oil.

Uses: Wood is used for making pencils and Pen-holders. The leafy twigs are used in "Havana" as an aromatic ingredient for Dhoop. Wood is also used as fuel.

***Lonicera govaniiana* Wall. ex DC.**

Local/Common name(s): Karmo

An erect, glabrous shrub upto 2.5 m tall found along river banks. Leaves petiolate, ovate or ovate-lanceolate, acute, base truncate or sub cordate, glabrous on both surfaces. Flowers 0.7 cm long, each pair borne on a single axillary peduncle. Bracts are linear; corolla pink, 2-lipped. Stamens and style rather shorter than the corolla. Berries globose, black on ripening.

Flowering and Fruiting: June-August.

Uses: The branches are used as brooms. Handspindles for wool spinning are made from the older branches. The people believe that if a tiny species of shrew bites the cattle and causes blot or swelling, an arrow of this plant is shot into the wound and a paste of red earth is applied as a cure.

***Lonicera spinosa* (Jacq. ex) Decne Walp.**
(Caprifoliaceae)

Local/Common Names: Trapp, Thapp, Tharsey

It is a rare compact, flattened shrub on glacial stony slopes in inner arid Himalayas and Tibet between 3200m to 4500 m. It is often dwarf, rigid shrub with often spinescent and leafless branchlets. Leaves are linear-oblong, minute with revolute margins, shortly petioled or sub-sessile. Bracts linear-oblong, foliaceous. Corolla white, tinged with pink. Berries ellipsoid, pale bluish red to almost white.

Flowering and Fruiting: June-August

Uses: The flat umbrella type spreading shrub is cut across the soil substratum detaching it from the root at collar portion and the entire spread of the shrub is utilized for thatching of muddy rooftops giving it strength and rigidity, protection from moisture seepage etc. Heaps of the shrub are a common scene on rooftop of the households in cold deserts for being used as fuel wood during snowy winter months.

***Myricaria elegans* Royle** (Tamaricaceae)

Local/Common name(s): Humbu, Umbu

An erect shrub, 3-4 m, with brown stem found in cold desert areas between Pakistan to Kashmir (2700-4000 m) on Stony slopes; common in Ladakh and Spiti along river banks and water courses forming dense patches at places and interrupted at others. Leaves oblong, lanceolate. Flowers pink and white in lateral and terminal spike like raceme.

Flowering and Fruiting: July-September

Uses: Twigs are used as cattle feed, while the wood is used as fuel. Leaves have antiseptic properties, which are applied to cure foul ulcers. The flowering shrub gives beauty to the landscape and protects the soil from water erosion.

***Myricaria germanica* Linn.** (Tamaricaceae)

Local/Common name(s): Hombuk, Umbu

It is an erect, bushy shrub, 2-3 m tall common along sandy river beds. Leaves are oblong-ovate to linear-lanceolate, sessile, often crowded. Flowers pink to purplish- white, in lateral or terminal spike-like dense racemes. Bracts ovate-lanceolate, 3-4 times as long as the pedicles, with broad scarious margins. Sepals free, lanceolate, shorter than the petals. Petals free. Stamens 10, alternately long and short.

Flowering and Fruiting: July to September

Uses: The Wood is used in making of weaving shuttles. The plant is used in preparation of rheumatic poultices. It acts as a soil binder along river beds and shores. A single monumental tree like plant can be seen in Gue village in Spiti (as an exception).

***Potentilla arbuscula* D. Don** (Rosaceae)

It is an erect or prostrate shrub, common on rocks and sandy gravelly slopes. Leaves are pinnate, variable in length, leaflets 3-7, oblong lanceolate or linear-lanceolate, entire, silky hairy above, glabrous beneath. Flowers solitary or terminal. Calyx lobes ovate-lanceolate or lanceolate. Petals yellow, obovate, much exceeding the sepals. Achenes numerous.

Flowering and Fruiting: July-September

Chemical constituents: Leaves yield triterpene.

Uses: The shrub alongwith its roots are collected staked alongwith other woody material for use as fuelwood during winters.

***Potentilla fruticosa* Linn.** (Rosaceae)

Local/Common name(s): Penma, Pinjung, Shang-Cha

A silky, dwarf, densely tufted shrub upto 120 cm high found in temperate and Sub alpine Himalayas at altitudes of 2,400-6000 m. and has also been recorded from Chenab basin, Spiti, Ladakh and West Tibet and Uttaranchal. Leaves are compound, aromatic with 3-7 narrowly lance-shaped, leathery, leaflets, arranged like the fingers of a hands; leaflets, 1.3 cm long on slender

stalks. Flowers white, 1.6-3.8 cm across, usually solitary or few together. Fruits consisting of numerous, minute fruitlets with long hairs and sunk in the dry cup of the fruit stalk.

Flowering and Fruiting: June-August.

Uses: Leaves are used as a substitute for tea. The branches are collected for use as fuelwood in Spiti.

***Prunus prostata* Labil.** (Rosaceae)

Local/Common name(s): Patlu, Talle, Tara, Ter

A leaf shedding shrub, 0.6-1.8 m high distributed in Himalayas in Jammu and Kashmir, and Himachal Pradesh at altitude of 2500-3000 m., fairly common in Lahaul and Pooch area of Kinnaur. Leaves are elliptic or nearly so, 2.5 cm long, toothed, white velvety on the underside rolled length wise in bud; leaf stalk glandular. Flowers pink, 7.5 mm long, 1-3 together; drupe-cherry like, reddish-purple when ripe, 1 cm in diameter with 1-seeded smooth stone.

Flowering and Fruiting: July-September

Uses: Fruit is eaten and is said to provide sweet drink for summer season.

