Banwali

(*Acacia jacquemontii* Benth)

A Multipurpose Shrub of Arid Zone

R. S. Mertia | Rajendra Prasad | J. P. Singh

भाकृअनुप
ICAR

CENTRAL ARID ZONE RESEARCH INSTITUTE
REGIONAL RESEARCH STATION, JAISALMER

CAZRI

भाकृअनुप
ICAR

Banwali

(*Acacia jacquemontii* Benth)

A Multipurpose Shrub of Arid Zone

R. S. Mertia
Rajendra Prasad
J. P. Singh

CENTRAL ARID ZONE RESEARCH INSTITUTE
REGIONAL RESEARCH STATION, JAISALMER

Published by :

Director
Central Arid Zone Research Institute
Jodhpur - 342 003 (Raj.) INDIA
Phone : +91 291 2786584
Fax : +91 291 2788706
Web site : http://cazri.raj.nic.in

August, 2009

Printed at :

Evergreen Printers
14-C, H.I.A., Jodhpur
Tel. : 0291-2747767

FOREWORD

Banwali (*Acacia jacquemontii* Benth.) is a potential lesser known multipurpose shrub of arid and semi-arid region. The species is hardy and well adapted to the harsh climatic conditions. It is a good source of fuel, fodder/browse, small poles, gum tannin etc. The unique sand binding ability due to profuse root system makes it potential species for sand dunes stabilization. It yields small poles that are used for making frames for thatched houses and huts. The young shoots/branches are used for making baskets, granaries and other household articles. Wood is good fuel and yields good quality charcoal which is used in making gun powder. Each plant yields 100-150g edible gum which is highly priced in pharmaceuticals. Its 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.

Poor natural regeneration and its continuous extraction by local people from natural stands is threatening the existence of this precious species. Raising of plantation of *A. jacquemontii* by state forest department and other agencies became difficult as information on its silvics and other management practices are sketchy and not available for ready reference. Despite its paramount importance, less attention was paid by the scientific community. At this juncture compilation of all the available information on this species in the form of a monograph entitled "Banwali *(Acacia jacquemontii* Benth.) A Multipurpose Shrub of Arid Zone" is a timely step for which authors deserve appreciation. The present monograph is a state-of-art report on this species and contains valuable information. It is hoped that this publication will be of immense help and use to the plant scientists, foresters and agro-foresters, desert development agencies and all those who are interested in conservation and propagation of lesser known but over-exploited plant species.

(K.P.R. VITTAL)
Director
Central Arid Zone Research Institute
JODHPUR

Place : Jodhpur
Date : 27.7.09

PREFACE

Acacia jacquemontii Benth. belongs to sub-genus *Acacia* of genus *Acacia* Mill. of family Mimosaceae. Popularly known as banwali or bhu-banwali, *Acacia jacquemontii* exhibits great diversity in its habitat, associated plant species, plant type, growth behavior, flowering, fruiting and gum exudation. It is very popular among desert dwellers due to its variable uses. Its poles are used for making frames of thatched houses and huts. Its young shoots / branches are used for making baskets, granaries and other household articles. The wood has very high calorific value and yields good quality charcoal used in making gun powder. The plant yields edible gum, which is highly priced in pharmaceutical industry. 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 a good source of tannin. Due to its profuse root system, it is a good sand binder and suited for sand dune stabilization. Making of granaries and basket is a good house hold industry. It is a good source of income for sustenance of poor desert dwellers particularly in the period of drought and famines. In desert *A. jacquemontii* is regarded as poor men's timber providing livelihood security against nature's calamities- droughts and famines. Due to multipurpose uses, *A. jacquemontii* has been over-exploited by local inhabitants. This has threatened its existence and necessitated efforts for its conservation. In this background it was felt necessary to compile all the available information on its distribution, taxonomy, phenology, techniques of artificial regeneration, growth and biomass production, harvesting and utilization. The information contained in this monograph will be of immense utility to local farmers, foresters and agro-foresters, researchers, environmentalists and other professionals interested in conservation of bio-diversity in arid ecosystem.

The authors have received help and encouragement from many people in compilation of this monograph. The generous help provided by Dr. R.K.Beniwal, Dr. M.L. Soni and Dr. B.K. Kandpal is thankfully acknowledged. In generation of field data, the technical assistance extended by Shri Daleep Singh Mertia, Chandra Prakash Prajapati and Sunil Kumar was of immense help.

R. S. Mertia
Rajendra Prasad
J. P. Singh

Jodhpur
August, 2009

Contents

List of Tables and Figures

Figures

List of Plates

CHAPTER I

INTRODUCTION AND DISTRIBUTION

INTRODUCTION

Banwali (*Acacia jacquemontii* Benth.) also known as bhu-banwali, is one of the most useful multipurpose shrubs of arid and semi-arid regions. Acacias belong to family Mimosaceae. *Acacia* Mill. is a very large genus containing trees, shrubs and climbers. The genus *Acacia* finds its greatest expression in Africa and Australia, however, the Indian sub-continent has also a fairly good representation. There are more than 1200 species of *Acacia* (Simmons, 1981) occurring naturally in all continents except Europe and Antarctica. Currently 729 species are recognized in Australia and about 120 taxa are yet to be described (Maslin, 1981). Among recognized species, 115 occur in Africa (Ross, 1973; 1981) and remaining are in Asia (including China). In India, *Acacia* is one of the five dominant genera of legumes and finds second place with 94 species (Rao and Chaudhary, 2002).

The trees, shrubs and climbers contained in genus *Acacia* Mill. are armed with prickles or stipular spines. Flowers are small, yellow or white in globose heads or cylindrical spikes with numerous scaly paleae between the flowers. Leaves are usually bi-pinnate. Calyx and corolla are usually tetra to penta-merous. The calyx is campanulate or cup shaped, toothed or lobed. Petals are indefinite, free, generally very numerous, not exceeding 1.25 cm in length, anthers are minute. Pods are dehiscent/ indehiscent with compressed seeds. The genus *Acacia* has been sub-divided into three sub-genera namely i) *Acacia*, ii) *Heterophyllum* and iii) *Aculeiferum* (Guinet and Vassal, 1978). The occurrence of sub-genus *Acacia* is mainly in Africa but also found in Asia, South America and to a limited extent in Northern Australia (Tindale and Roux, 1975; Simmons, 1981). By belief, the ancestral forms of angiosperms and acacias are evolved in the tropical low land forests of West Gondwanaland (Raven and Axelrod, 1974; Beadle, 1981). Speculation has extended to dispersal routes within Africa (Ross, 1981) and Australia (Beadle, 1981) after break up of Gondwanaland in to separate continents. Beadle (1981) suggested that a few species arrived in Australia before separation and subsequent species evolved and spread southwards from tropical Northern Australia. However, Tindale and Roux (1974) suggested that Eastern Australia was the center of origin of Australian acacias. Hopper and Maslin (1978) opined that there has been major proliferation of species presently occurring in South Western areas of West Australia. Some species are also supposed to have under gone long distance dispersal by Sea.

Acacia jacquemontii is known by various names in India like bhu-banwali ; bawali; bouli and gulli bouli in Rajasthan; ratabouli in Gujarat; and baul, kikar and bamul in Punjab. The other vernacular names commonly used in Pakistan are kikar, babul, babri, babli, bouli and rata banli. It is a potential lesser known multipurpose shrub of arid and semi arid region.

DISTRIBUTION

Acacia jacquemontii occurs mainly in desertic regions of Australia, Africa and Southern Africa. In Asia it is widely distributed in India, Pakistan, Afghanistan, Iran and Iraq (Baker, 1876; Parker, 1918). In India it is found in Gujarat, Punjab, Rajasthan, Delhi, Haryana, Tamil Nadu and Sourashtra. In Rajasthan it is widely distributed in sandy habitat in Pali; river bed, oran (grazing lands around temples where lopping is prohibited) and gauchar (common grazing lands) in Jodhpur (Plate 1 &2); sand dunes in Jaisalmer, Bikaner (Plate 3 & 4), Hanumangarh and Sriganganagar; scattered on farm boundary in Nagaur and Sikar; and on dunes and wasteland in Churu and Jhunjhnu districts of Western Rajasthan (Bhandari, 1990). On sand dunes and interdunal sandy plains, it is naturally distributed in patches, but on bare undulating sand dunes its frequency and

Plate 1 Natural stand of *A. jacquemontii* on bank of seasonal water stream

Plate 2 Natural stand of *A. jacquemontii* on Guauchar/ Oran land

density is more. The germplasm survey of promising browse shrubs (*A. jacquemontii, Haloxylon salicornicum, Calligonum polygonoides)* in western Rajasthan reveals decline in their density in natural habitat (Singh *et al.*, 2003).

Plate 3 Natural stand of *A. jacquemontii* on sand dune in Jaisalmer

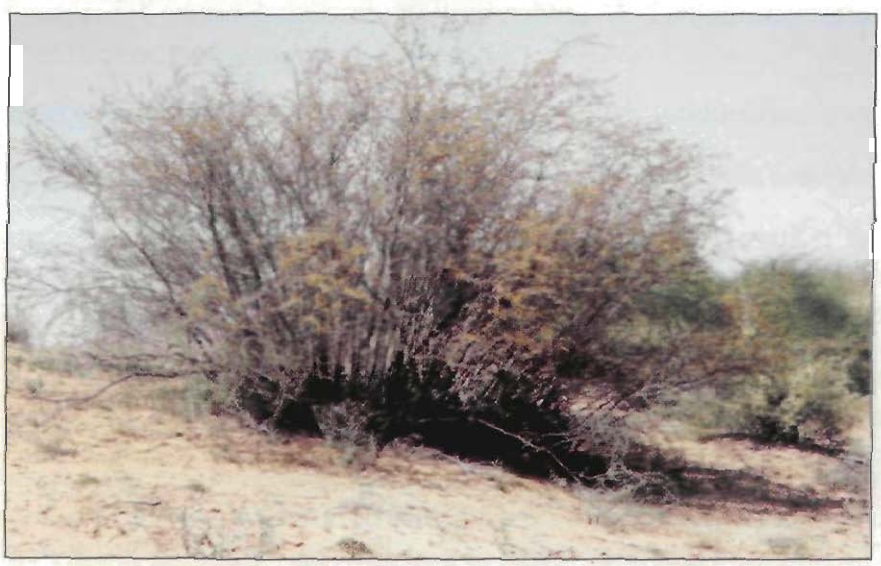


Plate 4 Natural stand of *A. jacquemontii* on dune at Jalwali, Bikaner

CHAPTER II

TAXONOMY AND PHENOLOGY

MORPHOLOGICAL CHARACTERS

A. jacquemontii is an erect, multi-stemmed, small to large shrub. It can attain height ranging from 1.5 to 4.5 m in different habitats and soil types. The crown is variable in size, flattened, spreading and erect.

Stem / Branch: An individual plant may have stems / branches varying from 4 to 46 depending on habitat and soil depth. The individual stem is stiff, smooth and brown in color. Thickness of stem may vary from 1.0 to 5.9 cm. Twigs are zigzag with greyish brown bark. Young shoots are slightly puberulous.

Spines: Spines are stipular paired, straight, slender and 2.0 to 5.0 cm long. They are ivory-white in color and most often smooth.

Leaves: Leaves are bipinnate 2.5-5.0 cm long with 2-4 pairs of pinnae. Leaflets are in 5-10 pairs, sessile, 2.5-3.0 mm long, linear-oblong, obtuse, and glabrous. Common petiole is 2.5 to 5.0 cm long with small or indistinct glands between the upper pair of pinnae.

Flowers: It produces yellow sweet scented flowers; inflorescence globose heads, 12-16 mm in diameter; peduncles 2-3, slender, axillary, fascicled, bracts 2-3, about the middle of the peduncle.

Calyx: Calyx campanulate, 1.2 to 1.5 mm long; the teeth short, deltoid.

Corolla: Corolla 3 mm long; lobes ovate-oblong, acute.

Androecium : Stamens indefinite; anthers are not gland tipped. The pollens of *A. jacquemontii* are recognized as *A. nilotica*-type (Parveen and Qaiser, 1998). Pollens are 12-16 celled polyads; and tectum sub-psilate. Length, breadth and exine thickness of pollens are 39.40, 50.26 and 1.79 µm, respectively.

Gynoecium : Ovary included in calyx tube or inferior.

Pods: Pods show considerable variation in shape, size and color. They are stalked ovate-oblong, round at base, flat, straight, transversely or reticulately veined, glabrous and 4 to 6 seeded. The length, width and weight of pod may vary from 5.2 to 10.0 cm, 1.0 to 1.7 cm and 0.22 to 0.60 g, respectively. Pods are pinkish white in color with prominent pink colored lining.

