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KHEJRI (PROSOPIS CINERARIA)

IN

THE INDIAN DESERT

Edited by

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F O R E W O R D

In recent years forestry and tree plantation has attracted world wide attention particularly in the context of energy crisis, fuel wood shortage, environmental pollution and conservation of natural resources. There has been extensive programme of tree plantation and soil conservation. The United Nations Conference on Desertification held in Nairobi in 1977 emphasized the role of forestry in combating desertification.

A common and naturally growing tree namely Prosopis cineraria locally known as khejri has played an important role in the lives of people in north west arid region of India. Generally tree growth in agricultural fields adversely affect crop yield and vegetative biomass under and around the tree. Khejri however, is known not only not to interfer with crop yield but it actually has beneficial effects on crop/vegetation yield under its shade. Farmers through the trial and error method and generation of experience recognizes the usefulness of Khejri. For scientific production and management of agro-forestry, afforestation and sand dune stabilization programme detailed information and data are needed about the trees, shrubs and grasses grown in this region.

Considering its present role and potential, the CAZRI has investigated the botany, physiology, silviculture of khejri and it has direct and indirect affect on soil. The scientific knowledge so gained has been compiled in this volume which is being published in the CAZRI Technical Monograph series. I like to compliment the scientists for their investigations on this tree and the contributions they have made to this publication. I am extremely happy to see that Dr. H.S. Mann and Shri S.K. Saxena have compiled and edited this valuable information which I am confident

will be of use to the scientists and development agenci not only from the scientific management point of view but eventually for the larger cause of combating desert fication and improvement of desertic environment.

The authors have made useful suggestion for scientific investigations with respect to Khejri. I am sure these will be incorporated for future studies. I hope similar efforts will be made for compilation of Monograph on the basis of scientific work conducted on specialized trees, shrubs, grasses, legumes etc. I wis all the success for such future undertakings.

Sd/-

(O.P. GAUTAM)
DIRECTOR-GENERAL

PREFACE

Historically Prosopis cineraria locally known as Khejri has played a significant role in the rural economy in the north west arid region of Indian sub-continent. This tree is an important constituent of the vegetation system and is a source of top feed, fuel and timber. Its pods are used as vegetable. Being a legume it improves soil fertility. It is well adapted to the arid conditions and stands well to the adverse vagaries of climate and browsing by animals.

The rural communities encourage the growth of Khejri in their agricultural fields, pastures and village community lands. Through experiences farmers have realised its usefulness and learnt that it does not adversely affect crop yields but it improves grain yield and forage biomass production. The methods of propagation, growth and utilization of khejri including lopping are based on traditional knowledge learnt by people by trial and error, through generations of experience.

In view of the usefulness of khejri and its potential, the CAZRI has carried out investigations on this tree since its inception in 1959. The contributions have been published by the individual scientists in scientific journals. In this volume an offer has been made to compile and put the available information at one place. This monograph will provide an insight into the researches conducted by Botanists, Physiologists, Silviculturists, Soil Scientists and others. It is hoped that the material presented in this publication will provoke further interdisciplinary studies by the scientist at CAZRI and other interested institutions to improve agricultural economy of the arid region.

The information presented here should be of value for planning, studies and investigations in Agro-forestry and Silvi-pastoral systems in which khejri is one of the components of the eco-system.

One of the limitations of khejri is its rather slow growth as compared to some of the other adapted exotic trees like Acacia tortilis and Prosopis juliflora. This is a challenge to the scientists to study the growth behaviour of this important tree which I am sure will be accepted by scientific community. It appears that this aspect has so far received limited attention.

My colleagues at CAZRI deserve appreciation for their contribution to this Monograph. I am sure that they will keep up their interests for further investigations into the role of this important tree of the region, particularly to develop technology to stimulate its growth rate. I must acknowledge the technical assistance provided by Mr.S.C.Rawtani, Senior Technical Assistant, CAZRI. But for his cooperation and assistance, it would not have been possible to publish this Monograph in its present form.

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Chapter's Contents

Khejri (*Prosopis cineraria* Mac Bride) in the Indian Scriptures

Vinod Shankar

Amongst the trees that are held in high esteem and treated as an object of veneration in the scriptures, Khejri has a unique distinction of being referred in a variety of contexts. Its Sanskrit name is *Sami* and its botanical name is *Prosopis cineraria* Mac Bride. It has, however, been named as *Mimosa suma* and *Acacia suma* in some of the translations of the scriptures by some of the European Sanskrit scholars (Monier-Williams, 1899). Khejri has been described as possessing a very tough hard wood, supposed to contain fire (Manu Smriti, Viii, 247 and Raghuwansa, iii, 9).

In the vedic times Khejri wood was primarily employed to kindle the sacred fire for *Yagna*. For this purpose two pieces of the hard wood i.e. one of the Khejri and the other of the '*Peepal*' or ' *Aswattha*' (*Ficus religiosa*) were rubbed together to produce fire. For example, the *Rig Veda*, the oldest of the four Vedas, says "when a barren cow being suddenly impregnated bears a calf, she the repeller of the evils free from pain, self protected, produces (offspring); when (*Agni*) the ancient son, is generated by two parents, earth ejects the *Sami* which the priests are seeking.

(*Rig Veda Sanhita* : 7 Astaka, 7 Adhyaya, 3 Annuvak 2 Sukta, 2.)

According to Wilson, 1888, "The mysticism of this verse is obscurely expressed, but the comment furnishes a key to it, although it does not explain all the allusions. The cow which was barren was the *Sami* tree, which brings forth the *Aswattha* and from the wood of these two trees are made *Agani* the two pieces of wood which are rubbed together to produce the

sacred fire - the upper and harder piece is the Sami (Acacia suma) and the lower and soft one is the Aswattha (Ficus religiosa)."

A legend in Atharv Veda relates that Pururuva generated primeval fire by friction of two branches of the Sami (Prosopis cineraria) and Aswattha (Ficus religiosa) trees. At another place in the Atharva Veda, Khejri has been described as follows:

शमीमश्वत्थ आरूढस्तत्र पुंसवनं कृतम् ।
तद् वै पुत्रस्य वेदनं तत् स्त्रीष्वा भरामसि ।।
अथर्व वेo /6।2/।।/।

The above Mantra says that Aswattha (Ficus religiosa) striking its roots into the fissures of the Sami (Prosopis cineraria) tree, if fed (perhaps, decoction of the bark) to a woman, she will become fertile and will bear a male issue.

Description of the us of the peg cut out of the hard wood of Khejri is found in another Vedic scripture - Satpath Brahmana. The above use is being given below:

"They now fix pegs round it, Palasa (Butea frondosa) one in the front; for the Palasa is the Brahmans; he thus makes him go to the heavenly world with Brahman for his leader; - a Sami (prosopis ~~spicigera~~ cineraria) one on the left (north corner) in order that there may be peace (Sam) for him; - a Varana (Crataeva roxburghii) one behind, in order that he may ward off (Varaya) sin from him; and a Vrita (perhaps stone) peg on the right (south corner) for sin not to pass beyond" (Sat path Brahman: xiii Kanda, 8 Adhyaya, 4 Brahma, 1; translated by Julius Eggeling (1855).

The Khejri wood has also been described as being used in oblations (Samidha) in the Satpath Brahman as under:

"He first puts on one of Sami-wood (Acacia suma). For at that time, when his oblation had been offered, he (Agni) was

enkindled and blased up. The gods were afraid of him lest he might enjure them. They saw this Sami tree, and therewith appeased him; as such as they appeased (Sam) him by that Sami, it is called Sami; and in-like manner this (sacrificer) now appeased him be means of that Sami-wood just with a view to appeasement, not for food." (Satpath Brahmans: ix Kanda, 2 Adhyaya, 3 Brahmana, 37; translated by Julius Eggeling 1885.

Thus, this mantra gives the etymology of the Khejri's Sanskrit name-Sami.

Reference of Khejri is also found in Mahabharata and Ramayana. As the story goes, Arjuna, alongwith his Pandava brethren had to go in hiding and he hid his bow named Gandiva in the stem hollow of Khejri tree. In Valmiki Ramayana, Khejri has been described alongwith other trees occuring on the hills at Panchvati. Lakshman used the branches of the Khejri tree as beams for the thatched hut-Parnakuti, wherein he alongwith Lord Rama and His concernt Sita, stayed during their 14- year exile. The description is as follows:

स्यन्दनैश्चन्दनैर्लीये: पर्णासैलकुवैरपि ।
धवाश्वकर्णखदिरै: शमीकिंशुकपाटलै: ॥
वाल्मीकि रTO/अरण्य कTO/15/18

शमीशाखाभिरास्तीर्य दृढ़पाशावपाशितान् ।
कुशकाशशरैः पर्णैः सुपरिच्छादितां तथा ॥
वाल्मीकि रTO/अरण्य कTO/15/22

"The hills covered with trees such as Syandana, Chandana, Kadamba, Parnas, Lakuch, Dhava, Asvakarn, Khair, Sami, Palas and Patal or Padar trees, were beautiful to look at"

"On these bamboos, he (Lakshmana) spread the branches of the Sami, tied the Sami branches down with strong ropes and thatched with Kush (Desmostachya bipinnata) and Sar (Sachharun munja) leaves."

To sum up, the Indian scriptures are replete with a variety of references on Khejri. Here, only a few examples have been given. These examples clearly indicate that (1) there were thick stands of Khejri in the past (2) Khejri was widely distributed, atleast, at the Vedic, Ramayana and Mahabharata sites and (3) it was put to various uses by the ethnic races of that period. Khejri is highly valued even today as a timber, fodder and fuel yielding plant in Western Rajasthan.