***Rhododendron anthopogon* D. Don** (Ericaceae)

Local/Common name(s): Talsar, Simris, Kotya, Balu

It is an aromatic, spreading, dwarf shrub with compact clusters of 4-6 white or yellow flowers tinged with pink. Grows sporadically in alpine slopes, of Himalayas from Kashmir to Sikkim, generally above the forest limit, between 3300-4800m in Lahaul-Spiti, Churdhar Morhi, Kinnaur, Kashmir, Kedar Kanta etc. Leaves approximate at the end of bracelets, 2.5-3.75 cm. long elliptic or elliptic oblong, shining above, ferruginous beneath, edge recurved. Flowers on short pedicels in short terminal corymbs. Capsule 5-celled, 5-valved.

Flowering and Fruiting: June-July

Chemical constituents: Quercetin-3-O-a-L-hamnopyranside, Kaempferol, its 4 Methyl ether and 3-O-glucoside have been isolated from leaves besides 24 methylene-cycloartenyl acetate, betulinic acid, ursolic acid, its acetate, epfriedelinol, b-Sito-sterol and rutin have also been identified.

Uses: Locally, the leaves are used as expectorant and it is also used by Lahauli people for preparing tea. The powder of the dried flowers mixed in bland oil is used as massage over the entire body in post-delivery complications like purpural fevers, cough and cold, body-aches etc.

***Rhododendron campanulatum* D. Don** (Ericaceae)

Local/Common Name(s): Cherailu

A Dwarf shrub, with ascending or erect branches. Common on slopes, generally found in association with *Betula utilis*, Kashmir to South-East Tibet. between 3000-4400m. Flowers pale mauve to rosy-purple, or rarely white, purple-spotted within above, broadly bell-shaped, in a lax cluster. Corolla 4 cm. long and broad, lobes rounded; calyx usually 1-2 mm. Leaves broadly elliptic to oval, 8-14 cm, with a rounded or shallowly heart-shaped base, dark glossy green above and with brown felted woolly hairs beneath. A widely branched, spreading shrub 2-6m.

Flowering & Fruiting: April-June

Uses: The root is a popular remedy for boils. The buds are said to be poisonous to goats.

***Rhododendron lepidotum* Wall. ex D. Don** (Ericaceae)

Local/Common name(s): Talispatra

It is found in Himalaya from Kashmir to Sikkim, between 3300m-4800m and has been collected from Lahaul-Spiti, Pangi-Bharmour, Kinnaur and various other places in Himachal. It is a small alpine shrub, aromatic, young parts with silvery or rusty coloured scales. Leaves approximate at the ends of branchlets, 1.85-2.5 cm. long, oblong or obovate-oblong, acute, the underside with a silvery or brownish film, edge recurved. Flowers red or pink in colour, strong smelling, solitary or 2-3 together, on pedicels 1.25-1.85 cm. long. Capsule 5 celled, 5-valved.

Flowering and Fruiting: July-September

Uses: The leaves are used as stimulant in native medicine. The tea made from the bark is supposed to be purgative. The leaves are also marketed as, "Talispatra" used in Ayurvedic formulations for cough and asthma.

***Ribes orientale* Desf.** (Saxifragaceae)

Local/Common name(s): Skuta, Yangke, Myomge (Fruit)

Description: The species is naturally found occurring from Hurling (3200 m) to Kee Gompa (4,000 m) in Spiti region of Himachal Pradesh. It also grows up to Hikkim (appx. 4600 m.) and is common on moist slopes generally found in association with *Rosa* species. It is a small shrub, unarmed, pubescent with short hairs. Flowers bisexual, racemes few flowered, pubescent, a tuft of leaves at the base, bracts minute. Berries black, 8 mm diameter, very aromatic.

Flowering and Fruiting: June to September

Uses: It act as a good natural soil binder. The fruit is cooling, laxative and anodyne. The fruits and leaves are considered diuretic and diaphoretic. Fruit jelly is used for sore throat and quinsy.

Other species: *R. glaciale* faciales, *R. alpestre* etc.

***Rosa webbiana* Wall. ex Royle** (Rosaceae)

Local/Common name(s): Sisa, Mendu, Chua

It is indigenous to Japan and China, but is also naturally growing in Spiti area adding beauty to the entire landscape by its presence. Common on open sandy slopes, it is a deciduous shrub with vigorous, long recurving or climbing spiny branches, leaflets usually 9, obovate to oblong, acute or obtuse, pubescent 2.3-4 cm long. Flowers in many flowered pyramidal corymbs, usually pink. Fruit small globular, red on ripening.

Flowering and Fruiting: June-September

Uses: Besides its role as a beautiful landscape shrub and a soil binder, the fruits of the genus *Rosa* are used as an application to wounds, sprains, injuries and foul ulcers, and are also eaten. They contain a high concentration of vitamin C (up to 8% in dry pulp). Branches and stems are used as tool handles and walking sticks.

***Salix karelinii* Turcz.** (Salicaceae)

Local/Common name(s): Goo

A shrub upto 120 cm. Tall, but sometimes a small tree attaining a height of 5 m common in *Betula-Rhododendron* forests from Afghanistan to Central Asia between 2100-4500 m. in open slopes, along streamsides; common and gregarious in the drier parts of Kashmir. Leaves 4-5 cm, elliptic to ovate, finely toothed, becoming paler and hairless beneath when mature; young leaves woolly-haired. Catkins borne on leafless stems; male catkin stout, very silky haired. 3-4 cm; female catkin stout, to 4 cm, very silky haired, with stipulate bracts which are blackish. Fruiting catkins to 9 cm; capsule 5 mm.

Flowers and Fruiting : June-August

Uses: Acts as a soil binder, fodder for sheep, goats and cattle and the branches are often gathered for fuel.