Seeds : Seeds are brown to dark brown in color, smooth, compressed and 5.5 to 7.5 mm in diameter. The individual seed weight ranges from 0.03 to 0.06 g and weight of 100 seed is about 4.9 g.

TAXONOMY

According to Ross (1973) *Acacia* was first described in 1754 by Phillip Miller who based his description on Egyptian Thorn (*Acacia nilotica*). The generic name *Acacia* is believed to have been derived from *greek akazo* (I sharpen) alluding to the spiny stipule of many African and Asiatic species. *Acacia jacquemontii* Benth. has been classified as a separate and distinct species by Baker (1876), Parker (1918) and Bhandari (1990) and recognition of it as one of three varieties under *A. nilotica* subsp. *indica* (Benth.) appears to be unjustified (Brenan, 1983). The Taxanomic position of genus *Acacia* is as below :

1. Ovules enclosed in ovary formed by stigma bearing carpels.

   ----Angiosperms

2. Leaves usually net-veined, alternate or opposite; floral parts usually in fours or fives or in their multiples; cotyledons 2; stem in cross section showing vascular bundles arranged in a ring.

   -----Dicotyledonae

3. Perianth differentiated into calyx and corolla.
4. Petals free, flowers dichlamydeous
5. Calyx of united sepals; ovary usually included in calyx tube or is inferior.
6. Fruit is a pod
7. Flowers actinomorphic

   ------Mimosaceae

8. Plants armed with prickles, thorns or spines.
9. Pods not splitting transversely into segments.
10. Pods not spirally twisted, straight, curved or falcate.
11. Stamens indefinite; anthers not gland-tipped.

-----*Acacia*

12. Stem without prickles; stipular spine present.

13. Heads bright or deep-yellow on axillary peduncles.

14. Pods not moniliform but flat; bushy shrub

-----*Acacia jacquemontii*

Morphological features of pods are important characteristics which form one of the important criteria for taxonomic classification of *Acacia species*. Hence, *Acacia jacquemontii* is a distinct species.

POLLINATION

Most acacias produce sweet scented flowers and attract birds and insects toward extra floral nectories. The yellow sweet scented flowers of *A. jacquemontii* make the birds and insects main vectors of pollination (Ford and Forde, 1976).

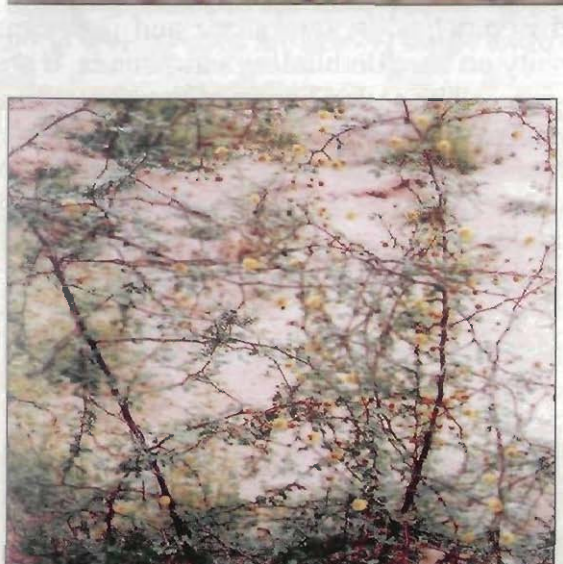
SEED SETTING AND DISPERSAL

The seed setting is mainly controlled by evaporation (Khan, 1970). Seed setting is poor if windy days are prolonged. Pods are dehiscent and burst on drying. Fallen seeds are blown by wind to distant places. Some seeds are also buried in the ground with deposition of wind blown sand on them. Seed dispersal also takes place by animals, which pass-out undamaged seeds through the digestive tract.

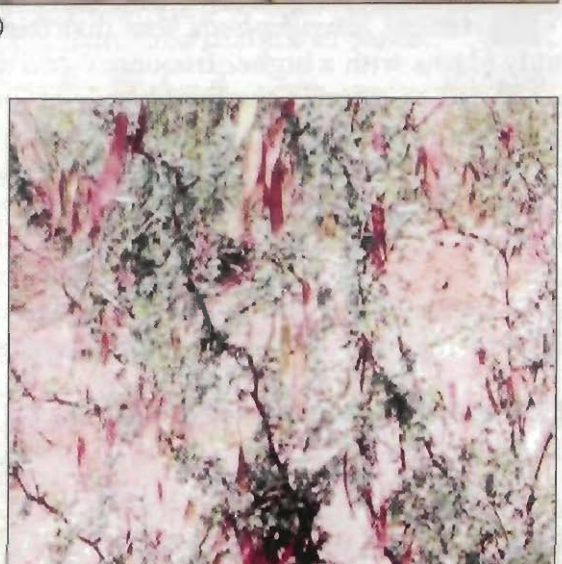
PHENOLOGY

The phenological behavior of *A. jacquemontii* is mainly influenced by rainfall, temperature and evaporation. Rainfall usually affects leafing while temperature influences flowering and fruiting. The time of flowering varies at different locations. The species generally flowers in December to February and pods mature in March to May (Bhandari, 1990). In hyper arid condition of Jaisalmer the flowering initiate in mid February and pods mature in last week of April- first week of May (Plate 5).

(a)



(b)



(c)

Plate 5. Phenology of *A. jacquemontii* a) Budding stage, b) Full boom and c) Mature pods

CHAPTER III

GERMPLASM DIVERSITY

Acacia jacquemontii exhibits great diversity in its habitat, associated plant species, plant type, growth behavior, flowering, fruiting and gum exudation. Wide variations in plant characters have been observed in an extensive survey in Bikaner, Sriganganagar and Jaisalmer districts. The variations in plant types viz., large and small, pod bearing characters viz., low and high, pod yielding plant types and variability in pods color viz., brown, light brown, dark brown and light pinkish have been observed. The pods also vary in shape and size to a great extent. They were ovate-oblong, flat straight and some time curved. The seeds also exhibited variability in color viz; brown, light brown, grayish brown, chocolate brown, pinkish brown, camel, yellowish green etc.; shape viz., elongated, oval and rarely triangular. A brief description of germplasm diversity in different areas of Bikaner and Sriganganagar is discussed herewith.

VARIABILITY IN OCCURRENCE AND ASSOCIATED PLANT SPECIES

Acacia jacquemontii was distributed in patches on sand dune and interdunal sandy plains with a higher frequency and density on bare undulating sand dunes. It was also found growing in the field bunds as live fence. The soils of most of the sites where, *A. jacquemontii* was found growing naturally were sandy in texture. However, scattered population in some interdunal plains having loamy sand texture was also observed. The growth of *A. jacquemontii* was better under loose deep sandy soils as compared to compact gravelly and shallow soils. As landform and soil type control the plant community to a certain extent, it shows variable distribution pattern with associated plant species. The distribution and associated species of *Acacia jacquemontii* on different regions in Bikaner and Sriganganagar districts are as under:

a) Bikaner-Pugal-Khajuwala region

Acacia jacquemontii was mainly concentrated at Jalwali and Karnisar villages in Bikaner district. At Jalwali site, it was the dominant shrub on sand dunes. The main associated shrubs were kheep (*Leptadenia pyrotechnica*) and sinia (*Crotalaria burhia*), however, few phog (*Calligonum polygonoides*) plants were also found. Among perennial grasses, murath (*Panicum turgidum*) was the associate species on sand dunes. It was associated with phog (*C. polygonoides*) and kheep (*L. pyrotechnica*) on sand dunes in Karnisar area. However, in Pugal and Khajuwala area it was not found. On these sites, lana (*Haloxylon salicornicum*) was the dominant shrub with phog (*C. polygonoides*) and kheep (*L. pyrotechnica*).

b) Bikaner-Chhatargarh-Anupgarh region

In this region, *Acacia jacquemontii* was mainly concentrated around Lakhusar village in Bikaner district and associated with phog (*C. polygonoides*), kheep (*L. pyrotechnica*) and bui (*Aerva* spp.) on dune sites. Natural population of *A. jacquemontii* was also observed in interdunal plains with hummocks and on farm field bunds near Barju and Nursar. After Lakhusar, it was naturally distributed up to Motigarh. It was not found in Chhatargarh as most of the area in the region has been brought under canal irrigation.

c) Bikaner-Kolayat-Bajju-Ranjitpura-Fattuwala region

Few scattered shrubs of *A. jacquemontii* associated with phog (*C. polygonoides*), sinia (*C. burhia*) and murath (*P. turgidum*) grass were observed nearby Bajju on the field bunds. On interdunal plains the occurrence was rare. Natural population of *A. jacquemontii* was noticed in interdunal undulating sandy area near Fattuwala. The soils were coarse textured with gravels in surface horizon at this site. Lana (*H. salicornicum*), a dominant shrub in the area, was the main associate species. It was not found in Kolayat region where, soils are heavy (sandy loam – silty loam) and shallow in depth.

d) Bikaner-Jorbeer region

Natural population of *A. jacquemontii* existed in regions having low dune and in fallow/ waste land in Jorbeer area in Bikaner. The associate vegetation included kheep (*L. pyrotechnica*), sinia (*C. burhia*) and bui (*Areva* spp.). At most of the sites, soil was sandy in texture and uniformly distributed throughout the profile.

e) Bikaner-Lunkaransar-Suratgarh-Sriganganagar region

The natural population of *A. jacquemontii* in this sector showed large diversity. In area around Bamanwali, short type plant population was observed as compared to other sites in Bikaner district. Early maturity of pods was also noticed in plants growing in this region. Phog (*C. polygonoides*), kheep (*L. pyrotechnica*), and sinia (*C. burhia*) were the main associate shrubs. In Lunkaransar area, where soil is saline, *A. jacquemontii* was almost absent and dominated by halophyte shrubs. However, *A. jacquemontii* was found near Malkisar and Mokalsar villages, where soils are non saline, on field bunds and fallow lands. Bordi (*Ziziphus nummularia*) was the associated shrub at this site. Large plant type with better growth of *A. jacquemontii* was the main feature at this site.

At Rajiasar site, good natural stand of *A. jacquemontii* with diverse plant type occurs on dune complex. Kheep (*L. pyrotechnica*), bui (*Aerva pseudotomentosa*), sinia (*C. burhia*) were the associated shrubs, while Israeli babul (*Acacia tortilis*) was the planted tree species. Good stands of *A. jacquemontii* existed around Birdhwal and on way to Thermal Power Station with kheep (*L. pyrotechnica*) as the main associated shrub. At this site large size of leaflets and more shattering of pods in *A. jacquemontii* was observed as compared to other sites. From Birdhwal to Suratgarh, good natural population of *A. jacquemontii* existed with short plant types. Kheep (*L. pyrotechnica*) was the associated shrub while Vilayati babul (*Prosopis juliflora*) was the planted species. Young geminated seedlings, indicating natural re-generation of *A. jacquemontii*, was the unique feature of this site.

f) Bikaner-Nokha region

Naturally scattered population of large plant types of *A. jacquemontii* was noticed around Alay village on sandy plains and also in few field bunds. These soils were sandy in texture and deep to very deep in depth.

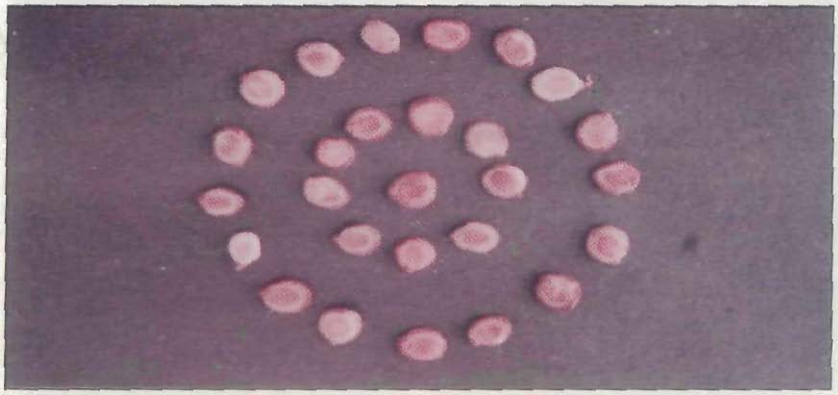
VARIABILITY IN PODS

The pods of *A. jacquemontii* show considerable diversity in the natural population (Plate 6). The pods also exhibited diversity in color and it ranged from brown, light brown, dark brown to light pinkish in different collections. Most of the collections had brown color followed by light brown and light pinkish color. Only two collections had dark brown colored pods. The pods also varied in shape and size to a great extent (Plate 7). They were ovate-oblong, flat, straight and sometimes curved. Small, medium and large type of pods were noticed at different sites and also within same site. Low and high pod yielding plant types were observed at different sites.