Taxonomy, morphology, growth and reproduction of Khejri and its succession in north-west India

S.K. Saxena

Introduction

Prosopis cineraria (Khejri) helds an increasingly important place in the economy of Indian Desert. This is the only leguminous tree which grows well against all the odds of climatic conditions. The new foliar growth, flowering and fruiting are borne by it during the extreme dry months (March-June) when all other desert trees may be seen as leafless and dormant. This peculiar behaviour of this tree is not fully understood. The plant sheds its leaves gradually through cold months. It is most common, medium sized tree of Indian Desert and can be recorded on most of the land forms exc the hills and saline depressions. Because of its economic value the tree is left standing in the arable land and its population is regulated by the farmer. Being well adapted to prevailing climatic conditions and its wider ecological amplitude, this tree may be seen from 150 mm to 500 mm rainfall zone. Its optimum density, referred elsewhere, can be seen between 350-400 mm rainfall tract.

Nomenclature

The oldest name for this species is Mimosa cineraria Linn. Sp. Pl. 517, 1753. Later Linnaeus himself treated this taxon under the genus Prosopis and called it Prosopis spicigera Linn. Mant. 68, 1767; Fl.Brit. India 2: 288, 1878. But as per the code of Botanical Nomenclature, Macbride (1919) validated the above combination under the genus Prosopis and species cineraria and thus the correct name is Prosopis cineraria (Linn.) Macbride (reference Contrib. Gay. Herb. n.s. LIX, 16 (1919). In some translations of the Indian Scriptures by few European Sanskrit scholars i.e. Monier-Williams 1899, thi tree has been described as Mimosa suma or Acacia suma while its sanskrit name is Sami.

Plant description

Prosopis cineraria (Linn.): Macbride. Syn. Prosopis spicigera Linn. Vern. name : Khejri, Khejri (Rajasthan); Janti Chonksa, (Delhi); Jhind, Jhand, Jand (Punjab and Haryana); Banni (Karnataka) Sumri (Gujrat); Kandi (Sindh) and Sami (Sanskrit).

A large, much branched, medium size tree of dark green foliage. Trunk dark grey; Bark splitted with deep fissures and rough but attached to the trunk. Branches slender, glabrous with small compressed, straight, scattered thorn of 3-6 mm length, Pinnae - mostly 2 pairs with a gland between each pair, opposite, 2.5 - 8.0 cm long; leaflets 8-12 pairs, oblong, obliquely rounded, mucronate at apex, unequal sides, base rounded and very oblique, 5-12 x 4 mm leaflet size.

Flowers: - Yellow in slender spike, axillary, 7-11 cm long, mostly solitary or in terminal panicles. Flowers during February - April and Fruits May - June. Calyx 5 x 1.5 mm long, cup shaped, faintly 5 toothed; corolla yellow, 3 mm long, recurved stamen, filament 3 mm long. Pods straight, cylindric, glabrous torulose, 10-20 cm long; thick, No. of seed 10-15, seeds embeded in brown pulp, 3-8 mm long dull brown and oblong. (Bhandari, 1978).

Flowering and fruiting: Plant flowers during February - March, the fruits are formed during April-May. In Rajasthan there is a common practice to harvest the green pods. They are boiled, dried and sold as dry vegetable either singly or with other local plant material called as "pach-Kutta" a mixture of five species. Green pods are locally called as "Sangri or Hangri." The same pods on ripening are termed as "Khokha." Children eat the pulp of dried pods and dispersed the seeds. The dispersal of pods from the tree is complete before the onset of monsoon. Pre-monsoonic wind and thunder storm bri down all the ripe pods on the ground. Squiril, Gerbil and few birds attack these pods and dispersal of seed takes place.

Few pods are attacked by insect which damage the seeds. There is severe insect attack at the time of flowering also. This lead to the gall formation. Gall size vary from branch to branch. 90% of these gall also come off the tree branches during the dust storm and pre-monsonic showers during May and June.

Leaf fall: In the year of heavy rainfall leading to water logging of fields for few hours, there is a severe leaf fall during August Septomber month. Thus in abnormal rainfall year the harvest of "loong" is compuratively low than the normal year. But in a drought year also the yield goes down due to moisture stress. The gradual leaf fall during winter months is mostly due to aging of leaf.

Lopping Practice: In Western Rajasthan there is a systematic lopping system of Khejri tree. The lopping schedule starts from middle of November each year and continue upto middle of January. Maximum lopping is carried out in the last week of November and first week of December month. In case the farmers wants to grow wheat in his fiel lopping will be completed by the end of October or first week of November. The prosopis trees are lopped with sharp axe. Older twigs branches are removed and 1 - 2 years old branches for making tree canopy are retained. The tallest branch of one or two year old is left with some foliage which serves as a flag for the tree. In Shekawati region the lopping pattern (See Fig.1) allows the tree to have a round canopy whereas in Western districts of low rainfall zone the cutting pattern is not followed. Only two to three branches with or without flags are left and rest material is ruthlessly lopped. Such lopping effects the normal growth of the tree and some time the tree gets set back and may even die.

The collected leaves of Khejri are called "Loong." It is marketed in the lean month (Feb. - June) and much utilized for feeding milch animals. During scarcity, newly sprouted twigs are als harvested during April - June and sold as such.

This is called "Hari loong." The lopped tree flowers late but some time such trees are found flowering during monsoon, leaves of Khejri "loong" contain 13.9% crude protein, 20.3% crude fibre. 0.2% phosphorus; 1.9% calcium and 0.5% magnesium.

Growth characteristics: Khejri is a slow growing tree in early stages of growth. Generally it take 10-15 years period to become a tree in 200 - 350 mm rainfall zone. The variation of growth varies due to soil depth and total rainfall in the year. In shallow soils and low rainfall zones of (100 - 200 mm) nearly twenty years are required by it to become a tree, whereas in higher rainfall zone of (350 - 450 mm) ten years period is sufficient for it to assume full growth. Slow growth of the aerial part is one of the adaptation of this tree. Khejri tries to establish itself first with its strong root system and then allows the top growth. In sapling stage, the studies have indicated that there is 3:1 root, shoot ratio. The tap root travels vertically down in the soil and ensures the establishment of this plant in its first ten years of growth. This deeper root system help this plant to withstand the drought successfully. It also has high frost tolerance capacity. At Jamsar mine area, the tap root of Prosopis was found 8.5 m deep. It travelled the top sand, gypsum layer and the soil below gypsum. Blagareschensky 1968, made the root studies of 5.8 m tall plant. It was recorded that its root reach to a permanent wet soil or Kankar pan from where it taps the water for larger part of the year.

Coppicing: Khejri tree when cut above the ground regenerate well. Numerous new buds become active and ... several (5-12) new shoots are produced. These in a years time assume the shape of bushy structure (1-1.5 m) (Photo). In orans and Beers (Common grazing land) the coppcing shoots are generally grazed. Continuous grazing lead to cushion farming habit of this tree. Under severe grazing and trampling stress all the sprouted branches trail on the ground and the plant spread horizontally instead of vertically (Fig. 2)

Such habit, in an oran, continuously provide top feed to the grazing stock.

Seed germination: Seeds of P.cineraria and A. nilotica were soaked in water for 24 hours and were sown in G.I. tubes filled with sandy loam soils. Daily germination was counted for four weeks. The results are given as follows:

Species	I	II	III	IV	Total
Prosopis cineraria	-	4	56	20	80
Acacia nilotical	40	24	-	-	64

P.cineraria did not show any germination in the first week whereas two third germination of Acacia nilotica was recorded in the first week. Highest germination of seed took place in the third week in case of Prosopis while no germination could be recorded in case of A. nilotica after second week

Habitats and Associations: The natural vegetation of the plains of north west India has highly modified owing to cultivation. In general the climatic climax of the Indian Thar Desert is represented by Prosopis cineraria and Salvadora oleoides (Satyanarayan 1964, Gupta and Saxena 1973, Saxana 1977). Prosopis tree is well distributed through out the plains of Western Rajasthan on sandy loam, loam and sandy clay loam soils with a hard kankar pan at varying depth (50 - 1

Older alluvial plains: The flat plains with 0 - 1 percent slope and sandy loam, sandy clay loam soils are invariably dominated by prosopis tree. The soils are moderately deep to deep with lime kankar pan of indurated or semi-indurated nature of varying depth (i.e. 30 - 150 cm). Soil depth and type of induration markedly influence the growth of this tree. By seeing the tree growth and den of Prosopis one can easily predict the soil depth of the plain.

This correlation has been effectively utilized in the photointerpretation of the plains. On flat plains, with sandy loam soils, the prevalent plant community is Prosopis cineraria - Zizyphus nummularia - Capparis decidua. On an average (with 60-90 cm soil) there are 15-20 trees/ha. The growth attributes will be 60-90 cm plant girth, 10-14m, height and 50 - 60% relative dominance.

In the uncultivated area, Oran or Beer, the plant density swells upto 200 with 4.8 to 17.8% crown cover. Saxena (1977) has recorded fourteen plant communities in association with Prosopis. The plant communities are found with the inclusion or exclusion of the tree or shrub species either single or in combination. Important trees and shrubs of its association are Tecomella undulata, Acacia nilotica, Salvadora oleoides, Balanites aegyptiaca, Zizyphus nummularia, Capparis decidua and Cassia auriculata.