***Salix lindleyana* Wll. ex Anders**

Local/Common name(s): Guang

A small, creeping, tight mat-forming shrublet, frequent on moist slopes from Pakistan to South West China between 3600-4500 m. in alpine slopes, screes,

rocks; gregarious in nature. Leaves glossy, hairless, elliptic, lanceolate, mostly 6 mm, but variable. Flowers appear after the leaves, terminating leafy shoots. Male catkins, 1-2 cm long, few flowered rather lax; sepals oblong-obovate, glabrous. Female catkins similar to male. Capsule ovoid, glabrous.

Flowers and Fruiting: May-June

Uses: Very useful as soil binder, fodder for grazing animals and occasional fuel.

***Salix flagellaris* Anderss in Sv.** (Salicaceae)

Local/Common name(s): Langma, Changma

It is frequently found in moist slopes in Dras, Lahaul and Kinnaur between 3300-4500 m. Generally a dwarf shrub with stout, glabrous, procumbent, branches. Leaves elliptic, obovate or suborbicular, acute or obtuse, crenulate, glabrous. Flowers appear after the leaves. Male catkins, 1.5-3.5 cm long, terminal on short leafy shoots, cylindrical rather lax in the lower half; tepals obovate, glabrous. Female catkins similar to male. Capsule ovoid, reddish, almost sessile.

Flowering and Fruiting: June August

Uses: Jealously planted in Lahaul division for fodder and fuel. Pollarding is practiced, which helps the plants throw vigorous, new shoots giving more foliage and biomass year after year.

***Sorbaria tomentosa* (Lindl.) Rehder** (Rosaceae)

Local/Common name(s): Bhiloka

A slender graceful spreading deciduous shrub, frequent in *Juniperus* forests from Afganistan to Central Nepal, Central Asia, North-China between 800-1200 m in open slopes, river sides, cultivated areas, often gregarious and common. Leaves pinnate, leaflets sessile, opposite, lanceolate or linear-oblong, base rounded, apex long acuminate, margins sharply doubly serrate, glabrous above, hairy or glabrous beneath. Flowers in large terminal panicles, 5-7 mm across. Calyx lobes rounded. Petals orbicular, white. Carples 5, 3-4 mm, hairless, many seeded.

Flowering and Fruiting: June-September

Uses: Bark is used for tanning. Branches are frequently used for making light walking sticks. The smoke of the dried fruits is inhaled by teenaged girls suffering from irregular menstrual cycle for getting relief.

Conclusion

For any geographical area, the importance of plants for regulating micro-climatic, maintaining water resources, preventing soil erosion, meeting day to day requirements of all living organisms directly or indirectly and contributing to the economic improvement of the people is greatly acknowledged. In this, the shrubs quite outnumber the trees and have, thus, a greater role to play in maintaining ecological balance and an healthy environment. Besides ecological and environmental benefits, the shrubs provide us the fodder for our cattle, fuel to cook our foods, edible fruits, medicines, fibres, dyes and tans besides various other benefits. Shrubby elements come in handy for creating biofences, checking soil erosion, reclaiming the barren and waste lands through the plantation of site specific species of shrubs, maintaining natural balance in vegetation, providing shelter and sustenance to wild life (animals, birds etc.) and thus, offer a major contribution to the ecological and socio-economic health of a locality. The importance of shrubby elements is greatly emphasized for remote tribal areas and more so for the cold desert areas of the country, which lack forest vegetation worth its name and suffer from landslides through snow, rain or air and thus making. The ecosystem extremely fragile, inhospitable less productive for agriculture and allied ventures. Abrupt, climatic changes lead to endangering of various economically beneficial species of plants, a less highly difficult to compensate.

For greening of cold deserts and bringing economic benefits to the inhabitants, the shrubs offer a great potential. This group of plants can be propagated easily through seeds, cuttings, suckers/layers or splits; can accommodate large number of plants in minimum space; tolerate heavy pruning and training and unlike trees will provide day to day benefits in minimum period of time on sustainable basis. The species of *Hippophae*, *Caragana*, *Astragalus*, *Ribes*, *Artemisia*, *Elaeagnus*, *Myricaria*, *Salix*, *Lonicera*, *Potentilla*, *Rosa*, *Clematis*, *Juniperus*, *Rhododendron* etc. not only help in soil conservation, but at the same time, provide various benefits like soil amelioration, fodder and fuel, wild fruits, essences, dyes and tans and also adding beauty to the otherwise barren landscapes. *Ephedra Gerardiana*, *Capparis spinosa*, species of *Berberis*, *Artemisia*, *Astragalus*, *Hippophae*, *Rhododendron*, *Juniperus* and *Hyssopus officinale* provide valuable medicines to improve the health care system of the people living in such harsh conditions.

Hence, it is strongly recommended that to succeed in greening the cold deserts and providing various benefits to the local populace; immediate attention has to be paid for planting suitable species of shrubs at suitable sites with proper application of intellect and management practices, the shrubs can play a highly significant role in crop diversification in cold desert regions of the country and afford sustainable and supplementary source of income for livelihood of tribal people and at the same time arresting water and wind-erosion.

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Seabuckthorn (*Hippophae L.*) - A Multipurpose Shrub of Cold Desert of Himalayas

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The dry temperate and cold deserts of high hill Himalayas, comprising Lahaul-Spiti, parts of Chamba and Kinnaur districts of Himachal Pradesh and Ladakh in Jammu and Kashmir, are characterized by extreme climatic conditions, high rates of soil erosion and land slides, shortage of fuel wood, timber and fodder, low productivity of agricultural lands and sparse vegetation. The past efforts of afforestation by poplar and willow trees in the region have met only mixed successes for the want of a multipurpose plant species that can simultaneously satisfy the long term conservation as well as the short term economic needs of the people (Negi *et al.*, 1996). The present paper discusses the problems of desertification, past efforts of afforestation, and potential of seabuckthorn in the economic development and ecological restoration of the degraded hills of cold deserts of Himalayas.