In collections from Bikaner, the pod length varied from 1.8 to 8.7 cm with an average of 4.3 cm. Pod length of most of the accessions ranged 3.0 to 5.0 cm. Only few accessions from Bridhwal in Sriganganagar districts were in the range of 6.0-9.0 cm. The pod width varied from 0.9 to1.9 cm, with an average width of 1.3 cm. Most of the accessions ranged in between 1.1 and 1.5 cm in width. In comparison to other locations, diversity in pod size was higher at Jalwali site. Likewise, the collections from Jaisalmer also showed vide variations in pod characters (Table 1). In general, collections from Jaisalmer had larger pods than those from Bikaner. Number of seeds per pod varied from 1 to 8 in Bikaner while in collections made at Jaisalmer it ranged from 4 to 8. The maximum seeds per pod (8) were found in collections from the Birdhwal in Sriganganagar and Murhar in Jaisalmer districts.

Plate 6. Variability in pods bearing characters of *A. jacquemontii*

(a)



(b)

Plate 7. Variability in pods (a) and seeds (b) of *A. jacquemontii*

Table 1. Variability in pod characters of *A. jacquemontii*

Characteristics	Bikaner			Jaisalmer		
	Min	Max	Mean	Min	Max	Mean
Length (cm)	1.8	8.7	4.3	5.2	10.0	7.24
Width (cm)	0.9	1.9	1.3	1.0	1.7	1.54
Weight/pod (g)	-	-	-	0.22	0.60	0.36
Number of seed / pod	1	8	4	4	8	5.4

VARIABILITY IN SEEDS

Great variability in color of seeds viz., brown, light brown, grayish brown, chocolate brown, pinkish brown, camel, khaki, yellowish green was observed among different collections. Most of the seeds were greenish brown in color. Considerable diversity was also observed in seed shape viz., elongated, oval, pea and triangular. Most of the collections had oval-round followed by elongated seeds. In elongated seeds, few accessions also showed slight curve. In addition to this, seeds of some of the accessions showed marks on one or both sides. Two accessions from Sriganganagar district showed U shaped mark.

The seed size in collections from Bikaner varied from 4.0 to 7.0 mm while in collections from Jaisalmer it varied from 5.5 to 7.5 mm. The corresponding range of 100 seed weight varied from 1.50 to 5.26 and 4.04 to 5.43 g. The variability in seed characters is summarized in Table 2.

Table 2. Variability in seed characters of *A. jacquemontii*

Characteristics	Bikaner			Jaisalmer		
	Min	Max	Mean	Min	Max	Mean
Seed diameter (mm)	4.00	7.00	5.10	5.50	7.50	6.65
100 seed weight (g)	1.50	5.26	2.98	4.04	5.43	4.93

VARIABILITY IN SEED GERMINATION

The seed germination of 42 collections of *A. jacquemontii* was studied under nursery condition at Central Arid Zone Research Institute, Regional Research Station, Bikaner. The freshly collected seeds were sown without any pre-sowing treatment in the second week of June in poly bags. The germination started within two days of sowing and continued up to 7 days to reach peak germination. Germination percent in various accessions ranged from 70 to 100 (Table 3).

Table 3. Variability in seed germination (%) of *A. jacquemontii*

	Days after sowing					
	3	4	7	8	9	13
Range	0-26.7	0-51.0	35.6-77.8	42.2-80	42.2-82.2	46.7-86.7
Average	6.7	11.6	60.9	65.6	67.4	70.2

VARIABILITY IN SEEDLING GROWTH IN NURSERY

Considerable variation with respect to seedling survival, growth in height and number of leaves at different periods was observed among seedlings of different collections. Maximum seedling survival was noticed in the collections from Bikaner district (Karnisar, Barju and Fattuwala sites). Minimum seedling survival was noticed in the collections from Birdhwal site. Seedlings obtained from most of the seeds collected from field bunds were outstanding in respect to plant height. Collection from field bund of Malkisar recorded more height and showed better plant growth. Variation in growth performance of different collections in nursery is given in Table 4. Among different collections number of leaves per plant ranged from 11-37 with a mean of 19.7. Collections from Mokalsar, Lakhusar, Malkisar recorded maximum number of leaves, while collections from Fattuwala and Jorbeer sites had the minimum.

Table 4: Variability in seedling growth of different collections of *A. jacquemontii* in nursery

Location	Number of collections	Seedling height (cm)		
		30 days	60 days	90 days
Fattuwala	2	10.4	14.3	14.5
Jorbeer	3	7.4	12.9	15.3
Jalwali	7	7.3	14.4	18.2
Karnisar	4	6.7	14.1	16.6
Barju	5	7.2	18.5	20.9
Lakhusar	3	6.9	17.9	21.0
Nursar	1	9.3	16.9	18.8
Rajiasar	3	8.1	15.2	18.1
Birdhwal	5	6.9	11.6	14.3
Suratgarh	2	7.7	11.1	13.6
Mokalsar	3	7.5	11.1	15.6
Malkisar	1	10.8	15.9	24.1
Bamanwali	1	7.3	13.8	15.5
Alai	2	7.7	15.1	18.1

VARIABILITY IN FIELD PERFORMANCE

To assess variation in field performance, different collections of *Acacia jacquemontii* were planted at research farm of CAZRI, RRS Bikaner, in July 2003 and their growth was evaluated under rain fed condition. The planting site was affected by wind erosion due to which considerable amount of topsoil was lost. The seedlings were planted at compact eroded site which was loamy sand in texture with low soil organic carbon (0.09%), and available N (90 kg/ha). The calcium carbonate concretions occurred at 150 cm soil depth. The survival of seedlings after two year of planting was 65.4%. In the third year, 11 collections showed 100% survival, 7 showed 75 % , 6 showed 50 %, 4 showed 25% and ten accessions showed total mortality of the seedlings. Highest plant mortality was recorded in collections from Rajiasar in Sriganganagar district, followed by Barju in Bikaner. The seedlings obtained from seeds collected from plants growing on dunes and on field bunds showed highest survival followed by seedlings raised from seeds of plants growing on interdunal undulating hummocks/plains. Higher survival percentage was observed in the collections of Karnisar, Fattuwala, Jorbeer sites in Bikaner district. However, plant growth was better in the collections made from the field bunds from Suratgarh, Malkisar and Mokalsar sites. Slow seedling growth was observed in most of the collections (Table 5).

Table: 5 Variability in growth performance of out-planted seedlings of different collection of *A. jacquemontii* in field

Location	No. of collections	Plant height (cm)				
		3 months	6 months	1 year	2 years	3 years
Fattuwala	2	28.1	30.7	48.7	70.8	80.4
Jorbeer	3	24.9	28.1	41.5	81.6	86.3
Jalwali	5	24.8	24.9	30.3	56.2	64.2
Karnisar	4	29.5	31.9	37.0	50.3	56.8
Barju	2	31.7	33.2	46.3	54.7	62.5
Lakhusar	1	33.3	37.7	44.7	70.0	72.0
Nursar	1	30.0	30.0	33.3	45.7	57.5
Birdhwal	2	26.7	26.8	31.6	50.8	52.3
Suratgarh	2	32.4	45.5	68.0	102.5	126.7
Mokalsar	2	35.2	43.5	70.2	92.3	106.0
Malkisar	1	26.0	30.7	42.3	78.3	105.0

Seeds collected from short type of plants from natural populations also showed relatively less height and slow plant growth in comparison to collections from field bunds which attained maximum plant height with better plant growth after three years of

planting. A large variation was observed in development of new stems/shoots (Table 6) at ground level and canopy cover (Table 7) of growing plant or thicket (multi-stemmed growing plant is referred as thicket). At the age of three years maximum number of stems per thicket was recorded from the collections of Suratgarh, whereas as it was minimum in collections from Nursar and Birdhwal. Like development of stems per thicket, the collections from Suratgarh continued to grow well and attained maximum canopy. The collections from Birdhwal showed minimum canopy growth. In general, collections from Suratgarh, Mokalsar, Malkisar and Lakhusar have put in better growth as compared to other collections. Different collections showed wide variability in development of new stem as well. In general, maximum new stems were developed when plants were 6 month to one-year-old. Thereafter, number of stems per thicket declined as tender shoots could not withstand the competition and died.

Table 6. Variability in number of stems developed in out-planted seedlings of different collection of *A. jacquemontii* in field

Locality	Number of stems per thicket				
	3 months	6 months	1year	2 years	3 years
Fattuwala	5.8	6.8	6.8	4.5	4.0
Jorbeer	3.2	4.2	6.3	4.4	4.8
Jalwali	4.9	4.3	6.0	4.0	4.6
Karnisar	3.1	5.0	3.9	3.8	3.6
Barju	6.2	7.3	6.7	2.6	3.9
Lakhusar	7.7	9.0	6.7	4.3	5.7
Nursar	9.7	8.0	7.3	2.3	3.0
Birdhwal	3.8	6.5	7.3	3.7	3.2
Suratgarh	7.3	12.8	11.7	6.7	7.8
Mokalsar	6.2	8.5	13.7	7.0	6.7
Malkisar	7.7	7.3	9.7	6.3	4.7

Table 7: Variability in canopy (m^2) in out-planted seedlings of different collections of *A. jacquemontii* in field

Locality	No. of collections	Canopy per thicket (m^2)			
		6 months	1 year	2 years	3 years
Fattuwala	2	0.137	0.222	0.337	0.443
Jorbeer	3	0.058	0.192	0.667	0.739
Jalwali	5	0.039	0.133	0.499	0.598
Karnisar	4	0.063	0.119	0.477	0.509
Barju	2	0.057	0.123	0.365	0.397
Lakhusar	1	0.078	0.177	0.378	0.484
Nursar	1	0.071	0.167	0.454	0.482
Birdhwal	2	0.054	0.101	0.386	0.395
Suratgarh	2	0.281	0.442	0.927	1.331
Mokalsar	2	0.387	0.724	0.933	1.215
Malkisar	1	0.353	0.524	0.839	1.147

VARIABILITY IN LEAF AND SPINE

Among different collections the length of stipular spines ranged from 0.7 to 5.4 cm. The number of pinnae pairs ranged between 2 and 6, however, most of the collections showed 2 to 4 pairs of pinnae. Leaflets varied from 4 to 11 pairs, while most of the plants had between 5 and 7 pairs of leaflets. The length of petiole varied from 1 to 7 cm, but in most of the plants it was 2 to 3 cm.

VARIABILITY IN GUM EXUDATION

The extent of gum production and optimum season for its collection is location specific. Local inhabitants normally collect gum in the month of April and May. Among different sites of Bikaner district, maximum gum production was at Lakhusar and Jalwali villages. High gum yielding types of *A. jacquemontii* were also noticed at Fattuwala site. The plants in Sriganganagar district were low gum yielding type.

CHAPTER IV

SILVICULTURAL CHARACTRESTICS

GROWTH HABIT

Acacia jacquemontii is an erect, multi-stemmed or much branched shrub. In deep sandy soils it attains a height of 4-5 m. At adverse sites having shallow/gravely soils, it seldom grows more than 2 m in height (Plate 8 & 9). The number of stems/branches per thicket may vary and is dependent on habitat. Basically, it thrives well on deep sandy soils, high dunes, interdunal plains and duny complex. Due to multi-stem growth character good canopy spread is attained with in 4 to 5 years. The growth of plant is very fast in early stage and slows down after 5-6 years.

SEED GERMINATION

The seeds of *A. jacquemontii* start germinating when favorable conditions are available. The germination of seed is epigeal. The radicle emerges and moves downward. The hypocotyl elongates and cotyledons are pushed above ground. The growth and elongation of roots is faster than that of shoot. The primary tap root is long and thick. Development of numerous laterals results in strong anchoring root system.

SEEDLINGS

Young plants of *A. jacquemontii* grow very fast and may attain a height of 30 to 70 cm in a year after transplanting in field. In sites where soils are shallow and gravely the growth of seedlings is slow and poor.

ROOT SYSTEM

A. jacquemontii develops profuse root system .The young plants quickly develop very long tap root with several laterals. The development of laterals is vertical and parallel to tap root and after 5-6 years it is difficult to distinguish between main tap root and laterals. Development of many sub-lateral roots (Plate 10) creates a strong root net work that binds sand in the rhizosphere. Normally root grows 4 to 6 m deep in search of water. In high dunes and duny complex the roots may penetrate even deeper in search of water. Study of root system of natural stand, carried out at CAZRI, RRS Jaisalmer, revealed that most often the lateral spread of root rhizosphere almost equals (Plate 11) the above ground canopy cover and extends up to 18.3 m^3 (Table 8). Development of root suckers has not been observed in *A. jacquemontii*.