Older alluvial plain with hummocks: Here the sandy plains assume gentle undulation due to the formation of hummocks of 1-2 m height. The slope of such land varies from 1-3%. These lands are mostly under the influence of wind erosion. Change of topography has marked effect on the existing vegetation. The hummocks are generally occupied by Capparis decidua (Kair) Calligonum polygonoides (Phog) Leptadenia pyrotechnica (Khimp), Aerva persica (Bui), A.Jacquemontii (Bawl) and Crotalaria burhia (Sannia) whereas Prosopis (Khejri) tree is separsely distributed (10-15/ha) between the hummocks. Tecomella undulata and Balanitis aegyptiaca are main tree associates to Prosopis. Here the soil depth is directly related to sand deposition. Sorting of loose sand does not allow congenial plant growth and hence sparse distribution. Here the plant reaches 10-12 m height with 40-80 cm trunk girth.

Flat plains with sandy clay loam soils are dominated by Salvadora oleoides - P. cineraria community. Here Prosopis functions as codominat in the community. Moderately heavy plains in District Jalore, Sanchors, part of district Pali and Churu etc. have 5-30% relative dominance of Prosopis.

In some Birs and Orans P. cineraria - S.oleoides - C.decidua forms the plant community. Here trees are short statured, 6-9 m height, 20-40 cm DBH, and 30-40 plant/ha density. Common associates are Cassia auriculata, Maytenus emarginata, Indigofera oblongifolia, Zizyphus nummularia.

Younger alluvial plains: Luni and its tributaries form a narrow belt of younger alluvium along the river banks. These lands are liable to innndation. Here the soils have heterogenous deposits comprising sand, silt, gravel and form deep sandy soils without a hard Kankar pan. Here the tree density and its growth is better due to good ground water potential. Acacia nilotica - P. cineraria is the most prevalent plant community. Khejri tree bears a height of 10-15 m, 40 cm DBH, and a density of 25-45 tree/ha. It chiefly associate with its codominant A.nilotica with 13-25% relative dominance. Here other trees and shrub associates are A.nilotica Ssp. Cupressiformis, Acacia leucophloa, Azadirachta indica C. mauritiana, Prosopis, juliflora, Salvadora oleoides, A.Jacquemontii, Cassia auriculata, Indigofera oblongifolia and Calotropis procera. The tree species, when excessively exploited, get degraded to the shrub community. This condition can mostly be seen on the orans situated near the river banks.

Piedmont plains: The lower piedmont plains have 3-5 per cent slope. They get covered by irregular and heterogenous deposits of varying depth. The top material is mostly course where as the lower strata has finer material. The sadiments decreases with the increasing distance from the hill. Sometime the aeolian sand piling takes place which is very deep. The tree density and their growth directly reflects the soil depth. Thishabitat support a mixer of species common to hill and plains. Such areas under forest protection support medium thick forest. Piedmont plains have Salvadora oleoides - P. cineraria - Euphorbia Caducifolia community

Here Salvadora is dominant while Prosopis as codominant with 25-35 per cent relative dominance. Here the tree is 6-8 m height, 15-40 cm DBH and density vary from 35-50 plant/ha (Jalore & Pangarh hills). Associated trees and shrubs are Maytenus emarginata, A. leucophloea, A.senegal, Grewia tenax, Balanites aegyptiaca, C. decidua and A. jacquemontii. The above community under degradation is generally dominated by Euphorbia caducifolia.

Burried pediment plains: Like flat alluvial plains, these are also flat with 1% slope. They are mostly covered with alluvial and colluvial deposits. The sediments are partly transported and partly developed in situ. The depth of deposits vary from 80 cm to 5 m. below which directly rock may encounter. Like lower piedmont plain, the vegetation of this consist of both rocky and plain elements. The common plant community is Prosopis cineraria - A.senegal - Capparis decidua. Here Prosopis (Khejri) being dominant show 50-65% relative dominance. 20-35 plant/ha 20-28 cm DBH, and 8-10 m height On the whole the canopy is sparse and trees widely scattered. A senegal, A. leucophloea, Zizyphus nummularia and Cassia auriculata as few associates.

Sand dunes: About 58 per cent area of western Rajasthan is covered with sand dune of varying magnitude and orientation. (Pandey et.al; 1964). Medium high stabilized parabolic, longitudinal and transverse dunes mostly support the tree community, if not much disturbed. The lower flanks and portion merging with swale are generally occupied by scattered trees of Prosopis cineraria. In lower rainfall zone (150-250 mm) the tree growth is comparatively poor with low density (3-10/ha). Area with 250-400 mm rainfall, the stabilized dunes have better tree growth and higher density (5-25/ha). Some dunes are religiously protected and have an open forest, supported by various trees in which Prosopis contribution ranges from 5-15 per cent.

The associates under various communities occuring on stabilized dunes with Khejri are Calligonum polygonoides, Clerodendrum phlomoides, lycium barbarum, Maytenus emarginata, Calotropis procera, Acacia Senegal and Saccharum bengalense. In district Nagaur, longitudinal stabilised dunes are invariably supported by P. cineraria - S. bengalense community. All these dunes are under regul cultivation and hence no other associates can be seen over them.

Interdunal plains: The plains are generally flat or with undulated topography. Flat areas have a good density (40-60/ha) of Prosopis while undulated hummocky areas show comparatively low density (20-40/ha). Common communities of interdunal plains are (1) Prosopis cineraria, (2) P.cineraria - S. oleoides (4) cineraria -Capparis decidua, (5) P. cineraria - C. polygonoides. Majority of interdunal plains are cultivated and hence the stand is generally associated with few species like C. decidua - Z. nummularia, and Calligonum polygonoides. In low rainfall areas (150 - 250 mm) the interdunal plains have very poor Khejri growth. Trees are stunted (3-4 m high) less branching (2-3 main branches) and the tree density varies from 3-10/ha. In higher rainfall zone of Nagaur, Sikar and Jhunjhunu, the flat interdunal tract have high Khejri density (50-80/ha) while there is low density in undulating hummocky interdunal plain (20-35/ha.).

Succession: Inspite of higher percentage of cultivation on flat and undulating plains and continuous removal of matured Khejri trees, it continue to dominate the tract. This tree has achieved to survive the odds by acquiring high drought hardiness. Once established, its removal is noteasy. The plant has high regeneration capacity. In a year of high and timely rainfall (1973 & 1975) the regeneration of this was as high as 200 - 250/ha on flat alluvial plains (Saxena, 1977). If such areas are allowed to maintain the regenerated stock, a medium thick forest will come up in a period of 20 to years. During our ecological surveys several stands of almost uniform girth (DBH) have been recorded in Jodhpur and Nagaur district, indicating favourable years of rainfall.

Distinctive communities are found on various habitat of Rajasthan. The original vegetation is disturbed almost everywhere and all the communities are represented by disclimax. On alluvial plainsthe succession proceeds in these different series (Satyanarayan 1964) depending upon the edaphic conditions but finally converging to the same climax community. On heavy textured soil the colonization starts by Riccia Sp (green patched) which on protection are invaded by earlier colonizers like Aristida mutabilis, Melanocenchris sp. followed by Cenchrus and Dichanthium species. With prolonged protection shrub species like Z.nummularia, Cassia auriculata, Indigofera oblongifolia gets foothold which are finally culminate into Prosopis cineraria - Salvadors oleoides climax.

On sandy plains early colonizers like Indigofera linifolia, I.Cordifolia, few species of Eragrostis, Cenchrus biflorus and C. prieurii are pioneer to establish. These annual species make suitable conditions for the appearance of perennial species like Eleusine compressa, Cenchrus setigerus, Lasiurus sindicus, Tephrosia purpurea, Crotalaria burhia which form the next stage of succession. This is followed by shrub species like teptadenia pyrotechnica, Calotropis procera. Zizyphus nummularia and Maytenus emarginata. These species are represented in larger area and exist as disclimax. Those species under protection ultimately proceeds to climax of Prosopis cineraria. On younger alluvial plains with sandyloam soils under irrigated conditions, Cyperus rotundus, Cenchrus and Aristida species seems to be the earlier colonizer followed by Solanum surratense. Xanthium strumarium, T. purpurea and Desmostachya bipinnata. With pretty long protection, species like Tamarix, Vitex negando, Capparis decidua, Balanites aegyptiaca replace the grassy vegetation. These finally culminate into Prosopis cineraria - Acacia nilotica climax (Saxena 1977).

Sand dunes: Various stages of development or degradation have been encountered on different dune types in Western Rajasthan. The pioneer colonizer of this special habitat are Cyperus arenarius, Aristida funiculata, Cenchrus biflorus, Indigofera cordifolia. I.linifolia, later these are supported by perennial species like Crotalaria burhia, Aerwa Pseudotomentosa and Sericostemna pauciflorum Perennial grasses also support this stage like Panicum turgidum, P. antidotale. If this phase is undisturbed for a long period Acacia jacquemontii, Clorodendrum phlomoides, Calligonum polygonoides and Maytenus emarginata form the penultimate stage to the climax community of Prosopis cineraria and Acacia senegal. But this stage is rarely encountered on sand dunes.

Distribution of Khejri (Prosopis cineraria Mac Bride) in Western Rajasthan

Vinod Shankar

Introduction

Khejri (Prosopis cineraria Mac Bride) has been described (Champion and Seth, 1964) as the prominent constituent of the Desert Thorn Forest (Type 6B/CI) "With very open crops of scattered trees." Pollen stratigraphic studies of Singh (1970) revealed abudance of Khejri in western Rajasthan during the last 10,000 years when it also enjoyed a higher ecological status (Vishnu Mittre 1975). Khejri continued to be the dominant formation on alluvial and sandy undulating plains (Satyanarayan, 1964) of western Rajasthan. Sprinkling of Khejri can be found on other habitats too. In the present paper distribution pattern of Khejri in western Rajasthan has been described and discussed in detail.