Information on geography, rainfall, snowfall and vegetation of district Lahaul-Spiti, were obtained from the offices of Departments of Forests and Meteorology, located at Keylong in Lahaul and Kaza in Spiti. The silt data for Spiti River was collected from Silt Testing Laboratory at Khab (Kinnaur). Extensive surveys on geographical distribution and taxonomy of seabuckthorn growing in the region were carried out in 1994-95. Biochemical analysis of seabuckthorn fruit was done following AOAC (1984). Information on the desert development programmes was collected from the office of Additional Deputy Commissioner at Kaza. Literature on the economic and ecological potential of seabuckthorn was compiled, which is based on the studies carried out on seabuckthorn in Russia, CIS countries and China.

Cold Desert in Himachal Pradesh

In India, the cold deserts occur in Ladakh region of Jammu and Kashmir and districts of Chamba, Lahaul-Spiti and Kinnaur in Himachal Pradesh state, located in western Himalayas. The total geographical area under cold deserts is about 12,640,000 ha, which constitutes about one-third of the total geographical areas of both the states. The cold deserts of Himachal Pradesh state are located in the districts of Lahaul-Spiti, Pir Panjal area of Chamba

and Sumdo area of Kinnaur. These areas have very difficult terrains with ice fields, perpetual snow covered peaks and extreme and hostile climatic conditions. Pir Panjal, the Great Himalayan range and Zaskar range delimit the region. The district of Lahaul-Spiti lies in the west of the Great Himalayan range between 31°44'57" and 33°42'54" north latitude and 76°56'29" and 78°41'34" east longitude. It is surrounded by Tibet and Kinnaur in east and Ladakh region of Kashmir in the north. On the southern side, it is adjoined by Chamba and Kullu and Bara Bengal area of Kangra district and on the west by Chamba district. Lahaul-Spiti district comprises two subdivisions, Lahaul and Spiti. The Kunjam La pass (4740 m above msl) keeps these two regions isolated from each other for more than 8 months in a year due to heavy snowfall in winter.

Lahaul comprises an area of 6097 sq. km. and is situated on the western side of the district. The tract is narrow, steep and with mountain peaks rising to an average of 5480 m, highest peak reaching at 6400 m. The river Chenab starts from Baralacha pass at 4891 m, where the two sources of the Chandra and Bhaga rivers are about 1.6 km apart and start off in opposite directions making Chandra and Bhaga valleys till they meet at Tandi (2958 m asl), making a common river Chandra-Bhaga or Chenab, which flows down through Chamba to Kashmir. Lahaul is enclosed between high mountains, which forms a barrier against monsoon rains. Rainfall fluctuates from 300 to 700 mm yr⁻¹ depending on place to place. The winter is very cold and starts from the month of October and continues till mid April. This is followed by a short spell of spring (mid April - mid May) and a bigger summer (May - September). The temperature shows considerable variation throughout the year (a maximum of 27°C in July and a minimum of -16°C in February). During the winter this region is affected by a series of western disturbances, which cause heavy snowfall (200-400 mm yr⁻¹). The dry conditions of region are responsible for the occurrence of the forest patches of *Betula utilis*, *Pinus wallichiana*, *Juniperous macropoda*, *Cedrus deodara*, *Abies pindrow* and *Picea smithiana* and *Hippophae rhamnoides* growing at an altitude range of 2500-3300 m above msl. Farmers

have done heavy afforestation of willow (*Salix daphnoides*) and poplar (*Populus nigra*). About 14,000 farmers live in over 200 village, mostly located on river sides. The region has a mixed Hindu-Buddhist culture.

Spiti covers 7589 sq. km. of area and adjoins Tibet on its eastern border and Ladakh on its north. It is surrounded by Kinnaur on the southeastern side. There are numerous mountains with altitude ranging from 6100 to 7000 m above msl. Spiti is completely rugged with broad sandy valleys. The cold desert area of Kinnaur falls adjacent to the eastern part of Spiti. Spiti river forms the main Spiti valley, which originates from a glacier near Kunjam La at 4750 m above msl. Length of the river within Spiti is 130 km. Spiti River swallows numerous rivulets and rivers on its way and amalgamates into Sutlej River flowing through Kinnaur. Spiti has a minimum altitude of about 3120 m above msl at Sumdoh and maximum of 4090 m above msl at Lossar, the last village of Spiti. With exception of seabuckthorn growing at river sides, there are no natural forests in Lahaul. This valley also falls in the rain shadow of Himalayas. The climate of Spiti is characterized by the absence of rains during summer and resembles arid Tibetan type of climate for most of the area. Some important herbs and shrubs are seabuckthorn (*Hippophae rhamnoides* and *H. tibetana*), *Ephedra Gerardiana* and *Capparis spinosa*. There are 47 villages, which are inhabited by 11,800 persons, all Budhists.

Environmental and Other Problems

Glacier action, high wind velocity, road and other construction activities, deforestation and grazing etc. had resulted into considerable soil erosion in both the valleys. During summer and early winter, clouds of dust can be seen at a number of sites. High rates of soil erosion can be measured in Spiti, where, Spiti river carries a substantial silt load, even before merging into Sutlej river at Khab in Kinnaur. For example, maximum silt in Spiti varied from 3.9 g l⁻¹ in 1970, to 13.5 g l⁻¹ in 1974, 7.8 g l⁻¹ in 1979 and 3.3 g l⁻¹ in 1983. Problem of landslide is also quite severe in the whole region. Scarcity of fuel wood and timber are most severe problems for inhabitants of Lahaul and Spiti. Farmers in the region not only need fuelwood for cooking their food materials but their survival depends upon the availability of fuelwood for heating their houses, particularly during winter, when the night temperature drops to a minimum of -20°C. Farmers of Lahaul partially meet their demands by collecting fuel wood from natural forests of Pinus, Picea and Juniperous, as well as plantations of willow and poplar growing around

their villages. However, consumption rate of fuel wood is increasing rapidly over years.