Plate 8 Growth of *A. jacquemontii* in deep soils

Plate 9 Growth of *A. jacquemontii* in shallow soils

Plate 10 Profuse root system of 5- year old *A. jacquemontii*

Plate 11 Excavated roots of 5- year old *A. jacquemontii*

Table 8. Root system of about 5-years old *A. jacquemontii* plant growing on sand dune in Jaisalmer

Parameter	Number	Mean length (m)	Mean root diameter (mm)		Underground Root rhizosphere (m^3)
			Collar	Tip	
Total roots	38	-	-		18.33
Tap root	1	3.42	33.3	2.1	
Primary root	13	2.61	15.1	0.9	
Secondary root	24	1.41	8.6	1.4	

COPPICING

Acacia jacquemontii is a strong coppice and coppices well in all locations when cut at ground level. Its young coppice shoots grow very fast and plant attains status of a dense thicket in one year after the cut. Site conditions have significant impact on development of new shoots. Normally *A. jacquemontii* is coppiced once in every 5-6 years when plant attains a height about 4 m. However, studies at CAZRI, RRS Jaisalmer, revealed that to obtain young branches for making basket, it can be coppiced every time.

RESISTANCE TO DROUGHT, FROST AND SALINITY

Acacia jacquemontii is hardy species and can withstand extreme drought. The drought tolerance is said to be due to high proline content found in acacias. Several plant species including acacias are known to accumulate free amino acids especially proline, during moisture stress (Stewart *et al,* 1966; Singh *et al,* 1972). Full grown plants escape frost damages, however, young seedlings are susceptible to frost. Normally, the plants affected with frost re-sprout but, in extreme cases of damage they are killed. Plants growing in riverbeds or close to river banks are not affected by frost (Joshi *et al,* 1983). Not much information is available on tolerance of *A. jacquemontii* to soil salinity but, grows well on arid saline soil.

SITE FACTORS

Temperature

In its natural habitat, the summers are very hot, where maximum temperature may go up to 49° C. During winter mercury level touches the freezing point. This shrub normally tolerates temperature varying from 0°C to 48° C. The high temperature in summer poses no problem to this species.

Rainfall

Acacia jacquemontii is drought resistant species and grows well in regions where average annual rainfall ranges from 180 mm to 350 mm. Most of the annual rainfall is received during monsoon (June to September) in 6 to 12 rainy days. It grows in lower rainfall areas also, but growth is comparatively poor. For optimum growth annual rainfall of about 200 to 300 mm is required. The plant grows well with faster rate under irrigated condition. The normal rainfall in regions where this plant is known to grow in western Rajasthan is given in Table 9.

Table 9. Mean annual rainfall and its coefficient of variation in Western Rajasthan

District	Mean annual rainfall (mm)	Coefficient of Variation of annual rainfall
Barmer	267.7	58
Bikaner	293.7	55
Churu	366.3	40
Sriganganagar	213.6	43
Jaisalmer	185.0	59
Jalore	369.1	53
Jhunjhunu	404.4	37
Jodhpur	361.4	53
Nagaur	315.3	50
Pali	419.5	45

Ecological association

Acacia jacquemontii grows well in loose deep sandy soils as compared to compact and gravely soils. The preferred habitats viz. sand dunes, interdunal plains, riverbeds etc. are mainly embodied with sandy to loamy sand textured soils. *Acacia jacquemontii* shows variable distribution pattern of associated species in different rainfall zones (Table 10). The main associated species of *A. jacquemontii* in different landforms observed in extensive survey of Bikaner and Sriganganagar districts are given in Table 11.

Table 10. Associate species of *A. jacquemontii* in different rainfall zones

Rainfall zone (mm)	Region	Associated species		
		Trees	Shrubs	Grasses
<200	Jaisalmer, western Bikaner, Western most Barmer	*Prosopis cineraria*	*Calligonum polygonoides*	*Lasiurus sindicus, Panicum turgidum*
200-300	Barmer, western Jodhpur, central Bikaner, Sriganganagar and western Hanumangarh	*Prosopis cineraria, Tecomella undulata*	*Calligonum polygonoides*	*Cenchrus ciliaris, C. setigerus*
300-400	Jalore, Pali, northern Jodhpur, Nagur, Churu, Hanumangarh	*Prosopis cineraria, Acacia nilotica*	*Ziziphus nummularia, Crotolaria burhia*	*C. setigerus, Dichanthium annulatum*

Table 11. Associate species of *A. jacquemontii* in Bikaner and Sriganganagar districts of Western Rajasthan

Land forms	Soils	*Associated species*
Sand dune	Sandy	Kheep (*Leptadenia pyrotechnica*), Sinia (*Crotolaria burhia*), Phog (*Calligonum polygonoides*), Murath (*Panicum turgidum*)
Inter dunal plain with hummocks	Sandy	Phog, Kheep and Bui (*Aerva* spp).
Low dunes fallow / wasteland	Sandy	Kheep, Sinia and Bui.
Field bunds undulating area	Coarse with gravel on surface	Phog, Sinia and Murath.

CHAPTER V

REGENERATION

NATURAL REGENERATION

Acacia jacquemontii can regenerate naturally. The species occurs in patches and large natural dense forest areas are unseen. Natural regeneration occurs mainly through seeds. Generally, the pods burst while still on the plant and seeds are blown away by the wind. Some times ripe pods of *A. jacquemontii* fall on the ground which burst due to sun-drying and seeds are scattered. The fallen seeds are often buried in soil due to deposition of wind blown sand, a common phenomenon in its natural habitat in sandy desert. The buried seeds may remain dormant for one to two years. Generally seeds germinate in monsoon as adequate moisture is required for germination.

A. jacquemontii faces mainly two problems in its natural regeneration viz. poor germination due to burial of seeds and damping off of sprouted seedlings. The seed fails to germinate and emerge out if; it is buried 1.0 cm below the surface. The possibility of burial of seed remains very high because seeds mature and fall on ground in the month of April and May. Immediately thereafter during April to June and some times even up to July wind velocity is high and dust stroms common. Often deposition of blown sand results in burial of seeds. On getting favorable conditions after onset of monsoon, seeds germinate and seedlings start growing. In the event of long dry spell of drought after seed germination mortality of seedlings occur. Occasionally, excessive moisture or flooding, particularly in low lying area also damages, young seedlings. Annual weeds and grasses compete for moisture and nutrients with young seedlings, which often results in failure of seedling establishment. Thus poor germination and environmental stresses are the main constraints that make regeneration of *A. jacquemontii* difficult in nature.

ARTIFICIAL REGENERATION

In favorable conditions *A. jacquemontii* regenerates naturally and grows well. Under drought and intense competition from grasses and weeds, the plant does not regenerate naturally. Over-exploitation of natural stands by local inhabitants for small poles and fuel wood coupled with poor natural regeneration has threatened the existence of this species (Singh, 2004). Therefore, efforts are needed to conserve the plant through artificial regeneration.

Artificial regeneration by direct sowing

Artificial regeneration by sowing seeds directly in field has not been reported in *A. jacquemontii*. However, in acacias artificial regeneration by sowing seeds directly in the fields is a common practice (Ghosh, 1977) and same can be implied in case of *A. jacquemontii* too. The right period of sowing seeds in field is the early July after onset of monsoon rain (Mishra *et al,* 1983). It is better to sow seeds early after the first monsoon shower when the surface soil is sufficiently moist. However, long spell of dry period after first shower may result in germination failure. To minimize the risk, it is better to sow seeds when monsoon has set in and the ground is moist up to some depth.

Depending on method of sowing the seed rate varies from 0.25 kg to 0.50 kg/ ha. Instead of broadcasting, dibbling of seed is preferable for small areas. Dibbling consists of digging of small pits, placing 3-4 seeds in each pit and covering them with thin layer of soil. This is labor intensive as seeds have to be put in pits manually. The seed dibbler used for agricultural purposes can also be used for dibbling of *A. jacquemontii* seeds for covering large areas. Seeds can also be sown in trenches having 30-45 cm cross section made 3-4 m apart. This method is beneficial in conserving the soil moisture and prolonging the moisture availability to young plants. In case of drought, a common phenomenon in arid areas, conserved moisture may help seedling to sustain and survive. In plain areas, line sowing is recommended.

Germination of seed is complete within a week and newly emerged seedlings start growing. Young seedlings are very tender and need proper care as these are likely to be suppressed by weeds and grasses. Development of tap root is very fast in *A. jacquemontii* and once established it becomes hardy and resistant to drought.

Artificial regeneration by nursery raised seedlings

Till recent, development of *A. jacquemontii* plantations by direct seeding or through nursery-raised seedlings was not practiced. When the natural stands of *A. jacquemontii* confined to certain pockets, started disappearing due to over-exploitation by local inhabitants, efforts were made for its conservation and multiplication. Like any other acacia, raising of nursery does not pose any problem in *A. jacquemontii*. The species can be easily grown by seed in nursery and after 6-8 months out planted in the field during monsoon season

Healthy seedlings of *A. jacquemontii* can be raised by sowing seeds in poly-bags of 20x10 cm size. The most common potting mixture consisting of soil, sand and FYM in

1:1:1 ratio is used. For filling in root trainer containers, mixture consisting of sand and FYM in 20:80 ratios gives better results (Prasad *et al*, 2002). Tray type root trainers having 250 cm^3 cell sizes are the best for raising plantable size seedlings. If seedlings are to be retained for an extended time in nursery to get long and sturdy seedlings, 500 cm^3 single cell root trainer pots are better suited. The development of plantations artificially involves seed collection, proper storage, pre-sowing seed treatment, nursery management planting seedling in the field and protection and maintenance of out planted saplings.

Seed collection

Generally, seeds are produced almost every year during April-May. Seed production is more profuse in 4-to 5-year-old plants. The ripe pods on drying usually burst while still on the plant. The seeds fall on the ground and are either blown away or buried. It is difficult to collect seeds fallen on the ground. For collection of healthy seeds, it is desirable to pick up mature pods manually before they get burst on drying. They can also be collected by beating off the branches with stick and the fallen pods are collected. The pods can also be collected safely by clippers mounted on bamboo poles. The collected pods are sun dried for 6-8 days. On drying pods burst and seeds are separated. Some time seed extraction may require light beating of the pods with sticks or mallets. Seeds can also be separated by trembling on pods wrapped in bags or by pressing pods between hands. Usually over 50% of the pod forms the seed part and the remaining is chaff and other impurities. Seeds are separated from chaff and other impurities by sieving and winnowing. Seeds need to be completely air dried and stored in air tight containers in cool and dry place. They can also be stored in tins. Freshly collected seeds can be used up to two years without any loss of viability.

Pre-sowing treatment and seed germination

The dormancy in *A. jacquemontii* seeds is due to hard and impermeable seed coat. Pre-sowing seed treatment is required to get not only rapid and uniform germination after sowing, but also to ensure high germination percentage. Germination studies on pre-sowing treatment of *A. jacquemontii* by Mertia and Prasad (2006) have revealed that soaking of seeds in cold water for 12 hours gives maximum germination followed by seeds soaked in hot water (80°C) for two hours. Untreated seeds gives minimum germination (Table 12).

Table 12: Effect of pre-sowing treatments and seed size on germination of *A. jacquemontii*

Treatments	Per cent germination after hours of seed setting			
	8	16	24	32
Pre-sowing treatments				
Untreated seeds (control).	0	13.3	47.5	75.8
Soaking seeds in cold water for 12 hours.	35.0	83.5	85.8	100.0
Soaking seeds in hot water (80^{0}C) for 2 hours.	0	62.7	77.8	80.0
LSD (P<0.05)	8.386	7.116	9.334	3.880
Seed size				
	11.1	75.6	77.6	100.0
	12.2	30.7	63.0	77.2
LSD (P<0.05)	NS	5.810	7.621	3.197

Table 13. Effect of pre-sowing treatments and seed size on germination behavior of *A. jacquemontii*

Observation	Untreated seeds (control)		Soaking seeds in cold water for 12 hours.		Soaking seeds in hot water (80^{0}C) for 2 hours	
	Large	Small	Large	Small	Large	Small
Time for earliest Germination (hours)	16	24	8	8	16	16
Germination after 32 hours of seed setting (%)	100	71.6	100	100	100	60
Germination energy	67.7 (32) *	61.7 (24)	67.7 (16)	36.7 (20)	100 (16)	30.4 (24)

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

Study further revealed that besides pre-sowing treatments, size of seed influences germination significantly. Large seed germinated at faster rate in comparison to smaller ones. Large seeds subjected to cold and hot water pre-sowing treatment had resulted in 100% germination in 16 hours whereas, untreated seeds could attain same level of germination in 32 hours. For initiation of germination process, seed treated with cold water took minimum time (8 hours) whereas; untreated small seeds took the maximum (24 hours). Size of seed and pre-sowing treatments also affect germination energy (Table 13). Germination energy refers to percentage of seeds that are actually germinated when the rate of germination is at its peak. In general large seeds exhibited high germination energy than small seeds. Emergence of radicals and its development proves the effectiveness and suitability of particular pre-sowing treatment. Pre-sowing treatment of seed significantly affected root development and /or radical enlargement up to 33 hours of germinated seeds (Table 14). Maximum root development has been reported in seed subjected to cold water treatment where as, it was least in untreated seeds.