Geographical Distruction: Naturally occuring Khejri has been reported (Puri al. 1964) from Afghanistan, Iran (Persia), Pakistan (Baluchistan and Sind), and India (Rajasthan, Delhi, Haryana, Gujrat, North Karnataka and Madhya Pradesh). Distribution of Khejri in India (from western Rajasthan to Karnataka in the south) is, however, discontinuous. In the arid western Rajasthan too the distribution pattern along a transect from Aravalis in the east to Jaisalmer in the west is discontinuous and varied. Region-wise distribution and density of Khejri is being discussed below.

Pali-Sirohi-Jalore Region: Out of the several sites covered under the project on the arid shrublands of western Rajasthan, Khejri has been recorded from 12 sites (Table-1) representing four land use types (grazinglands, cultivated fallows, barren lands and reserved forests) and four broad habitat types. (Older alluvial plains, younger alluvial plains, low [illegible] dune sequences, and lower piedmonts). The soil of these habitats range from sandy to gravelly in texture but predominantly

sandy loam to sandy-clay loam soils showed abundance of Khejri. The RIV (relative importance value) which is the percentage summation of relative frequency, relative density and relative abundance, varied on different sites depending on the kind of associated shrubs/trees present therein. Highest RIV (37.31) was recorded on the older alluvial flats and the lowest on the dunes (5.69). Highest density (250 trees/ha) was also recorded on this habitat. The riverine tract formed by the Luni river system showed high density of Khejri.

Barmer-Jaisalmer: Distribution of Khejri in this region is patchy and its density poor. Khejri has been observed (Table-2) occuring naturally on habitats ranging from rocky pediments to low dune sequences but its density was high (90 trees/ha) in the reserved forest on older alluvial plains in the Barmer-Sanchor zone. Around Jaisalmer its density was 10 trees/ha in the grazinglands. The current fallows with sandy soil had a density of 20 trees/ha in Barmer-Sanchor zone. The tree growth was also poor as compared to that from the Pali region.

Nagaur-Bikaner Region: A variety of habitats were covered from the eastern part of the Bikaner to the eastern and the western parts of the Nagaur district. Khejri occured on the older alluvial flats and in sandy undulating plains (Table-3) covering two lands use types i.e. grazing lands and cultivated fallows. The soil texture of these habitats ranged from sandy loam to clay loam. Broadly speaking the eastern part of Bikaner around the town of Nokha and the western part of Nagaur district had lower density of Khejri as compared to that in the western part of Nagaur district i.e. Nava, Degana and Parbatsar. The RIV of Khejri in the western part of Nagaur district was 100% at places, e.g. the site Rajliya (Table-3).

Shergarh-Pokaran-Kolayat - Osian-Phalodi Region: Khejri was recorded from sixteen sites in the region (Table-4) The habitats covered were sandy undulating plains, interdunal plains, older alluvial plains with s deposits and pediment plains with light sand deposits. The present land use of these habitats were mainly old fallows and grazinglands. Besides

Table 1: Density of Khejri in Pali-Sirohi-Jalore Regions.

S i t e	Habitat	Present land use	Soil texture/ depth(m)	Density plant/ha	RIV.
Gandoj (Pali)	Lower pediment	Grazing land	Gravelly (0.60)	170	33.17
Netra (Pali)	Pediment plain	Grazing land	Gravelly (0.60)	20	9.81
Sindru (Pali-Sirohi)	Older alluvial flat	Waste land	Sandy, Saline (0.90)	25	18.18
Akoli (Jalore)	Alluvial plains	Grazing land	Sandy-Clay loam(1.00)	60	29.76
Pali	Older alluvial flat	Grazing land	Sandy-Clay loam (1.00)	250	23.64
Chanod Basimada (Pali-Sirohi)	Older Alluvial flat	Grazing land	Clay, Saline (1.00)	20	13.58
Palri (Research Forest) (Pali-Jalore)	Older Alluvial flat	Reserved Forest	Sandy clay loam(1.00)	100	30.03
Loonawas (Pali)	Older Alluvial (Low lying)	Grazing land	Sandy loam (1.00)	10	37.31
Araba (Pali-Jalore)	Older Alluvial flat	Grazing land	Clay loam (1.00)	10	35.25
Asotra (Pali-Jalore)	Older Alluvial flat	Grazing land	Clay loam (1.00)	130	122.8
Asoda (Pali-Jalore)	Older Alluvial flat	Grazing land	Sandy clay loam(1.00)	120	22.44

Table 2: Density of Khejri in Barmer - Jaisalmer Regions.

Site	Habitat	Present land use	Soil texture & depth (m)	Density plant/ ha	RIV.
Devikot (on Barmer Jaisalmer Road)	Rocky pediment	Grazing land	Gravelly (0.5)	10	17.45
Hanthi tala (Barmer-Sanchor Road)	Dune	Current Fallow	Sandy (1.00)	20	10.52
Khundala (Barmer-Sanchor Road)	Flat (Older alluvial plains)	Reserved Forest	Sandy loam(.60)	90	125.29

Table 3 : Density of Khejri in Nagaur-Bikaner Region.

S i t e	Habitat	Present land use	Soil texture depth (m)	Density plant/ha	RIV
Barnad (Nagaur-Nokha-Bikaner	Older Alluvial Flat	Grazing Land	Sandy loam (1.00)	10	10.00
Jakhora (Nagaur-Nokha-Bikaner)	Sandy undulating/ Plains	Cultivated fallow	Sandy loam (1.10)	160	136.45
Uncharua (Nagaur-Nokha-Bikaner	Older Alluvial Flat	Grazing land	Sandy loam (1.00)	40	27.88
Chuna (Nagaur-Nokha-Bikaner)	Older Alluvial Flat	Grazing land	Sandy loam (1.00)	10	7.45
Katothi (Nagaur-Nokha-Bikaner)	Older Alluvial plains	Grazing land	Clay loam (1.00)	40	36.60
Thibri (Nagaur-Nokha-Bikaner)	Older Alluvial Plains	Cultivated Fallow	Sandy loam (1.00)	30	35.23
Rajas (Nava Tehsil)	Older Alluvial Plains	Cultivated Fallow	Sandy loam (1.00)	56	..
Bansa (Nava Tehsil)	Older Alluvial Plains	Cultivated Fallow	Sandy loam (1.00)	30	..
Ghetwa (Nava Tehsil)	Older Alluvial Plains	Cultivated Fallow	Clay loam (1.00)	30	100
Rajliya (Nava Tehsil)	Older Alluvial Plains	Cultivated Fallow	Sandy loam (4.00)	170	..
Degana (Nava tehsil)	Older Alluvial Plains	Cultivated Fallow	Sandy clay loam (0.9)	60	..
Parbatsar (Nava Tehsil)	Older Alluvial Plains	Cultivated Fallow	Sandy loam (0.8)	65	..

these, barren lands and reserved forests were also explored for the density of Khejri. The soil texture of these habitats was mostly sandy and the soil depth was more than one metre. Highest density (42 trees/ha) of Khejri was recorded in the old cultivated fallow in the sandy undulating terrain at Khindasar (between Kolayat and Phalodi). In the famous Gajner Wild Life Sanctuary which is protected and supports a reserved forest on the sand covered pediment plains, the density of Khejri was 33 trees/ha. In another reserved forest near Kolayat on similar habitat the density of Khejri was 33 trees/ha. The RIV of Khejri varied primarily according to the habitat and then the land use which affects the vegetation associated with the Khejri. By and large, the RIV of Khejri in this tract was low . Highest RIV was recorded in an old fallow on sandy undulating plain (18.72). In the reserved forests at Kolayat and Gajner the RIV of Khejri was 12.45 and 9.06, respectively (Table 4). This indicated that Khejri was not the dominant component of the vegetation of this region.

Gangnagar-Bikaner-Churu Region: Out of seventy sites sampled in this region Khejri was recorded from 22 sites mostly representing sandy undulating plain and older alluvial flats (Table 5). These sites were mainly grazinglands, cultivated fallows and waste lands (Table 5). In the Ganganagar district it was difficult to find a cultivated fallow or a grazing land and so observation were recorded on the vegetation of the cemetaries and graveyards where the vegetation was like that of a reserved forest or a relict vegetation. In general the density of Khejri was higher than in the Shergarh-Pokaran, Kolayat-Phalodi region. The tree height was also greater in the western part of Bikaner and Churu districts. The density was lower than that in the Ganganagar district. Highest density of Khejri was recorded from the reserved grassland, on the older alluvial flats at Kishanpur (near Ganganagar). The Ganganagar-Suratgarh-Hanumangarh tringle had, in general, high density of Khejri. At Rangemahal (on Suratgarh-Hanumangarh Rd) that lies on the dried river bed of Ghaggar, the density of Khejri was 100 trees/ha.

Density of Khejri around Lunkaransar was poor (20 trees/ha). This indicated that Khejri is not a salt tolerant species. The RIV of Khejri around Ganganagar was very high (94.33). That shows domination of shrubby vegetation by Khejri. The next in order of RIV was Zizyphus numularia which formed the associated vegetation with Khejri constituting the upper layer only.

Ecological Distribution: Khejri alongwith Jal (Salvadora oleoides) represents the mixed xeromorphic woodlands which is the largest among the five formations (Satyanarayan 1964) that together constitute the vegetation of the western Rajasthan. This formation is associated with the alluvial plains both younger and older and the lower piedmont plains with deep soil deposits. The soil texture of these habitats range from clay with intermediate types i.e. sandy loam and sandy clay loam etc. A hard kankar pan is also met with at depths ranging from 25 to 100 cm. The density and height of Khejri and kind of its associates is influenced by differences in the soil depth and the soil texture.