In Lahaul, livestock graze at lower altitude pasturelands lying close to habitations. These lower regions (2500-3200 m above msl) constitute the forest areas, where the locals have grazing rights. Being near the villages, these grazing grounds are badly denuded and eroded due to overgrazing. In Lahaul, population of livestock is considerably high, i.e. local and migratory livestock were 68,023 and 2,38,371 respectively in 1982. Migratory herds graze at higher altitude pasturelands, where the main nutritious grass *Fescue alpina* is readily eaten by migratory sheep and goats between June and September. Farmers have introduced improved varieties of lucern (*Medicago sativa*), clover (*Trifolium pratense*) and *Melilotus*. However, the stored grasses are exhausted during late winter and farmers are forced to lop the branches of willow trees to feed the livestock for their survival. In Spiti, the total pasturelands are about 228,000 ha and total population of livestock, both local and migratory is about 31,000. The region has enough pasturelands for grazing. However, the region suffers severely from fodder shortage during winter season.

Past History of Afforestation

In order to meet the growing demands of fuel wood, tribal farmers of Lahaul have done massive afforestation of willow trees (*S. daphnoides*) along the water channel (Kuhuls), on the boundaries of crop fields and wastelands on the riversides. These stands of willow also meet partially the demands of fodder, as livestock eat the bark and small branches for their survival during late winter. In the higher altitude area, farmers have also raised trees of *P. nigra* as a source of timber. At lower altitude areas, they have also raised a few trees of walnut (*J. regia*) around their fields. Forest department have also raised plantations of willow and poplar at a number of sites. However, rubinia (*R. pseudoacacia*) has not been accepted by the farmers, as it contains thorns. Despite the massive afforestation mainly by the farmers, the problems of soil erosion and landslides remain quite severe in Lahaul.

The denuded, rugged and treeless tract of Spiti, called for a massive afforestation programme. The afforestation efforts in this arid region have been, however, economically disappointing. An impact study was carried out on the plantation successes in Spiti valley by a team of experts led by Negi *et al.* (1996). Although high rates

of successes were found in the plantations raised under DDP programmes, but failures were also observed at several sites. This has been in part due to the fact that forest trees were planted only on lands remaining after all other land users had selected the more productive and accessible land for their use. Nothing was left for afforestation except dry soils or land by riverbeds or mountains slopes. Further, there were wrong choice of species, lack of irrigation facilities, water logging, die back, community disputes and lack of proper technical knowledge in raising of species. For example, there was not proper knowledge of plantation technology in case of juniper. Blue pines, species of humid conditions of 3000 m, were wrongly planted at Ghidang in Pin valley at an altitude of 3,770 m. At Tabo, farmers were not allowing the irrigation facilities for afforestation purpose and plantations at Lalung were destroyed by the farmers. These experiences clearly indicate that plantation of these tree species cannot be imposed on the people of the region. Participatory management for involvement of local farmers is required in any afforestation programme. This is only possible when indigenous species are planted on which people have depended throughout the ages for various uses (Negi *et al.*, 1996).

Why Seabuckthorn?

Seabuckthorn (*Hippophae* L.), a nitrogen-fixing member of family Elaeagnaceae, is such a plant, which meets the above requirements. The plant is indigenous to the region and widely distributed (2500-4300 m asl). Fruit of this plant is quite rich in vitamin C (300-2400 mg/100g), vitamin A, E and K, protein, organic acid, carotenoids, flavonoids and steroids, which have been used in countries like Russia, CIS states, Mongolia and China for the production of several medicines, cosmetics and food products. Since 1954, seabuckthorn has also been widely planted to control soil erosion on fragile mountainous lands in China, which has climatic and geographical similarities to cold desert areas of Indian Himalayas. Therefore seabuckthorn makes a suitable choice for the afforestation programmes of cold deserts of Himalayas in India.

Characteristics of seabuckthorn

Seabuckthorn grows very widely in Europe, central Asia and temperate regions of South Asia and China, ranging in altitude of a minimum of 60 m asl in Europe to a maximum of 5200 m asl in China. In India, seabuckthorn has been reported growing in Ladakh region of Jammu-

Kashmir, cold deserts of Himachal Pradesh and dry temperate areas of Kumaun-Garhwal regions in Uttar Pradesh and Sikkim. In Himachal Pradesh, seabuckthorn grows in the cold desert areas of Lahaul-Spiti, parts of Chamba and Kinnaur districts (Singh *et al.*, 1995). There are some reports of its distribution in high altitude areas of Kangra, Kullu and Shimla districts. However, only district of Lahaul-Spiti and part of Kinnaur have rich resources of seabuckthorn. There are six species of seabuckthorn in the world, i.e. *Hippophae rhamnoides*, *H. salicifolia*, *H. tibetana*, *H. neurocarpa*, *H. goniocarpa* and *H. gyantsensis*. In India, only three species have been found, i.e. *H. rhamnoides* subspecies *turkestanica* Rousi, *H. salicifolia* D.Don, and *H. tibetana* schelechtend. *H. rhamnoides* is a plant of small to medium height (2-5 m), most dominant and widely distributed (2500-4000 m asl) in cold deserts. Trees of *H. salicifolia* are medium to tall in height (4-7 m) and distributed at an altitude of 3100-3700 m, whereas *H. tibetana*, a dwarf shrub (0.2-0.6 m), is confined at higher altitude (4000-4300 m asl). In seabuckthorn, male and female plants are separate. It bears foliage from April to November, whereas small flowers are attached for 7-10 days in June-July. Female plants bear fruit of pea size from mid-August to mid-April. It has well developed root system, which bears nitrogen fixing *Frankia* bacteria in the root nodules (Catner and Cardner, 1970).