Table14. *Effect of pre-sowing treatments and seed size on root development of A. jacquemontii*

Treatments	Root elongation (cm) after hours of seed setting			
	27	30	33	36
Pre-sowing treatments				
Untreated seeds (control)	0.17	0.20	0.33	0.83
Soaking seeds in cold water for 12 hours	1.30	1.43	1.63	1.83
Soaking seeds in hot water (80^0C) for 2 hours	0.60	1.00	1.25	1.43
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

Large seeds give better germination due to larger embryo or gametophytic tissues and bigger cotyledons (Farmer, 1980). Poor rate of seed germination in smaller seeds is attributed to their ability to imbibe less water. Mertia and Kunhamu (2000)

reported highest seed germination and germination energy for seeds of *Salvadora oleoides* treated with cold water. 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 (Table 14).

For better and uniform germination of seeds, it is desirable to soak seeds either in cold water for 12 hours or hot water (80°C) for two hours. The treated seeds should be air dried in shade for 30 minutes before sowing. The treated seeds should not be kept for longer time to prevent loss in viability. If these pre-treated seeds need to wait for a longer time, they should be stored at lower temperature. Studies at CAZRI RRS Bikaner, revealed that freshly collected untreated seeds resulted in 60% germination in seven days and reached maximum (70%) in 13 days. The delay and slow germination rate of seeds in nursery produces uneven planting stock.

Seed sowing in nursery

Depth of seed sowing is very important (Nagarajan and Mertia, 2006). Normally, in each poly pot 1-2 seeds soaked in cold water for 12 hours should be sown at 0.5 to 1.0 cm depth. In their study on seed germination and seedling growth of *A. jacquemontii* in Thar Desert, Mertia *et al.*, (2005) reported that sowing depth, as well as seed size significantly influenced germination in nursery (Table 15). Maximum germination (100%) was obtained when seeds were sown at 0.5 cm depth. Large seeds gave higher germination than smaller ones. Study further revealed that the growth of seedlings was also affected by seed size and sowing depth.

Table 15: 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:					
0.5 cm	76.7	81.7	100.0	100.0	100.0
1.0 cm	50.0	50.0	91.7	91.7	91.7
1.5 cm	10.0	11.6	80.0	90.0	90.0
2.0 cm	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

Seed size influenced growth of seedling up to 30 days while sowing depth up to 14 days. However, number of leaves remained unaffected with seed size and sowing depth (Table 16).

Table 16. 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:								
0.5 cm	9.6	11.0	17.9	27.6	2.3	3.0	5.5	7.9
1.0 cm	7.4	9.4	17.9	28.6	2.0	3.4	4.7	8.2
1.5 cm	7.2	9.4	19.9	27.5	2.2	2.7	6.1	8.6
2.0 cm	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

Watering in nursery

Frequent watering in nursery is required till germination is complete. Seed of *A. jacquemontii* starts germinating on 2nd and 3rd day and is completed within a week. During this one-week period light watering is done daily. After completion of germination, alternate day watering is sufficient for few weeks. Watering in nursery is the most crucial operation which decides quality of planting stock in the nursery and success or failure upon its transplanting in the field. Excess watering results in production of pampered seedlings which fail when planted out in harsh field conditions. Therefore, frequency of watering in nursery has to be planned most judiciously. The number of watering and quantity of water per plant or per bed depends on locality and the season.

Shading

Young seedlings of *A. jacquemontii* need to be protected from scorching heat in summer months and severe cold in winter. Thatched shade of locally available Kheep (*Leptadenia pyrotechnica*) is the best way to protect seedlings from heat in summer and frost in winter. Proper shading of nursery increases germination (Goda, 1987) and enables seedlings to grow well.

Hardening of seedlings

Hardening of seedlings is a necessary to prepare seedlings for planting in the field. In nursery, seedlings are kept under constant care for their development. The good seedlings are selected and placed separately where they are given less watering and exposed to sun gradually to condition them for planting out in field. Normally one month time is sufficient to harden and acclimatize seedlings to natural environment.

Size and quality of planting stock

Healthy and quality seedlings of *A. jacquemontii* should be selected for transplanting in field. Generally, seedlings attain 40-50 cm height with a woody stem in six months. Small and poor seedlings should be culled out in nursery. Eight-month-old seedlings with an average height of 53 cm gave maximum survival at CAZRI, RRS Jaisalmer. The quality parameters of polybag-raised seedlings of *A. jacquemontii* are given in Table 17. It may be noted that in comparison to eight-month-old seedlings the quality parameters viz., sturdiness, root shoot ratio and Dickson quality index (DQI) has improved considerably in 12-month- old seedlings. Hence, it would be desirable to plant one-year-old seedling if planting is to be done on difficult sites where facility of irrigation is not available and plantation is to be established during monsoon.

Table 17. Quality parameters of nursery stock of *A. jacquemontii*

Parameter	8-month-old	12-month-old
Plant height (cm)	53	56
Collar diameter (mm)	2.2	2.7
Dry shoot weight (g)	0.80	1.04
Dry root weight (g)	0.42	0.55
Total biomass (g)	1.22	1.59
Sturdiness (height cm/ collar diameter in mm)	24	20.7
Root shoot ratio	0.517	0.528
DQI (Total biomass/sturdiness)	0.0505	0.0768

PLANTING

The seedlings should be planted in of 30x30 cm pits at 3x3 m spacing in July or August after monsoon has set in. For proper growth and establishment of seedlings, it is desirable to provide one or two waterings after planting, if monsoon rain is not received and dry spell follows transplanting. Studies at CAZRI, RRS Jaisalmer, revealed that in first year, monthly watering in summer months (April to June) ensures better survival and establishment.

Planting for sand dune stabilization

Arid shrubs are of paramount importance as they are most resistant to environmental stresses in hot arid regions (Singh *et al*, 2006). *A. jacquemontii* is one of the most important arid shrubs for sand dune stabilization in Thar Desert. It is an excellent sand binder on bare sand dunes and improves the soil conditions (Table 18).

Table 18. Soil characteristics of *A. jacquemontii* habitat

Properties	Below canopy	Out of canopy area in open
pH	7.9	8.0
EC dS m^{-1}	0.39	0.37
Organic carbon (%)	0.23	0.10

It is evident that soil pH and electrical conductivity (EC) in soil samples collected from below plant canopy and open field are comparable. However, a significant increase in soil organic carbon at 15 cm depth in samples collected from below canopy area as compared to open field indicates that the species has got the ability to improve soils. Vigorous growth due to its efficient moisture utilization makes it a promising species for planting on sand dunes (Tewari *et al*, 2000). In a comparative study on *A. jacquemontii* and other woody perennials viz., phog (*Calligonum polygonoides*), kumat (*Acacia senegal*) and mopane (*Colopospermum mopane*) on sand dune at Pugal in Bikaner, revealed that after 3 years of planting, maximum survival was recorded in *A. jacquemontii* in comparison to other species. Maximum plant growth in terms of plant height (78.8 cm) and canopy cover (1.19 m^2) was also recorded in *A. jacquemontii* as compared to other species. The grass cover of murath (*Panicum turgidum*) and sewan (*Lasiurus sindicus*) was also higher in association with *A. jacquemontii*. The multi-branched root behavior of *A. jacquemontii* help in binding and trapping the soil, which is otherwise lost during high wind velocity and adversely affects the nearby-cultivated

fields. Significant reduction in soil loss has been observed at plantation site in comparison to that on bare one.

Planting in agri-silvi-pasture system

Recently *A. jacquemontii* is being evaluated for its suitability for integrating it in agri-silvi-pasture system as boundary planatation in arid zone. Because of its multiple uses, it is viewed as potential species for alternate land use system or agroforestry. In a study, conducted in sandy soil in Bikaner, *A. jacquemontii* has been integrated in agri-silvi-pasture system along with other woody perennials viz., phog (*C. polygonoidus*), rohida (*Tecomella undulata*) and khejri (*Prosopis cineraria*). It showed relatively fast growth and attained average plant height of 119.3 and 149 cm after 12 and 36 months after planting, respectively.

Planting as bio-fence or Shelterbelt

Due to fast growth habit, *A. jacquemontii* is suitable for planting at field boundary in single or double row as bio-fence (Plate 12). It develops dense canopy in 2-3 year which acts as a barrier for any biotic interference. Studies conducted at CAZRI RRS, Jaisalmer, revealed that when planted on field bund, it attained height of 2.5 m in 3 years with 16 stems per plant. In a five row shelterbelts with a pyramidal shape having one row of tall tree followed by two rows of smaller trees and then followed by two rows of shrubs at the edge in the flank (Kaul, 1969); planting of *A. jacquemontii* as outer or flank row increases effectiveness of shelterbelt plantation by reducing speed of wind and interception of blown sand.

(b)

(a)

Plate 12 Planting of *A. jacquemontii* as bio-fence or shelterbelt along field boundary . a) Bikaner and b) Jaisalmer

CHAPTER VI

GROWTH AND BIOMASS YIELD

In spite of multiple uses and wide occurrence of *A. jacquemontii* in arid and semi-arid regions, it remains a species of low profile. It is only in recent years that the species has attracted attention of ecologists, foresters and other researchers due to threat of its disappearance from its natural habitat. As the species remained unattended, much data is not available on its growth and biomass. Very little efforts are made to collect and collate the growth information from entire range of its distribution and growth conditions. The data discussed here on its growth and biomass yield mainly pertains to Indian arid zone particularly of western Rajasthan.

GROWTH

Acacia jacquemontii shows considerable variation in its growth in different habitats, localities and sites. In nature it acquires maximum growth in rainy season and growth may vary with quantum of rain received in different regions. The growth parameters of *A. jacquemontii* in natural stands in different localities of Bikaner district is given in Table 19.

Table 19. Growth of *A. jacquemontii* in natural stands in Bikaner

Locality	Growth parameters		
	Plant height (m)	Number of stems /thicket	Canopy diameter (cm)
Lakhusar	3.0	37	511
Karnisar	3.2	47	425
Jalwali	3.4	20	450
Barju	3.1	54	595
Kalasar	2.2	87	370
Mean	2.97	49	470.2

When planted as protective live hedge along a water channel different collections of *A. jacquemontii* showed varying growth (Table 20).

Table 20. Growth of *A. jacquemontii* in protective hedge in Bikaner

Age in months	Height (cm)			Number of branches /plant			Canopy cover (m^2)		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
12	17	155	87.7	2	23	9.3	0.10	3.73	1.27
18	30	180	108.2	3	23	11.2	0.11	4.34	1.90
21	40	247	180.2	4	33	16.1	0.17	6.21	3.58
24	50	348	196.6	2	40	13.3	0.32	9.9	8.45
30	65	373	203.9	2	27	11.4	0.42	8.45	3.19

For assessing performance and growth behavior of planted seedlings of *A. jacquemontii*, a field trial has been undertaken at CAZRI RRS, Jaisalmer. The planting site slightly sloping (1-3%) toward south was divided in to three soil categories based on the soil classification (Soil Survey Staff, 1992) namely deep (>100 cm deep calcareous, Typic Torripsamment), medium (50-100 cm deep, calcareous, Typic Torripsamment) and shallow (< 50 cm deep, sandy skeletal, calcareous, Lithic Torriorthents). The site was low in soil organic carbon, available nitrogen content, and water holding capacity and medium in phosphorus and potassium content. The planting was done in randomized block design along the contour lines in all three soil units with five replicates at 3×3 m spacing. The findings revealed that site conditions significantly influenced the growth of the plants (Table 21).

Table 21. Growth parameters of five-year-old *A. jacquemontii* in Jaisalmer

Soil Depth	Plant height (m)	Stem diameter (mm)	Number of stem/ thicket	Canopy spread (m^2/thicket)	Basal cover cm^2/thicket
Deep (>100 cm)	4.5 a*	23.8a	31.4a	22.4a	141.6a
Medium (50-100 cm)	2.7b	18.3b	11.4b	10.5b	30.8b
Shallow (<50 cm)	2.2bc	14.0c	9.8bc	8.2bc	17.4bc

*Mean followed by same letter in a column do not differ significantly

Highest plant growth was obtained in deep soil, whereas in shallow the growth was least. Plants attained maximum mean height (4.5 m), stem diameter (23.8 mm), canopy spread (22.4 m^2) and basal cover (141.6 cm^2) in deep soils followed by medium and shallow soils. Except stem diameter, other growth parameters of plant were at par in medium and shallow soils. Large variation in all the growth attributes was noticed.