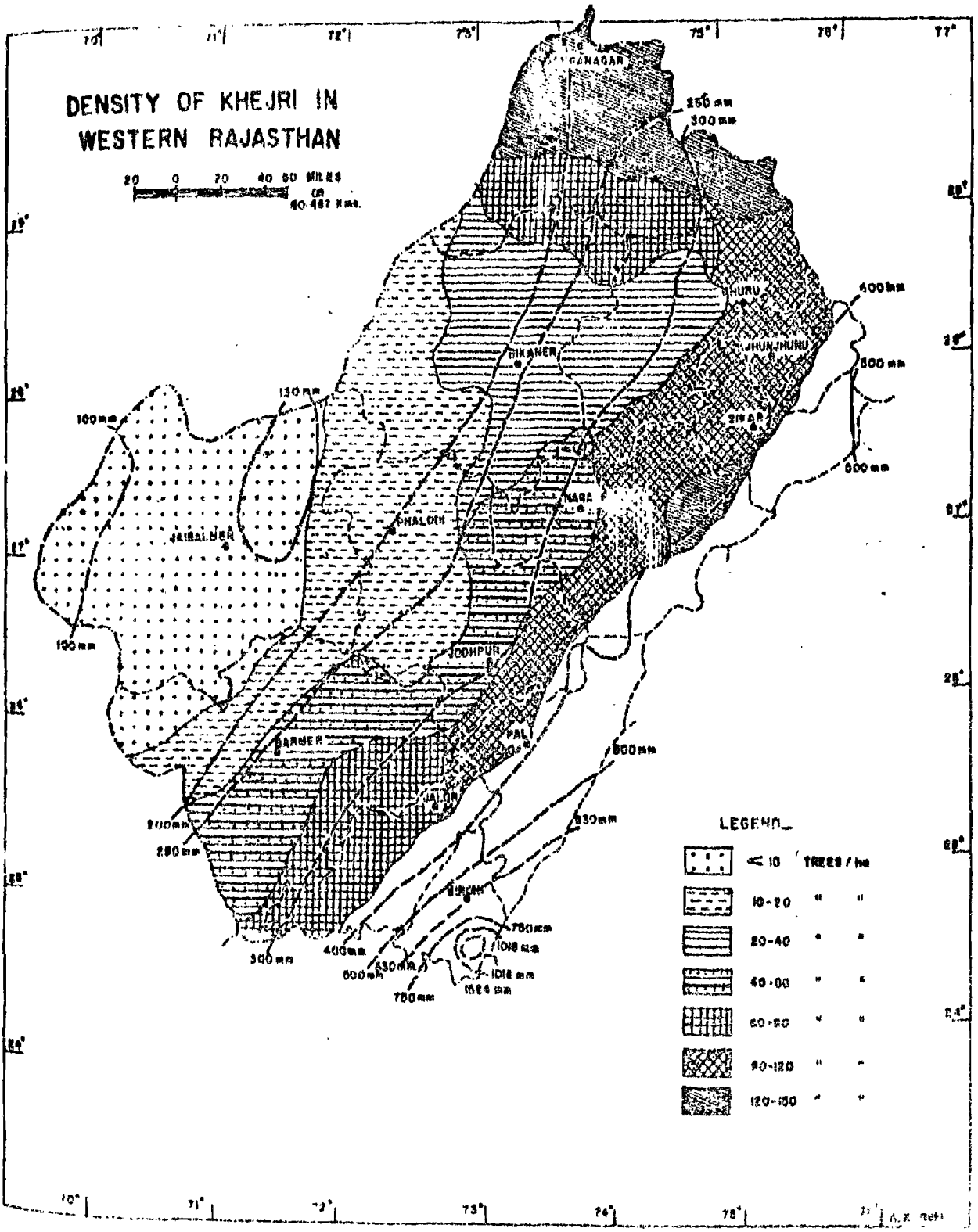
On lower piedmont plains covered with deep deposites of haavier soils and in 300 - 400 mm rainfall zone, Khejri is generally associated with Salvadora oleoides, Maytenus emarginata and Acacia leucophlaea and in the older alluvial plains of lower rainfall zone (150 - 300 mm) it is associated with Zizyphus nummularia and Capparis decidua. In the narrow belt of younger alluvium formed on both sides of the coarses of Jawai, Sukri Mitri and Luni rivers, Khejri is associated with Acacia nilotica, ssp. cupressiformis and Cassia auriculata. High density of Khejri has been found (Fig.1) on sites located in alluvial plains.

Alongwith the edaphic relationships discussed above, the distribution of khejri seems also to have some relationship with the rainfall. Its density increases (Fig. 3 & 4) from west (low rainfall zone) to east (higher rainfall zone). Largest concentration of Khejri lies between 300 - 400 mm rainfall isohytes. In between 250-300 mm rainfall isohytes, the density of Khejri declines and beyond 200 mm rainfall isohytes its density diminishes greatly. Barring a few pockets in Jaisalmer district where unusually dense stand of Khejri has been reported (Prakash and Gupta 1976) hardly few Khejri trees can be noticed.

Table 4 : Density of Khejri in Shergarh, Pokaran, Kolayat, Phalodi and Osian Region

S i t e	Habitat	Present land use	Soil Texture depth(m)	Density plant/ha	RIV
Chaba (Shergarh-Shiv Road)	Sandy undulating plains	Old fallow	Sandy (0.5) Gypsum	20	1.46
Solankiawas (Shergarh-Shetrava Road)	Sandy undulating plains	Grazing land	Sandy (+1.00)	10	3.33
Shergarh (Shergarh-Shetrava Road)	Sandy interdunal plains.	Waste land	Sandy (+1.00)	20	2.23
Nachna (Pokaran-Nachna Road)	Sandy plains	Grazing land	Sandy (+1.00)	5	4.45
Gajner (Kolayat-Bikaner Road)	Pediment plains	Grazing land	Gravelly (.10)	6	7.93
Gajner (Wild life Sanctuary Road)	Pediment plains	Reserved forest	With sand deposit (.10)	33	9.06
Khari (Kolayat-Bikaner)	Pediment plains	Grazing land	With sand deposit (.15)	20	3.97
Golari (Kolayat-Bikaner)	Pediment plains	Old fallow	With sand deposit (0.50)	10	8.74
Kolayat (Near Kolayat-Bikaner)	Pediment plains with heavy sand	Reserved Forest	Sandy (0.3)	21	12.45
Kichan (Phalodi)	Pediment plain with heavy sand deposit	Old fallow	Gravelly (0.5)	7	10.07
Luna (Kolayat-Phalodi)	Sandy undulating	Oldfallow	Sandy (+ 1.00)	35	12.38
Hindasar(Kolayat-Phalodi)	Sandy plains	Old fallow	Sandy (+ 1.00)	32	18.72
Khindasar (Kolayat-Phalodi)	Sandy undulating burried pediment	Old fallow	Sandy (+ 1.00)	42	17.65

S i t e	Habitat	Present land use	Soil texture depth (m)	Density plant/ha	RIV
Padiyal Raner (Phalodi-Nagaur)	Sandy plains	Old fallow	Sandy (+ 1.00)	10	5.34
Ghevra (Phalodi-Osian)	Older alluvial flat with sand deposit	Old fallow	Sandy (+ 1.00)	30	2.25
Khabra khurd (Osian-Chiral Road)	Older alluvial flat with sand deposit	Old fallow	Sandy (+1.00)	20	3.45


DENSITY OF KHEJRI IN
WESTERN RAJASTHAN
20 0 20 40 60 MILES
OR
60-467 Kms.
GANGANAGAR
200 mm
300 mm
400 mm
500 mm
600 mm
HANUMANGARH
BIKANER
JHUNJHUNU
SIKAR
NAGAUR
JAISALMER
PHALODI
JODHPUR
PALI
BARMER
JALOR
SIROHI
100 mm
130 mm
190 mm
200 mm
250 mm
300 mm
400 mm
500 mm
530 mm
750 mm
1016 mm
1524 mm
LEGEND
< 10 TREES / ha
10-20 " "
20-40 " "
40-60 " "
60-90 " "
90-120 " "
120-150 " "