Nature has synthesized a number of useful nutrients in the fruit, leaves and other parts of seabuckthorn. Fruit of seabuckthorn is very rich in vitamin C (300-1600 mg/100 g), which is 4 -100 times higher than any vegetable and fruit (Table 1). High content of organic acid (2-4 per cent) and vitamin C make it highly useful for beverage industries, particularly health protection juices. Vitamin E, which has strong anti-cancer activity, varies from 61-113 mg/100 g in seed oil, to 162-255 mg/100g in fruit juice and 350-540 mg/100g in fruit residue (Fushion, 1987). Vitamin K promotes normal coagulation of blood during the injuries of blood vessels, and its content varies from 59-64 mg/100g in pulp oil to 110-230 mg/100g in seed oil, which is more than many horticultural crops (Fushion, 1987). Content of vitamin A, B1, B2, is also quite high (Table 1). Protein content in seabuckthorn is about 30 per cent. The amount of lysine is also quite high. All the protein forming amino acids in free form were found in the juice, which make seabuckthorn food products highly nutritious and digestible. Among the microelements, important are Fe, Co, Mo and Se. Selenium, an important element in

medical world, varies from 0.91 to 1.11 ppb (Tigong, 1988 and Zhendong *et al.*, 1989).

Table 1. Comparison of the vitamins of seabuckthorn and other fruits and vegetables

Plant	Vitamin (mg/100g)				
	A	B ₁	B ₂	K	C
Seabuckthorn	11.0	0.04	0.56	100 - 200	300 - 1600
Ambla	NA	NA	NA	NA	600
kiwi	NA	NA	NA	NA	100 - 470
Orange	0.5	0.08	0.03	NA	50-68
Tomato	0.3	0.03	0.02	NA	12
Carrot	4.0	0.02	0.05	NA	8

Source: Zhonglu (1956), Singh (1967), Dengyi (1984), Houmou (1985) and Singh *et al.* (1995), NA=Not available

Oil of seabuckthorn carries several bioactive substances (Vitamin E, and K, carotenoids, flavonoids and steroids), which makes it highly suitable for treating several diseases. The total oil content varies from 2-4 per cent in pulp to 10-20 per cent in seed. Unsaturated fatty acids make about 85 per cent of total oil and among them linoleic and linolenic acid are important (about 60 per cent). β -carotene and vitamin E contents in seabuckthorn oil are quite higher than other oils (Table 2), making it highly useful in pharmaceutical industries. Carotenoid content usually is 0.31-20.0 mg/100g in fresh fruit. Seabuckthorn carotenoids are dominated by carotene, lycopene, polylycopene-3 and zeaxanthin. The content of α -carotene in seabuckthorn fruit, the most active bioactive compound is 15-55 per cent. Lycopene prevents vitamin A deficiency in human being and promotes their growth (In Rongsen, 1992). Flavonoids are also quite rich in seabuckthorn. Flavonoids content varies from 0.2 to 0.6 per cent in juice and dried fruit residue respectively. Flavonoids mainly are leucoanthocyanidin, catechin, flavonol and flavone (Lachman *et al.*, 1989). Flavonoids have been found effective in curing high blood fat content, coronary heart problems and angina pectoris. Steroids constitute the main portion of unsaponifiable matter. It is well known that steroids are one of the important components in forming the somatic cell membrane synthesis. Some steroids have the significant functions to promote tenacy of skin capillary blood vessels and to prolong life. All steroids in seabuckthorn oil belong to the following four series, i.e., ergosterols, stigmsterol, lanosterols and amyryns (Huaqin *et al.*, 1989). Richness of seabuckthorn fruit in various useful nutrients makes it an important raw material for many food and medicine industries.

Table 2. Comparison of the composition of seabuckthorn oil and other nutrient oils

Oil type	Fatty acid component (%)		Vitamin (mg/100g)	B-Carotene (mg/100g)
	Saturated	Unsaturated		
Seabuckthorn	13.7	86.3	203	249
Wheatemby	NA	NA	145	--
Safflower	8.0	92.0	3	--
Maize	15.2	84.8	34	0.8
Soybean	14.8	85.2	8	0.1

Source: Fushion (1987), Guoli (1987), Rongsen (1988) and Chongju *et al.* (1989). NA=Not available.

Economic potential

Since the second world war several seabuckthorn based industries have been established in Russia and CIS countries, producing a range of wines, beers, beverages and other food products (Table 3), which have been successfully marketed. In order to meet the growing demands of industries, more than 6000 ha of land area have been brought under seabuckthorn orchards in Russia. China became aware of significance of seabuckthorn only in early 1980s. Immediately research work started on various aspects of seabuckthorn and extraction technologies. Since 1984, more than 250 industries based on seabuckthorn have been established in 19 states of China, producing a range of products like wines, beverages, medicines and cosmetics. Yellow pigment or colour has been obtained from seabuckthorn fruit by Chinese scientists and being made by the Food Additive manufacturer of Beijing Municipality. It is made of flavones (95%), carotene, vitamin E, etc. The colour has been used as a colourant of creams, cakes, sweets, ice creams, etc. (Duohua *et al.*, 1989).