Development of number of stems at ground level gave the plant a typical shrubby look. Profuse plant growth in deep soils in comparison to that in moderately deep and shallow soils is attributed to its preference for sandy plain or high dune habitat where the roots could easily penetrate and use sub-surface soil moisture. It appears that successive improvements in soil from shallow to deep have improved the duration for which moisture is available. The uninterrupted moisture availability for longer duration in deep soils probably allow plant protoplasm to multiply at maximum rate and utilize photo-synthetically active radiation (PAR) efficiently to produce higher growth (Kandpal *et al*, 2005). It appears that in medium and shallow soils water supply is not sufficient to meet plant water requirement. This results in water stress leading to poor plant growth.

Growth behavior of plants in different soil conditions was studied by working out relationship between the age and mean height, stem diameter and number of stems/ thicket that grew over a period of five year (Mertia *et al*, 2007). Polynomial linear model fitted the best (Fig. 1). The maximum growth rate in plant height was noticed between 2nd and 4th year and thereafter, it became static. Maximum growth in plant height was in deep soils and was followed by medium and statistically at par shallow soils. Similarly, maximum growth of stem diameter was evident in plants growing in deep soils whereas it was the least in shallow soils. The trend of proportionate annual increase in stem diameter was similar at all sites.

The polynomial relationship between age and number of stems shows that maximum numbers of stem were developed between 2nd and 4th year of plant age and thereafter no new stem developed. Deep soil yielded maximum number of stem whereas; medium and shallow soils had less, but comparable stem numbers. A typical shrubby growth behavior yielding polynomial linear relationships between age and plant height, stem diameter, and number of stems/ thicket of *A. jacquemontii* is comparable with those of other perennial shrubs like *Acacia bivinosa* and *Prosopis juliflora* grown in the region (Tewari *et al*, 2005). Saplings planted in deep soils registered maximum growth rate in plant height (0.9 m/year/plant), stem diameter (4.8 mm/stem/year) and number of stems per thicket (6.3 stem/year/thicket) while saplings in shallow soils had the lowest corresponding values of 0.44 m, 2.8 mm and 2.0 stems, respectively.

The annual growth of the plant is mainly influenced by the rainfall. The linear relationship between annual rainfall and various growth parameters are presented in Table 22. The rainfall contributes maximum toward growth of all parameters and explains considerable variation in them except stem diameter in medium and shallow soils. The contribution of rainfall in expansion of stem diameter in medium and shallow soils is apparently overridden by the adverse effects of site.

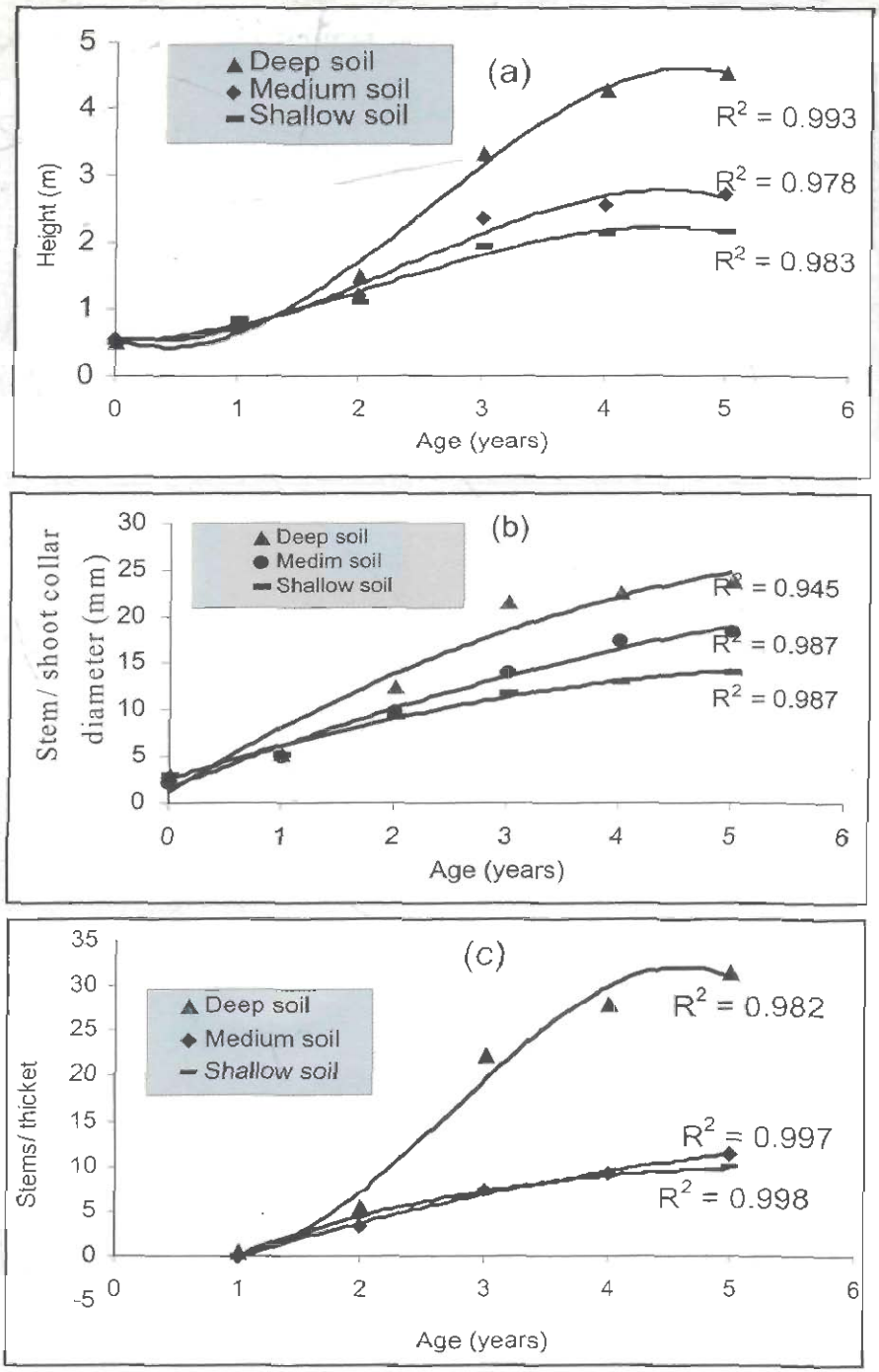


Fig 1. Relationship between age and plant height (a), stem diameter (b) and stems/thicket (c) of *A. jacquemontii*

Table 22 Linear relationships between annual rainfall and growth parameters of *A. jacquemontii*.

Growth parameter	Soil depth	Equation	R^2
Plant height (cm)	Deep	y=11.20+0.39x	0.479
	Medium	y= -2.01+0.23x	0.850
	Shallow	y=2.63+0.17x	0.532
Stem Diameter (mm)	Deep	y= -0.48+0.0.03x	0.696
	Medium	y= 2.52+0.004x	0.106
	Shallow	y=1.56+0.004x	0.126
Number of stems/thicket	Deep	y= -2.25+00.052x	0.819
	Medium	y=0.31+0.013x	0.742
	Shallow	y=0.53+0.009x	0.313

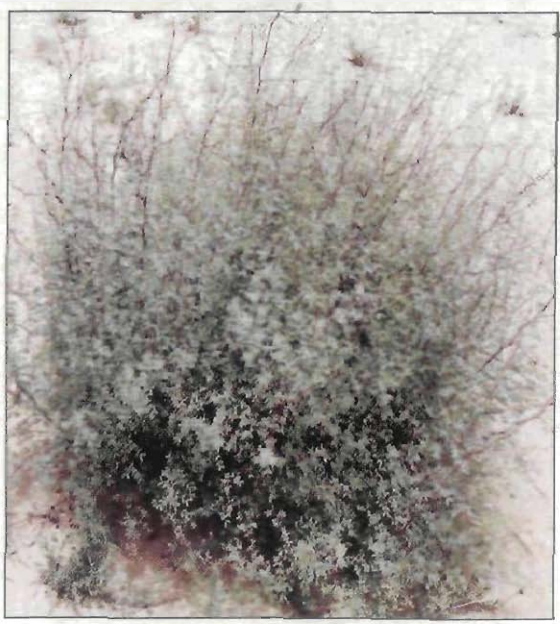
COPPICING BEHAVIOR

Acacia jacquemontii coppices well when cut at ground level (Plate 13). The coppicing behavior of new shoots of *A. jacquemontii* was studied in five-year plantation at three different soils viz., deep, medium and shallow soils at CAZRI, RRS Jaisalmer. Maximum coppice shoots were noticed in saplings planted on deep soils whereas shoots in plants on medium and shallow soils were at par (Table 23). The growth of coppice in terms of height and stem diameter was profuse. Young new coppice shoots regenerated up to three months as evident by increase in their number. After three months, number of coppice/thicket declines due to mortality of some of the tender shoots and became static after five months (Fig 2.).

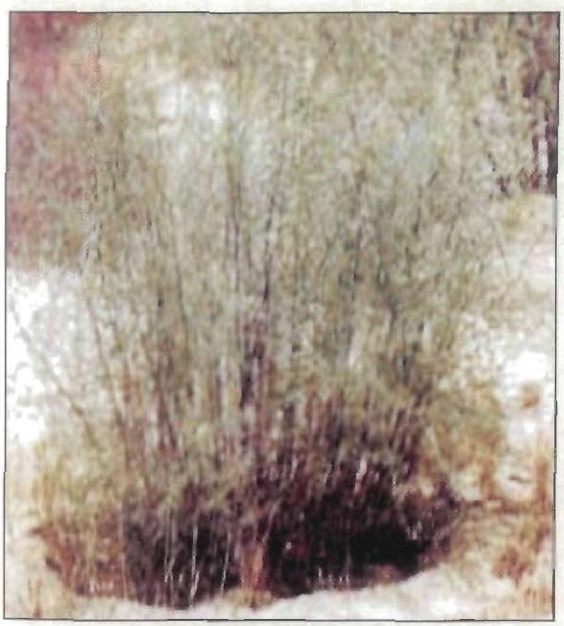
Table 23. Regeneration of new coppice shoots of *A. jacquemontii* at different sites

Site (Soil depth)	No of coppice shoots regenerated after months of cut						Mean collar diameter (mm)	Mean height (m)
	1	2	3	4	5	6	6 Months	
Deep (>100 cm)	36	103	117	89	78	76	10.6	3.5
Medium (50-100 cm)	7	18	24	23	22	22	9.77	2.1
Shallow (<50 cm)	5	20	31	27	23	21	7.16	1.95

(a)



(b)



(c)

(d)

Plate 13 Coppice growth of *A. jacquemontii* in deep soils at CAZRI RRS, Jaisalmer . Coppice shoots of a) one- month old, b) Six- month old, c) One- year old and d) Two-year old.

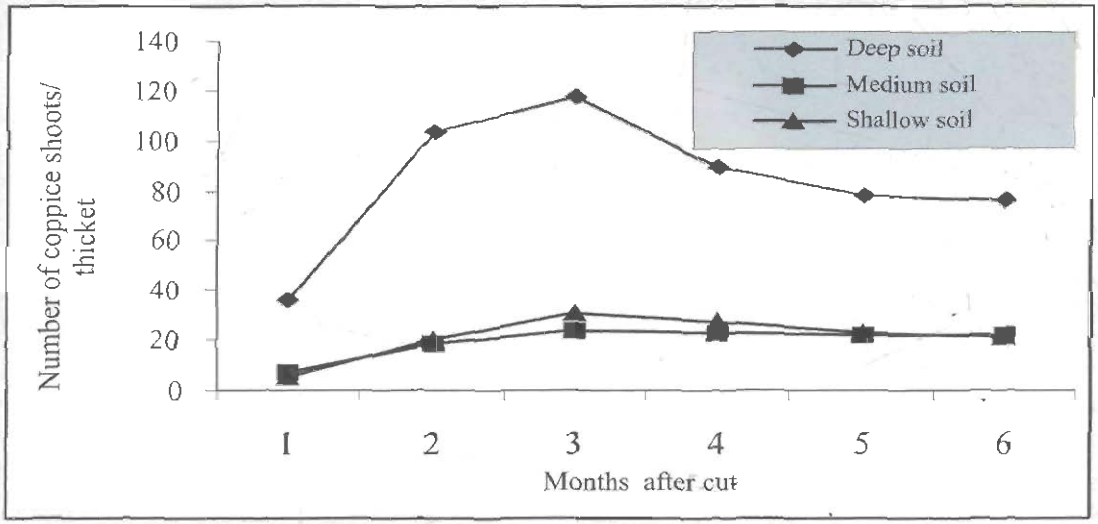


Fig 2. Coppicing behavior of *A. jacquemontii* at different sites

Irrespective of site conditions the length of spines was more in coppiced plant as compared to those not coppiced. Similarly, irrespective of coppicing, maximum length of spines was in medium soil followed by in shallow and deep soils. Similarly, plant growing on medium soil had maximum thickness of spines followed by those on deep and shallow (Table 24).