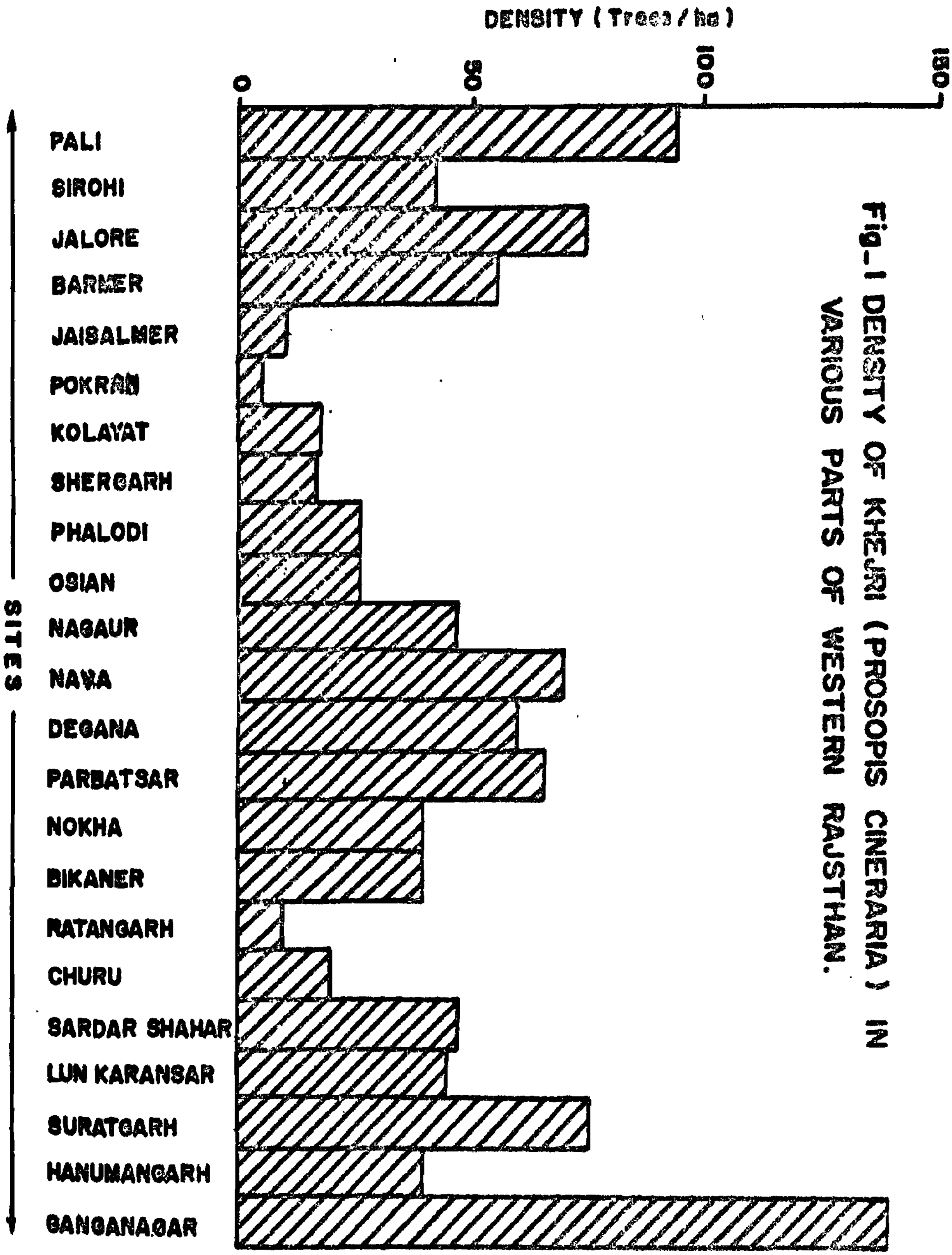
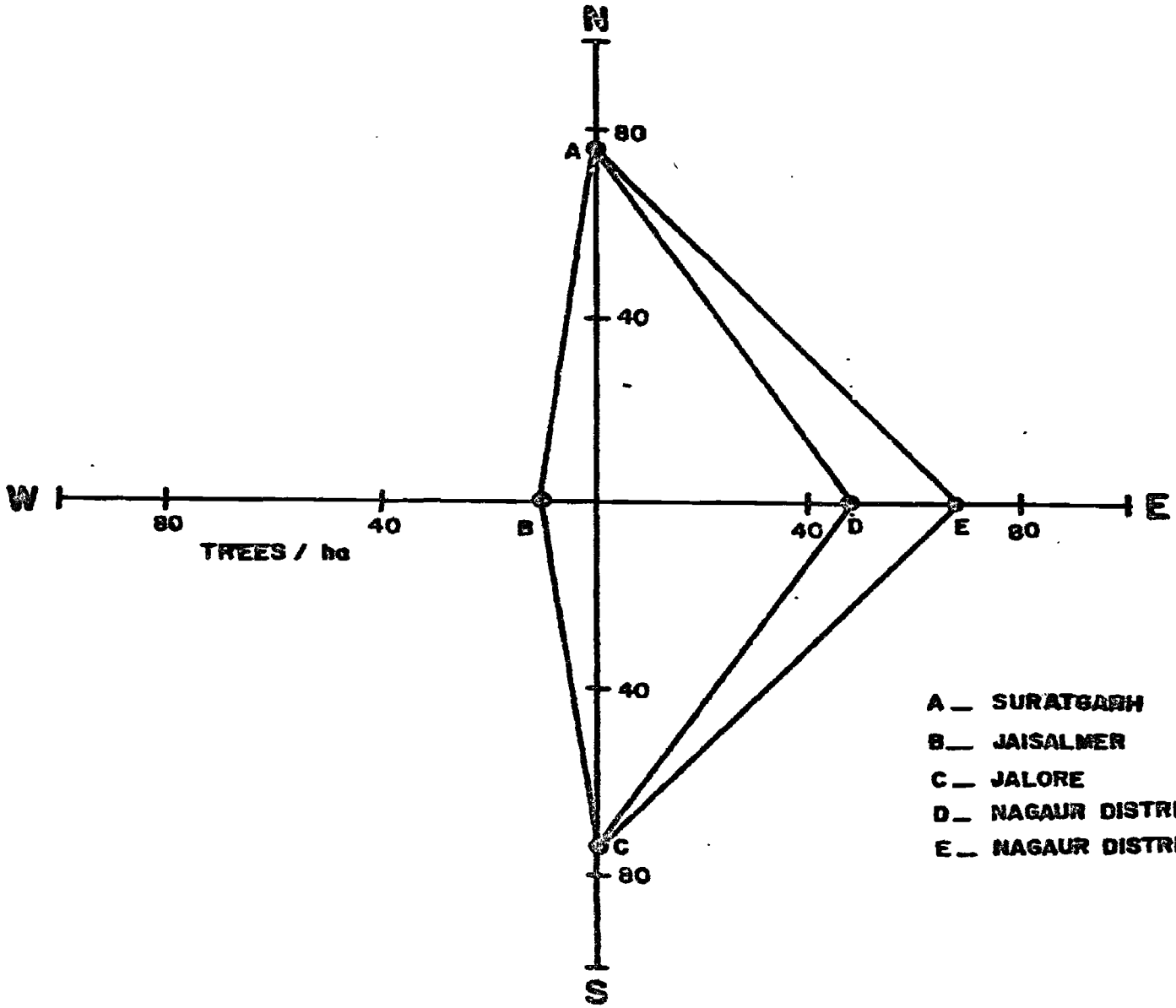


Fig-I DENSITY OF KHEJRI (PROSOPIS CINERARIA) IN VARIOUS PARTS OF WESTERN RAJSTHAN.



CONCENTRATION (TREES / ha) OF KHEJRI (PROSOPIS CINERARIA)

The highest density of Khejri has been observed in the western part of Nagaur and Sikar and Ganganagar districts. The sites which meet the requirements of water balance of Khejri apparently support dense stands. Root excavation upto 10 M indicated (Lahiri 1965) thick secondary roots of Khejri going deep drawn penetrating the stratified kankar layers. Khejri has been considered (Lahiri, 1968) as a phreatophyte mainly due to its deep root system and other associated characters. The habitat preferences i.e. alluvial plains and its concentration in 250-300 mm rainfall zone indicate that for its requirements of water these are the ideal situations. According to Prakash and Gupta (1976) the exceptionally dense patch in the 100 mm rainfall zone in Jaisalmer may be due to the capacity of Khejri to utilize perched water in the stabilized dunes. there. Apart from this, Khejri has also the capacity to absorb moisture from rains through its foliage (Bhatt and Lahiri, 1964). Due to these two reasons Khejri may possibly be able to meet its niche requirement in the extremely arid tract where dense stand of Khejri has been reported (Prakash and Gupta, 1976).

Conclusion: Density of Khejri increases from the western to the eastern part of the western Rajasthan. Older and the younger alluvial plains are the two habitats preferred by khejri but it also grows well in lower piedmonts with thick soil deposites and sandy undulating plains. The rainfall belt between 250 to 400mm shows high concentration of Khejri. Because of its capacity to avail perched water and to absorb moisture from rains through its foliage it can grow in the extremely arid tract (100 mm rainfall); The distribution pattern of khejri is discontinuous evidently due to its habitat preferences and its specific water requirement. On less favourable habitats the density, height and crown cover of Khejri is lower than that of the preferred habitats.