Table 3. Food products made from the fruit of seabuckthorn

Type	Varieties of products
Raw material	Clean juice, thick juice, condensed juice, pulp oil, seed oil, residue oil, raw powder, pigment and flovone
Soft drinks	Syrup juice, mixed juice, health protection drinks, carbonated juice and soda water
Hard drinks	Sweet wine, medium dry wine, carbonated wine, champagne, beers
Sweets and Jams	Carrot jams, cheese, butter, tea, dye, cakes and chocolates

Source: In Rongsen (1992)

The application of seabuckthorn in medicines can be traced back to the 8th century. The Tibetan medical classic - the Rgyud-Bzi (The Four Books of Pharmacopoeia), completed during the Tang Dynasty (618-907 AD), has 36 chapters, which had recorded the prescriptions for curing the diseases of blood circulation systems, skin wound, anti-inflammation and strengthen and coordinate the balance of functions among liver, stomach, spleen, kidney and heart. Russian scientists discovered four main pharmacological functions of seabuckthorn fruit oil, 1. Anti-bacteria 2. Diminishes inflammation 3. Relieves pain and 4. Promotes regeneration of tissues. Several drugs have been made from seabuckthorn oil, curing a number of diseases like blood pressure, heart problems, cancer, ulcers, burns aging, etc. In the countries of former Soviet Union, the demand of seabuckthorn oil is so large that the currently available output of oil cannot meet the increasing demands of industries. For example, Biysk Vitamin Factory, the biggest seabuckthorn oil factory in Russia, doubled its output again and again to meet the increasing demand of drug and cosmetic industries and reached to 125 tons, which was poured into 25 million bottles (In Rongsen, 1992). In China, too, production technology of seabuckthorn oil has progressed from natural seepage method used 12 years ago to supercritical gas extraction method. The progress in the processing technology has greatly improved the quality and quantity of seabuckthorn oil drugs and cosmetics.

Based on its nutrients, many medical studies, testing its effects on the skin, showed that seabuckthorn extracts could effectively improve the microcirculation of blood capillaries and nourish the skin and hair. Chinese scientists utilized its nutrients and medical effects to develop several kinds of seabuckthorn beauty creams and cosmetics. Seabuckthorn oil is the raw mineral oil and natural nutrients with natural pigments. Seabuckthorn beauty creams are quite stable for a long period. Vitamin E was added to the creams as anti-oxidant. Seabuckthorn beauty creams were found to possess good therapeutic efficacy on senile skin, wrinkle, melanosis, keratoderma, xeroderma, senile plaque, face acne, chemical corrosion, etc. Seabuckthorn beauty creams made the skin fair, clear and delicate. (Xuejiao *et al.*, 1989). Chinese studies have also shown that seabuckthorn fruit and leaf extracts can improve metabolism, retard skin maturation and make the skin smooth and soft. Hair care also retarded baldness and promoted hair growth. Clinical trials showed that seabuckthorn cosmetics cured 16 tropical diseases of malaria, scabies, summer dermatitis, pityriasis sicca, seborrhea sicca, alopecia, impetigo, acne vulgaris,

pustule vulgaris, contact allergic reactions, lentigo, xanthopsia, dry skin, and verruga (Chongju *et al.*, 1989). Shaan Xi Chan Qing Medical Seabuckthorn Oil Factory is one of the big industries in China, producing the beauty creams and cosmetics from seabuckthorn.

Ecological rehabilitation

Wide adaptation, nitrogen fixation, extensive and well developed root system, compact canopy and dense forest of seabuckthorn protect the soil from wind and water erosion. There are several success stories of control of soil erosion by seabuckthorn forests in China. In Shanxi province, China, 74 km of seabuckthorn forest was planted on the bank of yellow river, which decreased sediment discharge by 3-5 million tons/yr (Min *et al.*, 1989). Seabuckthorn forest, when raised in a watershed area in Zhungar country, increased vegetation cover from 20 to 61 per cent, soil erosion decreased from 40,000 to 5000 tons/km²/yr after 3 years of plantation in 1989. Grain yield increased from 160 to 373 kg/person and per capita income increased from 330 to 4260 rupees. In some of the areas it reduced soil erosion up to 96.6 % (Table 4). Local people called it 'Green hope'. Seabuckthorn has an outstanding ability to take roots even in poor soils, because of its ability to fix atmospheric nitrogen through the presence of symbiotic bacteria *Frankia* in the root nodules and add about 180 kg of nitrogen per ha per year (Jike and Xiaoming, 1992). Seabuckthorn plants when planted in poplar stand, later achieved 4 times height and 3.7 times diameter than a pure stand of poplar. The nitrogen content of the cultivated layer (0-20 cm) and organic matter content in the mixed forest also increased by 11.5 and 26.6 percent respectively as compared to pure stand of poplar (Quanzhong *et al.*, 1989). Seabuckthorn also plays an important role in the conservation of wild life. In Loess Plateau region of China, 51 out of 350 bird species are entirely dependent upon seabuckthorn fruits as a food and 80 bird species are partly dependent upon seabuckthorn (Zhiben *et al.*, 1989).

Table 4. Comparison of runoff and soil loss in seabuckthorn and wastelands

Parameters	Wasteland	Seabuckthorn land
Plant cover(%)	25	90
Runoff (m ³ /ha/yr)	1672	7
Soil loss (kg/ha/yr)	314	11
Runoff reduced (%)	0	99.6
Soil loss reduced (%)	0	96.6

(Source: Quanzhong *et al.*, 1989)

Other applications

Fruit residues, which account for about 20 per cent of the total fruit weight, are rich sources of protein, fat, amino acids, vitamin A, C, D, and E, carotenoids, flavonoids and micronutrients (Tigong, 1988). Feeding on supplementary seabuckthorn foliage and fruit residues, pigs increased their weights by 9-21 per cent, milk production in goats by 6-7 per cent; chickens enhanced their rate by 9-13 per cent and laying output by 25-29 per cent (In Rongsen, 1992). Livestock in Lahaul-Spiti feed on its green foliage during the early winter, when all the fodder resources dry up (Singh and Dogra, 1996). Chinese study revealed that crude protein content of seabuckthorn leaves is equivalent to red clover (17.1 %), however lesser than white clover (24.7%), whereas the fat content of seabuckthorn leaves (4.6 per cent) is significantly higher than both red clover (3.6 %) and white clover (2.7%) (Jikai, 1983, Rongsen, 1991). Singh *et al.* (1999) estimated 18-22% crude protein and 4-5% fat in the leaves of Indian seabuckthorn. Branches of seabuckthorn plants are important fuelwood in the whole cold deserts of India. In China, a 6-year old plantation of seabuckthorn produced 18 tons of dry fuelwood/ha/yr, which is equivalent to 12 tons of standard charcoal. The average calorific value of dry seabuckthorn wood is 4785 kcal/kg, which is more than most of the tree species. One ton of seabuckthorn wood is equal to 0.7 ton of standard coal.