Table 24. Effect of coppicing on spines of *A. jacquemontii* at different sites in Jaisalmer

Soil Site Conditions (depth in cm)	Length of spine (cm)			Diameter of spines (mm)		
	Coppiced	Non Coppiced	Mean	Coppiced	Non Coppiced	Mean
Deep (>100 cm)	3.73	2.79	3.26	1.17	1.17	1.17
Medium (50-100 cm)	4.85	4.22	4.54	1.12	1.30	1.21
Shallow (<50 cm)	4.43	2.71	3.57	1.20	1.06	1.13
Mean	4.34	3.24	-	1.16	1.18	-

BIOMASS YIELD

Production of above ground biomass in *A. jacquemontii* depends on site, habitat and climate of the region. The study conducted by Mertia *et al*, (2007) revealed that plants growing in deep soils yielded highest above ground biomass whereas, plants in shallow soils the least (Table 25).

Table 25. Biomass yield of five-years-old *A. jacquemontii* in Jaisalmer

Site (Soil depth)	Green biomass yield (kg/thicket)			
	Stem wood	Twigs	Leaves	Total
Deep (>100 cm)	80.0a (48.9)	69.0a (42.2)	14.7a (9.0)	163.7a
Medium (50-100 cm)	9.0b (48.6)	7.0b (37.8)	2.5b (13.5)	18.5b
Shallow (<50 cm)	2.2c (48.8)	1.8c (40.0)	0.5bc (11.1)	4.5c
Mean	30.4 (48.9)	25.9 (41.6)	5.9 (9.5)	

Means followed by same letter in a column do not differ significantly. Figures in parenthesis indicate percentage of total biomass yield

Soil conditions had no significant bearings on proportionate allocation of different components of total accumulated biomass viz, stem wood, twigs/branches, and leaves. On an average stem wood accounted for major share of above ground biomass (49%) followed by twigs/branches (42%) and foliage (~10%). Accumulation of stem wood and branches/twigs was the maximum in deep soils followed by medium and shallow soils. However, foliage yield was at par in medium and shallow soils. Reduction in foliage percentage and corresponding increase in branch/ twigs wood was evident in deep soils. Slight reduction in foliage allocation and corresponding increase in branch wood formation indicates that stem wood formation was at peak in deep soils (Kunhamu *et al*, 2005).

Considering composition of small poles (taper ratio >0.65) in different height and diameter classes, maximum poles which, were suitable (height >3.0 m and diameter >40 mm) for making frame of the thatched houses and huts, house hold granaries (height 2-3 m and diameter 20-40 mm) and baskets (height <2.0 m and diameter<20 mm) were produced in deep soils (Table 26). Shallow soils yielded poles which were suitable only for making baskets while; medium soils produced poles which could be used only for household granaries and baskets. Medium and shallow soils did not yield any pole which could be used for making frames of thatched houses and huts. Wide variation in height and thickness of small poles increases base for multiple uses in making frame of thatched houses/huts, granaries and baskets thus making it choice species for social forestry programs.

Table 26. Yield of small poles (number/thicket) from five-year-old *A. jacquemontii* in Jaisalmer.

Site (Soil depth)	Number of poles in height class (m)			Number of poles in diameter class (mm)		
	<2.0	2.0-3.0	>3.0	<20	20-40	>40
Deep (>100 cm)	17	6	10	14	10	10
Medium (50-100 cm)	8	3	0	6	5	0
Shallow (<50 cm)	14	0	0	14	0	0

CHAPTER VII

UTILIZATION

Almost every part of *Acacia jacquemonti* is utilized for some or the other purpose. The wood is very strong. Important mechanical properties of wood are given in Table 27 (Dwivedi, 1993).

Table 27. Important mechanical properties of wood of *A. jacquemontii*

Property	Value
Standard specific gravity	0.634
Moisture content (%)	68.4
Static bending	
Fiber stress at elastic limit (kg/cm^2)	436
Modulus of rupture (kg/cm^2)	836
Modulus of elasticity*103 kg/cm^2	100.5
Compression parallel to grain	
Maximum crushing stress (kg/cm^2)	436
Shear parallel to grain	
Radial kg/cm^2	121.1
Tangential kg/cm^2	123.7
Surface hardness	
Side kg	732
End kg	709

Due to multi-stem or much branched growth character of *A. jacquemontii*, it yields small poles, which are used by local people in rural areas for making frames of thatched houses and huts. Young shoots are used for making baskets, granaries and other house hold articles (Prasad *et al,* 2005). The stems and branches having high calorific value are used as fuel wood. The good quality gum produced from *A. jacquemontii* fetches high price in market. Leaves are good browse for camel and goats. Thorn, twigs and branchlets are used as fencing material. The bark yields tannin which is important for leather industry.

SMALL POLES

Depending on length and thickness of poles, local inhabitants use them for various purposes. Usually villagers cut the plant from ground level to get poles and above ground biomass. The poles with a height of 3 m or more and thickness of 40 mm or

more are preferred by villagers for making frames of thatched houses and huts. Poles of medium height (2-3 m) and moderate thickness (20-40 mm) are preferably used for making house hold granaries. Young shoots of less than 2 m height and 20 mm thickness are most preferred for making baskets and other household articles. Numbers of poles produced by a full grown thicket of 5-year age in Jaisalmer under different soil conditions are given in Table 26. The frames of huts made of poles of *A. jacquemontii* last for 10-20 years. For making granaries and baskets, the poles are cut longitudinally in to fine strips of 4-5 mm thickness as it is done in bamboo. These wooden strips are twined to make granaries and baskets of different sizes. Generally, the size of a grannarey varies from 200 to 300 kg storage capacity while size of basket ranges from 10 to 50 kg. The most common use of basket is to keep fodder for feeding the cattle. Depending on the size, the prices of granaries and baskets may vary from Rs. 200 to 500 and Rs. 50 to 150 in local market, respectively. Making of granaries and basket is a good house hold industry. It is a good source of income for sustenance of poor desert dwellers particularly in the period of drought and famines. In desert *A. jacquemontii* is regarded as poor men's timber providing livelihood security against nature's calamities- droughts and famines.

FUEL WOOD

As a fuel wood *A. jacquemontii* is an excellent material. It yields high quality charcoal which is used in making gun powder. It has gradual burning property, which enables the fire wood to burn for longer duration. On burning, the wood gives out intense heat and therefore, preferred by gold, silver and iron smiths (Bhandari, 1990). It is known for its high calorific value. Root biomass is the main source of fuel wood as above ground branches and stems are used for other house hold purposes. Extraction of root system from below ground by local inhabitants has proved as curse for this species threatening its existence. In spite of a strong coppice, it started disappearing from its natural habitats as plants fail to coppice once the roots are excavated.

FODDER

The leaves of *A. jacquemontii* are not a preferred fodder for cattle. However, it provides good browse for goats and camels (Plate 14 &15). The camels browse leaves, pods and green tender branches. During scarcity in drought years, the foliage and pods are threshed out and used as fodder (Bhandari, 1990) for goats. The foliage of *A. jacquemontii* is fairly rich in all macro and micro-mineral nutrients (Table 28) and can sustain feeding animals during scarcity of fodder (Dhir *et al*, 1984; Sharma *et al*, 1984).

Plate 14 Goats browsing on *A. jacquemontii*

Plate 15 Camel browsing on *A. jacquemontii*

Table 28. Mineral nutrients composition of foliage of *A. jacquemontii*

Macro-elements (%)					Micro-elements (ppm)			
Ca	Mg	K	Na	P	Fe	Mn	Zn	Cu
1.19 (72.6)*	0.59 (26.4)	0.51 (32.6)	0.13 (52.3)	0.13 (21.4)	243 (31.6)	28.4 (33.7)	28.5 (15.8)	13.7 (13.1)

* Figures in parenthesis indicate coefficient of variation (%)

BARK

The bark of *A. jacquemontii* is a good source of tannin. It has tan and non-tan ratio of 1:7. It is used in small size tanneries to impart brown to black color to the leather. The bark of the root is used in distillation of sprite (Bhandari, 1990). The bark is obtained as a by-product on felling of plant either for poles or fuel wood. It is separated by heating the poles / roots with wooden mallets and pealing off the strips. The separated strips are dried in open and chipped into smaller pieces for use in tanneries.

GUM

The gum produced by *A. jacquemontii* is edible and highly priced in pharmaceutical industries. The properties of gum obtained from *A. jacquemontii*, gum Arabic (*Acacia senegal*), and Indian gum Arabic (*Acacia nilotica*) are given in Table 29 (Harsh and Bohra, 2006).

Table 29. Physical, chemical and micro-biological properties of gum of *A. jacquemontii*

Property	*A. senegal*	*A. nilotica*	*A. jacquemontii*
Viscosity (CPS) at 40^{0}C	18	18000	60
Viscosity (CPS) at 100^{0}C	12	670	32
Ash (%)	2.5	2.5	3.7
Moisture (%)	3.5	5.8	4.5
Protein (%)	2.15	5.25	2.6
Heavy metal (ppm)	<20	<20	<20
APC /g	<1000	500	1100
Yeast and molds/ g	<100	<100	<100
E coli/12.5 g	Negative	Negative	Negative
Salmonella/25g	Negative	Negative	Negative
Staph. Aureus/10g	Negative	Negative	Negative

The local inhabitants in hyper arid region of India have reportedly been using gum of *A. jacquemontii* in their food stuff since ages (Bhandari, 1990). It is used in times of scarcity to sustain life for days when no other edibles are available. The production of gum from this plant is very low and varies from 100 to 150 g /plant /year (Mertia and Prasad, 2005). The gum occurs in the form a rounded ball or ovoid tears of about a centimeter in size (Plate 16). The color varies from pale-yellow to brown or some time black according to the age of the plants and the conditions under which collection is made. The gum is formed as a result of disintegration of internal tissues through a process known as gummosis. It exudes from branches or stems either naturally or in response to wounding. March to April is suitable period for gum collection (Plate 17). The exuded gum contains large amount of sugar which is colloidal in nature and soluble in water.

Plate 16 Gum exudation in *A. jacquemontii*

Plate 17 Local Inhabitant collecting gum from *A. jacquemontii*

SUMMARY OF ESSENTIALS

Acacia jacquemontii Benth. is one of the most important shrubs of arid region Due to its multiple uses for fuel, fodder/ browse, poles, gum, etc. the plant has been overexploited and its existence in natural habitat is threatened. The research efforts put in by CAZRI on various aspects; conservation, propagation and raising plantations to save this precious species from extinction have generated valuable scientific data. These research revelations will have significant practical implications in conservation and preservation of not only *A. jacquemontii* but whole desert ecosystem, so that it remains sustainable for livelihood of future generations.

The summary of research findings contained in this monograph are listed as below:

- *Acacia jacquemontii* popularly known as banwali occurs widely in sandy desert. In India its main habitats are found in arid region of western Rajasthan, Gujarat, Haryana and Punjab.
- Taxonomically, *Acacia jacquemontii* Benth. is a separate and distinct species of genus *Acacia* of Mimosaceae family.
- It exhibits great diversity in habitat, plant type, growth, flowering, fruiting, gum exudation and associate species. The germplasm collected from different locations in Bikaner, Ganganagar and Jaisalmer districts showed wide variation in pods, seeds, seed germination, seedling growth and field performance.
- Natural regeneration of *A. jacquemontii* is poor as seed germination in natural habitat is adversely affected by unconducive conditions. Further, the young seedlings are very tender as compared to other species and face tough competition from annual grasses and weeds for moisture and nutrients.
- Artificial regeneration of *A. jacquemontii* does not pose any problem. The stand can be developed by raising seedlings in nursery and planting them in field.
- For collection of healthy seeds, the mature pods are picked up; seeds separated from chaff and dried before storing in air tight containers.
- Quality planting stock of *A. jacquemontii* can be raised in nursery by sowing seeds in polybags or root trainers. Before sowing seed in nursery, it should be soaked either in cold water for 12 hours or hot water (80 ^{0}C) for two hours. Pre sowing treatment of seed results in better and uniform germination and produce

even sized planting stock. For better seed germination, seed should be sown at 0.5 to 1.0 cm depth. Seeds sown at more depth fail to germinate. In nursery proper arrangement for watering and shading should be made. Before planting seedlings should be hardened for one month to acclimatize in natural condition. Only good quality even size seedlings should be planted in field. At the time of planting seedling should be sturdy and have at least 50 cm height.