Table 5: Density of Khejri in Ganganagar-Bikaner-Churu Region

S i t e	Habitat	Present land use	Soil texture depth(m)	Density plant/ha	RIV
Kudsu (Nokha-Udasar)	Sandy undulating	Old fallow	Sandy loam(+1.00)	40	28.19
Ranisar (Ratangarh-Churu)	Low dunes	Old fallow	Sandy (+1.00)	10	4.81
Churu	Sandy undulating	Grazing land	Sandy (+1.00)	20	7.79
Sawai (Sardar Shaher-Dungargarh)	Sandy undulating	Grazing land	Sandy (+1.00)	70	17.47
Bhadasar (Sardar shaher-Dungargarh)	Dunes	Arable Land	Sandy (+1.00)	30	19.61
Bramsar (Sadur Shaher-Hanumangarh)	Flat plains	Grazing land	Gypsiforous loam (0.60)	80	23.29
Hariyasar (Sardar Shaher-Hanumangarh)	Low dune	Grazing land	Sandy (+ 1.00)	10	8.50
Narang deshar (Hanumangarh)	Alluvial plains	Grazing land	Loamy (+ 1.00)	40	23.81
Kishanpur (Ganganagar)	Older Alluvial Flat	Grass land	Loamy (+ 1.00)	250	94.33
Netewalia (Ganganagar)	Older alluvial flat	Waste land	Loamy (+ 1.00)	130	36.31
Suratgarh (Ganganagar-Suratgarh)	Sandy undulating plains	Waste land	Sandy (+ 1.00)	50	10.73
Rangmahal (Suratgarh-Hanumangarh Road)	Older alluvial plains	Waste land	Loamy (+1.00)	100	30.56
Hariyasar (Suratgarh-Lunkaar Road)	Sandy undulating plains	Grazing land	Sandy (+ 1.00)	10	5.61

Site	Habitat	Present land use	Soil texture depth (m)	Density plant/ha	IVI
Phuldeshar (Lunkaransar)	Sandy undulating plain	Grazing land	Sandy (1.00)	10	5.61
Lunkaransar	Sandy plains	Grazing land	Sandy loam (1.00)	10	13.32
Khera (Lunkaransar)	Sandy Plains	Grazing land	Sandy loam (1.00)	150	62.73
Palana (Bikaner-Nagaur Road)	Sandy undulating plains	Grazing land	Sandy (1.00)	20	20.42
Alai (Bikaner-Nagaur Road)	Older alluvial, low lying flat	Grazing land	Clay-loam (0.90)	20	4.83
Jamsar (Suratgarh-Lunkaransar)	Older alluvial flat	Grazing land	Loamy (0.70)	110	24.88
Banariya (Lunkaransar Bikaner)	Older alluvial flat	Grazing land	Loamy (0.45)	20	16.97
Kasturia (Lunkaransar-Bikaner)	Sandy undulating plains	Grazing land	Sandy (1.00)	10	6.05
Jamsar (Lunkaransar-Bikaner Road)	Low dune	Waste land	Sandy (1.00)	10	6.51

Silvicultural Aspects of Khejri

K.D. Muthana

Introduction

Substantial progress has been made in the silvicultural aspects of various desert tree species but many things are yet to be standardised. Khejri provides a challenge in its silvicultural complexities, though it grows in both thinly and densely populated areas. The proper management poses a difficult problem, due to its characteristic slow growth, e.g. in deciding sound silvicultural practices. Little work has so far been carried out in this tree and hence much attention is needed to standardize. The normal cultural practices especially various methods of its regeneration in different bioclimatic regions of Indian Desert are very much needed. On a long term basis this tree, in general, will help in the economic development of this region. The following information is primarily a summary and evaluation of some available data on this tree.

Silvicultural studies: Silvicultural studies were carried out at the Central Research Farm, Jodhpur. Some of the results are presented below.

Direct sowing: The plantation of this tree by direct seed sowing has not given significant results. Moreover they failed to establish satisfactorily due to negligible survival percentage of seedlings.

Transplanting: Seedling raised in the polythene or G.I. tubes gave maximum establishment (69%), mean maximum height growth (371 cm) and mean annual increment (27 cm) in 12 years period, when planted in 60 x 60 cm cross sectional trenches half filled with dugout soil. 68.0% establishment with mean maximum height growth (278 cm) and mean annual increment (20 cm) was recorded when planted in 60x60x60 cm pits filled with weathered soils. 63, 60 and 46% establishment with 296, 225 and 324 cm mean maximum height and 21, 15 and 23 cm mean annual increment when planted in strips of 22.5 cm wide and deep, in pits of 60 x 60 x 60c. half filled with weathered soil and in 30x30 cm cross section trenches

half filled with dug out soil respectively. The data are presented in Tables 6 and also illustrated through graph.

Wood characteristics: The wood of Khejri is hard but not very durable. The tree invariably develops hollowness as girth increases. The sapwood is large and creamy white, heart wood scanty brown to purplish brown, straight to slightly inter-locked grained, medium coarse textured, strong tough, very hard and heavy (weight 769-949 kg/cum). Wood season well with ease, 2.5 cm thick planks take 16-20 days in Kiln-season and require to be steamed atleast twice during the coarse of drying. It turns well and considering its hardiness, is not difficult to saw and work finishing to a smooth surface taking point and polish well. The wood is suitable for interior construction work such as column of huts, roofs, doors, windows, wheel and hubs of carts, small agriculture implements, tool handles, small turnery articles and well curbs (Anonymous 1969). Some times logs of Khejri act as a support in lining of lower most well walls in sandy soils. The wood has a high calorific value (7640, BTU/lb) and therefore, commonly used for fuel.

Root system: The tree is very valuable for afforestation on sandy plain and sand dunes in arid and semi-arid zone of Rajasthan. - The tree has a very deep tap root system. A specimen exhibited at Paris in 1876 recorded 86' in length and had penetrated vertically 64' depth. Another example of tap root from Sind (Pakistan) was found to be 117' in length (Troup 1921). Blagovershensky (1968) also carried out root excavation studies at Jodhpur and found it as a very deep rooted plant. Because of its deep tap root system it does not generally complete for moisutre with crop. This quality of Khejri is ideal for its introduction in Silvipastoral and Agro-forestry system. The roots of this tree contains significant amount of tanning material. But removal of roots, leads to the death of plant. Tender saplings of 1-2 years of age are sensitive to frost and drought but older plants are hardy and capable to resist the adverse climatic conditions.

Table 6: Studies on soil management and method of reboisement 1960-61 series

S.No.	Species	Treatment	Sowing seeds					Transplanting				
			W_1	W_2	W_3	W_4	W_5	W_1	W_2	W_3	W_4	W_5
1.	Prosopis cineraria	Av. Ht. (cm)	157,6	166.6	258.5	251.0	245.0	296.0	324.0	371.0	277.9	225.3
		survival (%)	1.0	10.0	13.0	79.0	100.0	63.0	46.0	69.0	68.0	60.0
2.	Albizzia lebbek	Av.Ht. (cm)	-	-	-	330.0	-	347.5	-	300.0	509.0	433.7
		Survival (%)				10.0	-	12.0	-	7.0	18.0	8.0
3.	Acacia Senegal	Av.Ht.(cm)	232.5	260.6	290.1	330.0	-	285.8	342.1	320.1	325.8	272.0
		Survival (%)	4.0	5.0	6.0	44.0	-	46.0	63.0	54.0	63.0	46.0
4.	Tecorella undulata	Av.Ht.(cm)	-	-	-	-	-	169.8	285.0	253.3	282.8	264.8
		survival (%)	-	-	-	-	-	36.0	15.0	31.0	71.0	53.0

Table 6(b) Mean annual increment in height growth of the four desert tree species (cm) under transplanting

Species	W_1	W_2	W_3	W_4	W_5
Prosopis cineraria	21.0	22.8	27.4	14.7	15.1
Albizzia lebbek	26.0	18.8	21.9	42.8	35.1
Acacia senegal	20.2	25.2	23.5	23.3	19.2
Tecomella undulata	12.0	20.3	17.8	19.9	18.5

W_1 - Soil working to a width and depth of 22.5 cm by pickaxe.
W_2 - 30 x 30 cm cross section trenches, 1/2 fitted with dug out soil.
W_3 - 60 x 60 cm cross section trenches, 1/2 fitted with dug out soil.
W_4 - 60 x 60 x 60 cm pits fitted in with the weathered soil
W_5 - 60 x 60 x 60 cm pits 1/2 fitted in, with weathered soil

Fuel yield: A Khejri tree is expected to be ready for lopping during 8th year of its life (350-400 mm rainfall zone). No systematic estimates of fife wood yield are available. The observations made on the farmers field indicated that 2-3 kg. of fire wood will be available in the initial lopping of 8-10 years old plants.

Fuel yield study conducted by Kaul et al. (1967) revealed that for *P. cineraria*, diameter at breast height (DBH) is highly correlated to its seed yield and can be taken as sole criterion for predicting pod and seed yield of a tree by fitting a linear regression equation. D.B.H. has also been found to be highly correlated with all the fuel yield components and the total fuel yield. There can also be two approaches for predicting the total fuel yield of a tree viz., i) measuring DBH and predicting with the help of an equation

$Yt = 0.2596 \quad X_1^{2.2437}$ where Y_t = total fuel yield and X_4 = D.B.H. (in cms) and ii) by estimating the weight of branches with the help of DBH + weight of clear bole by the multiple regression equation, $Y_c = 5.3335\ X_1 + 31.56 \quad X_2 = 92.1735$, where Y_c = total weight of clear bole (in kgs.), X_4 = DBH (in cm) and X_2 = length of clear bole (in metre).

Timber yield: The anticipated fuel wood yields from Khejri tree in 20th - 30th year age group is 40-70 kg/tree. Studies carried out on the fuel wood and timber production at C.R.Farm Jodhpur (350 mm rainfall) with known age group (15 years) ranges from 35-40 kg/tree. A general felling period of 25 years is proposed for this tree in 350-500 mm rain fall zone.

Pod yield: A fully grown tree (30-50 yrs. old) with well spread crown cover produces nearly 5 kg of air dried pods (350-500 mm rainfall zone) in good rainfall years. There is a severe pod reduction due to an insect attack during flowering period which leads to gall formation. A timely spray of an insecticide may provide a high pod production. Young trees (10-30 yrs. age group) which are not much lopped give 2-3 kg/tree pod yield.

Seed production: The dry seed yield has been estimated at one kg. per tree with moderate sized plants (20-30 yrs. age group) whereas two kg. per tree from a fully developed crown cover (above 30 years age group) in 350-500 mm rainfall zone.

Genetic variability: A study, which was initiated in 1977 at Jodhpur to determine the genetic variability for various growth attributes in P. cineraria also gave very encouraging indications. Seeds of selected individual trees from Jodhpur (Farm) and Bikaner (Udramsar) were collected and plants raised in the nursery. Sixty days old plants were transplanted in the field in Aug. 1977 In all 27 plants per progeny of Bikaner origin and 18 plants per progeny of Jodhpur origin were put in the experiment.