Studies on seabuckthorn in India

Although research on seabuckthorn has started much earlier, but these studies were carried out on seabuckthorn in association with other plants (Singh and Gupta, 1990). Main breakthrough came for systematic studies on seabuckthorn, when the First Consultation Meeting on Seabuckthorn was organized by State Council for Science Technology and Environment at Shimla on 3-4 January, 1994. As a member of task force on seabuckthorn, constituted by SCSTE, we carried out surveys on the geographical adaptation, distribution, taxonomy, morphological and biochemical variations, propagation and fodder values (Singh, 1994, 1995, Singh *et al.*, 1995, Singh and Dogra, 1996, Singh *et al.*, 1998 and 1999). Seeds treated with cold water for 7 days germinated well, when sown in middle of April at the soil depth of 1.0-1.5 cm. Better results were obtained when cuttings of 1.0-1.15 cm diameter and 20-22 cm were planted to raise nursery of seabuckthorn in early April.

A quite large variation was observed in the size of fruit, which varied from a maximum of 30-40 g/100 fruits in *S.salicifolia* to 8-29 g in *H.rhamnoides* and 21 g in *H.tibetana*. Vitamin C content varied from a maximum of 947 mg/100g in *H.salicifolia* followed by *H.rhamnoides* (219-642 mg/100g) and *H.tibetana* (356 mg/100g), which show high breeding potential of Indian seabuckthorn. Strains from Spiti were found to have high rates (98-100 %) of seed germination. The seeds of *H. salicifolia* had very low germination rate (37 %). Leaves of seabuckthorn were found quite rich in crude protein (18-22 %) and fat (4-5 %), therefore a useful fodder for the livestock (Singh *et al.*, 1999). Further studies have been started on genetic diversity and improvement of seabuckthorn populations raised in germplasm bank at our research station at Kukumseri in Lahaul. Presence of thorns, small fruit size, poor yield and low oil content are the main problems of seabuckthorn in cold desert region of Himachal Pradesh. Trials are in progress on different provenances of seabuckthorn, some of them having few desirable characters. We have also successfully introduced 5 high yielding Russian varieties at our station in Lahaul. Research on seabuckthorn has also started in other state universities and institutes of our country, whereas a massive afforestation programme on seabuckthorn has been started by the Forest Departments and other government and non-government agencies in the cold deserts of Himalayas.

Conclusion

The cold deserts of Himachal Himalayas are characterized by harsh climatic conditions, low rainfall, high rates of soil erosion and landslides, scarcity of fuelwood timber and fodder and sparse vegetation. Past efforts of afforestation by willow (*Salix* sp.), poplar (*Populus* sp.) and rubinia (*Rubinia pseudoacacia*) have met only mixed successes for the want of a multipurpose plant species, which can meet the requirement of long term conservation as well as short term needs of the peoples of the region. Seabuckthorn (*Hippophae* sp.), an indigenous species, is such a plant, which meets the above requirements. Fruit of seabuckthorn is quite rich in vitamins and other bioactive substances and has great potential for food, pharmaceutical and cosmetic industries. The nitrogen fixation and strong root system make seabuckthorn a suitable species for the environmental conservation of fragile ecosystem of degraded mountains of cold deserts of Himalayas.

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Author Index

A Chouhan	15	M.M. Bhandari	5
A. Kacker	145	M.S. Khan	87
A.K. Handa	125	Manjit Singh	51, 55, 66, 79, 83, 97, 111
A.K. Sharma	33	N.S. Chauhan	159
Ajit	125	N.S. Shekhawat	145
Amal Kar	121	Nighat Jabeen	125
A. Paliwal	145	P. Narain	1, 115
B.L. Jangid	66	P. Rai	125
B.S. Chundawat	131	P.K. Roy	66
D. Gupta	145	P.L. Regar	66
D. Panwar	145	P.R. Kothari	51
Deepa Singh	55	R. Raina	147
Farzana Parveen	15, 73	R.K. Beniwal	91
G. Pratibha	61	R.K. Goyal	115
G.R. Korwar	61	R.S. Mertia	105
Giridhar Gopal Sharma	39	Rajendra Prasad	105
Gurbachan Singh	111	Ram Harsh Singh	39
H.R. Dagla	145	Rekha Sivadasan	97
H.S. Gehlot	145	S. Goyal	15
J.B. Vibha	145	S.B.S. Tikka	137
J.C. Tewari	33, 115	S.K. Jindal	51, 55, 83, 97
J.P. Singh	27, 45, 79, 91	S.K. Saxena	127
J.S. Rathore	145	S.K. Yadav	61
K. Ram	145	S.N. Jaimini	51, 137
Khem Chand	66	S.P. Vyas	141
L.N. Harsh	33	S.S. Rao	66
M. Mohibbe Azam	73	Suresh Kumar	15, 45, 73, 79, 111, 115, 127
M. Parihar	145	V. Kataria	145
M. Singh	145	V.K. Mishra	147
M.S. Rathore	145	V.S. Rathore	27, 91
M. Srinivasa Rao	61	Virendra Singh	169
M.L. Soni	27	Y.V. Singh	66