- *A. jacquemontii* can be planted in all types of land except on hills, gravely and rocky areas. It gives luxuriant growth on sandy loam to loam soils. It has multi-stem growth character and develops a thick canopy which helps in trapping wind blown sand. Due to profuse root system, it has unique sand binding ability which helps in checking wind erosion.

- The seedlings are to be planted in of 30 cm^3 pits at 3x3 m or 4x3 m spacings in July or August after onset of monsoon season. One or two waterings after planting are essential if monsoon rain is not received and dry spell prolongs after transplanting.

- Plant growth and biomass production of *Acacia jacquemontii* is greatly influenced by soil conditions. Maximum plant growth and per plant above ground biomass yield is obtained in sandy deep soils. On an average stem wood accounts major share of above ground biomass (49%) followed by twigs/branches (42%) and foliage (~10%).

- *A. jacquemontii* coppice well and new shoots grow very fast.

- It has got multiple uses and almost every part of plant is useful. 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. 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. The plant yields 100-150 g/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 and goat. 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.

RECOMMENDATIONS

The full potential of *Acacia jacquemontii* has not been harnessed considering its multiple uses, profuse growth habit and adaptation to extremely difficult and harsh conditions. If efforts are not made to raise man-made plantations, this valuable species may disappear from its natural habitats due to overexploitation and excessive biotic pressure. Its extinction would not only imbalance the desert ecosystem and floral diversity, but also take away an important means of desert dwellers for sustaining their lives particularly in difficult times of drought and famines. For protection and conservation of *Acacia jacquemontii* in its natural habitat, and harnessing its full biomass production potential for benefit of community, following recommendations are put forth:

- *A. jacquemontii* should be included in afforestation programmes undertaken by State Forest Department in arid area so that its large stands are developed.
- Due to its profuse growth habit, unique sand binding ability and multi-stem character, it is most suitable species for stabilizing sand dunes. Hence, it should be included in the species planted under sand dune stabilization programs.
- It is suitable for planting as woody perennial component in rangelands and pasture as it provide good browsing material for camel and goats. It is the most desirable shrub for planting in three-tier silvi-pasture systems. For good browse it can be coppiced every year.
- It should be planted as bio fence and/ or shelterbelt on field boundaries for providing protection to the crops against hot speedy wind and moderation of microclimate.
- For obtaining small poles for making huts and thatched houses it should be cut every five year whereas for obtaining shoots suitable for making houschold articles (basket and granaries) the plant should be coppiced every two year.

REFERENCES

Baker, J.G. (1876). Leguminosae. In: *Flora of British India*. (Ed. Hooker, J.D.) Vol.2. Reev & Co., London, England.

Beadle, N.C.W. (1981). Origins of Australian angiosperm flora. In : *Ecological Biography of Australia*. (Ed. A. Keast). Junk: The Hague.

Bhandari, M. M. (1990). *Flora of the Indian Desert*. MPS REPROS, Jodhpur, p.132.

Brenan, J.P.M. (1957). Notes on Mimosoideae III. *Kew Bulletin* 12: 83-86.

Brenan, J.P.M. (1983). Manual of taxonomy of *Acacia* species : Present taxonomy of four species of *Acacia*. Rome, Itlay ; FAO, 47 pp.

Dhir, R.P., Sharma, B.K. and Datta, B.K. (1984). Mineral nutrient elements in natural vegetation of arid Rajasthan : I Macro elements. *Annals of Arid Zone* 23 : 111-117.

Dwivedi, A. P. (1993). Babul (*Acacia nilotica*) a multipurpose tree of dry areas. Arid Forest Research Institute, Jodhpur 166 pp.

Farmer, R.E.J.(1980). Comparative analysis of first year growth in six deciduous tree species. *Can. J. For. Res.* 10:36-41.

Ford, H. A. and Forde, N. (1976). Birds as possible pollinators of *Acacia pycnantha*. *Aust J. Bot.* 24: 793-795.

Guinet, P and Vassal, J. (1978). Hypothesis on differentiation of the major groups in the genus *Acacia* (Leguminosae). *Kew Bull.* 32:509-527.

Ghosh, R.C. (1977). *A handbook of afforestation techniques*. Controller of Publication, New Delhi, 418pp.

Goda, S.E. (1987). Site factors and growth of *Acacia nilotica*. Khartoum, Sudan Khartoum University Press. Department of Forestry, University of Khartoum, Sudan 30pp.

Harsh, L.N. and Bohra A. P. (2006). Personal communication.

Hopper, S.D. and Maslin, B.R. (1978). Phytogeography of Acacias in Western Australia. *Aust. J. Bot.* 26:63-78.

Joshi, H.B., Loganey, R.N., Patnaik, L.K., Choudhary, D.C., and Chauhan R.S. (1983). *Troup's The Silviculture of Indian Trees*. Vol IV. Revised and enlarged by Editorial Board FRI and Colleges, Dehradoon.

Kandpal, B.K., Mertia, R.S. and Singh, Daleep (2005). Assessment of soil-site suitability for commercial cultivation of *Cassia angustifolia* Vahl. in extreme arid situation of Jaisalmer. In : *Multipurpose Trees in the Tropics: Management & Improvement Strategies*. (Eds : V.P. Tewari and R.L. Srivastava). Arid Forest Research Institute, Jodhpur 306.

Kaul, R. N. (1969). Shelterbelts to stop creep of the desert. *Science and Culture* 24: 406-409.

Khan, M.A.W. (1970). Phenology of *Acacia nilotica* and *Eucalyptus microtheca* at Wad Medani (Sudan). *Indian Forester* 96(3): 226-248.

Kunhamu, T.K., Mohan Kumar, B and Vishwanath, S. (2005). Tree allometery, volume and above ground biomass yield in a seven year old *Acacia mangium* Willd. stand at Thiruvazhamkunnu, India. In : *Multipurpose Trees in the Tropics: Management & Improvement Strategies* (Eds. V.P. Tewari and R.L. Srivastava). Arid Forest Research Institute, Jodhpur. p 415.

Maslin, B.R. (1981). A report on phytogeographic studies of *Acacia* in Australia. International group for study of Mimosoeae. Bulletin No 9: 56-60.

Mertia, R.S., Prasad, R. and Daleep Singh. (2005). Seed germination and seedling growth of *Acacia jacquemontii* (Benth.) in relation to its seed size and sowing depth in Thar Desert. *Annals of Arid Zone*. 44: 167-170.

Mertia, R.S. and Prasad, R. (2006). Pre-sowing treatments and seed size effect on germinative behaviour of *Acacia jacquemontii* (Benth.) seeds in Thar Desert. *Annals of Arid Zone*. 45 (2): 215-217.

Mertia, R.S. and Prasad, R. (2005). *Acacia jacquemontii* Benth. - A potential multipurpose shrub. In : *Shrubs of Indian Arid Zone* (Eds. Pratap Narain, Manjit Singh, M.S. Khan and Suresh Kumar). Arid Eco-system Directorate, Central Arid Zone Research Institute, Jodhpur. 105-110.

Mertia, R.S., Prasad, R. and Kandpal, B.K. (2007) Growth and biomass production potential of *Acacia jacquemontii* Benth. in diffrent soil conditions in hot arid region of India. *Annals of Arid Zone*. 46 (2): 183-188.

Mertia, R.S. and T.K. Kunhamu (2000). Seed germination trial on *Salvadora oleoides* Decne. *Journal of Tropical Forestry* 16: 50-52.

Mishra, C.M. Singh, S.L., Banerjee, A.C. (1983). Performance of *Acacias* in Southern part of Uttar Pradesh Forest. *Van Vigyan*: 21:11-15.

Nagarajan , M and Mertia, R.S. (2006). Effect of seed size and sowing depth on germination and seedling growth of *Colophospermum mopane*. *Indian Forester* 132 (8): 1007-12

Parker, R.N. (1918). *A Forest Flora for the Punjab with Hazara and Delhi*. Lahore.

Parveen, A. and Qaiser, M. (1998). Pollen Flora of Pakistan-XI Leguminosae (sub family Mimosoideae). *Tr. J. of Botany* 22: 151-156.

Prasad, R., Lohra, R. R., Mertia, R. S., Rathor, S. S., Shukla, U. and Sushil Kumar (2002). Growth and quality of *Acacia nilotica* seedlings raised in root trainers with potting media varying in physical and chemical properties in arid zone. *Annals of Arid Zone* 41: 153-160.

Prasad, R., Mertia, R.S. and Kumar, Sunil. (2005). Seed, seedling and growth characteristics of *Acacia jacquemontii* Benth: A potential multipurpose species in Indian arid zone. In : *Multipurpose Trees in the Tropics: Management & Improvement Strategies* (Eds. V.P. Tewari and R.L. Srivastava). Arid Forest Research Institute, Jodhpur. p220.

Rao, R.R. and Choudhary, L.B. (2002). Legume diversity in India; Current status and future prospects. In: *Advances in legume Research in India* (Ed. : R.R. Rao). Bishen Singh Mahendra Pal Singh, Dehradun.

Raven, P. H. and Axelrod, D. I. (1974). Angiosperms biogeography and past continental movements. *Ann. Missouri Bot. Gard.* 61:539-673.

Ross, J H (1973). Toward a classification of the African acacias. *Bothalia* 11(1&2): 107-113.

Ross, J. H. (1981). An analysis of the African *Acacia* species: their distribution, possible origins and relationships. *Bothalia* 13 (3 & 4): 389-413.

Sharma, B.K., Dhir, R.P. and Datta, B.K. (1984). Mineral nutrient elements in natural vegetation of arid Rajasthan : I Micro elements. *Annals of Arid Zone* 23 : 235-241.

Simmons, M. (1981). *Acacia* of Australia. Thomas Nelson, Melbourne.

Singh, A. K. (2004). Endangered Economic Species of Indian desert. *Genetic Resource and Crop Evolution*. 51(4): 371-380.

Singh, J.P. Soni, M.L., Mandal, B.C. and Talwar, H.S. (2003). Arid shrubs in western Rajasthan – biodiversity and conservation. In: *Abstracts, Desert Technology – 7.* International conference, Jodhpur, November 9-14, 2003. pp 22-24.

Singh, J.P., Soni, M. L. and Rathore, V. S. (2006). Role of shrubs in rehabilitation of degraded lands in hot arid regions. In: Abstracts, Conference on Natural Resource Management for sustainable development in western India. (Indian Association of Soil and Water Coservationists, Dehradun). 11-13, October, 2006, Pune pp 63-64.

Singh, R.V., Chandra J. P. and Sharma S.N. (1973). Effect of depth of sowing on germination of kail seeds. *Indian Forester,* 99: 367-371.

Singh, T .N., Aspinwal, D. and Paleg, L. G. (1972). Proline accumulation and varietal adaptability to drought barley: a potential metabolic measure of drought resistance. *Nat. New Biol.* 236:188-190,.

Singh, V. and Sah, V.K. (1992). Effect of seed weight on germination and seedling growth in Silver Fir (*Abies pindrow* Spach) *Van Vigyan.*30: 104-106.

Soil Survey Staff. (1992). *Keys to Soil Taxonomy* (5th Ed). SMSS Technical Monograph No.19, USDA.

Stewart, C. R., Morris, C. L. and Thomson, J. F. (1966). Changes in amino acids content of exercised leaves during incubation. Role of sugar in accumulation of proline in wilted leaves. *Plant Physiology*. 41: 585.

Tewari, J.C., Harris, P.J.C., Harsh, L.N., Cadoret, K and Pasiecznik, N.M. (2000). Managing *Prosopis juliflora* (Vilayati babul) -A Technical Manual . CAZRI, Jodhpur, India and HDRA, Coventry, UK. p19.

Tewari , J.C., Harsh, L.N. and Sharma, A. K. (2005). Some important introduced shrub species and their production potential in hot arid Regions of India. In : *Shrubs of Indian Arid Zone* (Eds. Pratap Narain, Manjit Singh, M.S. Khan and Suresh Kumar). Arid Eco-system Directorate, Central Arid Zone Research Institute, Jodhpur. p33

Tindale, M. D. and Roux, D. G. (1974). An extended photochemical survey of Australian species of *Acacia*: Chemotaxonomic and Phytogenetic aspects. *Phytochemistry* 13:829-839.

Tindale, M. D. and Roux, D. G. (1975). Phytochemical studies on the heartwoods and barks of African and Australian species of *Acacia*. *Boissiera* 24: 299-305.