The results indicated that survival was almost 66 to 100 per cent in most of the progenies. However, there appeared to be considerable variation with regard to mean height of the progenies which varied from as low as 20 cm to as high as 65 cm. Three plant progenies of Jodhpur have shown performance above 100 cm per plant height (Table 6). It was very encouraging to note that height attained by some of the best plants was fairly comparable with the average height attained by Acacia tortilis (a fast growing tree species) of some age. Hence it was apparent that selection of mother trees is important while collecting seeds for raising seedlings.

Types: In Shekhawati region of Rajasthan two distinct ecotype of Prosopis cineraria (Khejri) have been recognised. Common tree has small spines all over its branches. The main branches of this type have a tendency to grow slightly on the upward direction giving a clear cut identity. These trees have hard twigs. Leaflets are dark green in colour but altogether less foliage on the branches which makes the tree canopy somewhat open. Locally it is called as "Khejra". The second type has thornless twigs in upper and terminal branching. These twigs are soft, pendulus with more number of leaflets, which are comparatively less green. Higher terminal branches and more number of leaflets provide dense canopy. This type thus provide higher percentage of top feed.

HEIGHT GROWTH OF PROSOPIS CINERARIA UNDER DIFFERENT SOIL WORKING TREATMENTS (1960-1972)

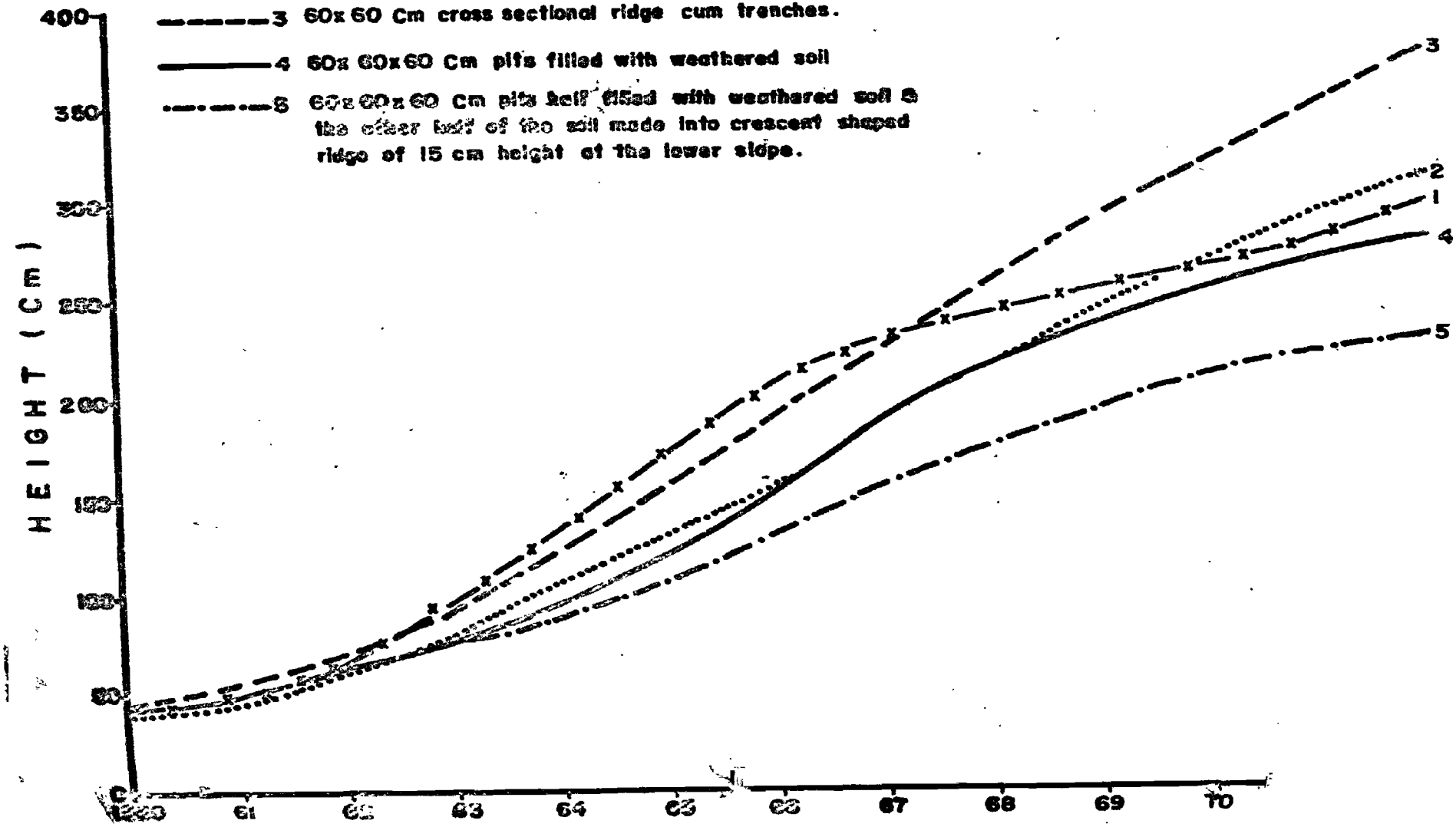
x—x—x—x 1 Soil worked by pick-axe to a width and depth of 22·5 Cm.

2 30x30 Cm cross sectional ridge cum trenches.

3 60x60 Cm cross sectional ridge cum trenches.

4 60x60x60 Cm pits filled with weathered soil

5 60x60x60 Cm pits half filled with weathered soil & the other half of the soil made into crescent shaped ridge of 15 cm height at the lower slope.



This is locally called "Khejri". There are some intermediate type as well but not easily distinguishable from the others. Some have less spines with few non spined twigs (Memeo 1976).

Herbage growth under Khejri Canopy

S.K. Saxena

Introduction

There is a general belief that the crop growth is better under Khejri tree than the adjoining areas under similar management conditions. Singh and Lal 1969 tried to confirm the above belief on scientific ground. They carried out various soil studies and reached to the conclusion that better crop of plant growth is due to higher organic matter contents, total nitrogen available P_2O_5, soluble calcium and low pH value. Studies of Aggarwal et. al; (1976) have also confirmed the above findings. They have also indicated higher available micronutrient and macro-nutrients. Net only this higher moisture status and forage biomass have also produced under the canopy of Khejri tree(Gupta and Saxena 1978). Highor amount of forage production and its subsequent litter production which gets mineralized below the canopy of this tree boost up high crop growth. Shankar et al; (1976) have indicated marked improvement in the botanical composition, and vigour of major grasses grown under Khejri tree. Sown pasture of Dhaman gas (Cenchrus ciliaris) showed gradual and significant differences in plant height, tussock diameter and herbage yield as the distance from Khejri tree increased.

Herbage growth: Observations on the botanical make up and temporal changes were made for three consequtive years (1973-75) under the canopies of five plantation of desert tree spe-cies i.e. Prosopis cineraria, Tecomella undulata, Albizzia lebbeck and Prosopis juliflora. The results of these studies are summerized in table 8 and 9.

Plant density: Amongst all the five species, the herbage plant density per unit area was found to be highest (358.1/m^2 below P. cineraria tree and it was followed by Tecommela undulata (351 4/m^2) whereas it was lowes under P. juliflora (132.7/m^2).

Tecomella undulata supported more number (125.7/m^2) of perennial species while annual were higher (245.6/m^2) under P.cineraria

Number of species: Number of different perennial species was similar (6.7) in P.cineraria & T. undulata but the annual species number was higher with Khejri (19.4). Thus total number of species supported by Khejri was higher under its canopy. It was lowest (11.7) in case of P.juliflora.

Forage biomass: Higher number of plant population and number of species resulted into higher above ground biomass (234.8 g/m^2) under the tree canopy of P.cineraria. The values recorded under P.juliflora were lowest (117.7 g/m^2).

Height of forage species: Few important forage species common under other tree canopy as well were scaled for their height characteristic. Herbage under various tree canopies showed different growth trend. Almost all the species scaled for their height have shown more height (Table 9) under the tree canopy of P.cineraria.

Litter: The litter collection was carried out before the onset of monsoon under each tree canopy. Here again it was highest (68.0 g/m^2) under P.cineraria (Table-8)

Water table: Khejri grow well on sandy to sandy loam soils of flat alluvial plains where the water table is 60-90 ft. deep. Chatterji and Gupta 1969 in their geobotanical investigation on various plant communities have shown the association of P.cineraria tree where water depth varies fr 9-24 m and a salinity of 5000 - 10000 ppm.

Table 7: Data on plant height and survival per cent for different plant progony of 2 years old *Prosopis cineraria*.

Tree No.	Source	Survival (%)	Mean height (cm)	Range in mean ht. (cm)	± SEM	No. of plants above 100 cm
B-1	Bikaner	77	27.8	17-60	1.33	-
B-2	Bikaner	100	27.6	17-48	0.99	-
B-3	Bikaner	100	30.3	14-75	1.30	-
B-4	Bikaner	100	32.4	20-60	1.10	-
B-5	Bikaner	100	30.8	15-75	1.78	-
J-1	Jodhpur	66	20.5	15-46	2.27	-
J-2	Jodhpur	90	35.1	16-96	1.96	-
J-3	Jodhpur	100	55.7	20-105	2.20	1
J-4	Jodhpur	83	56.6	18-147	5.89	3
J-5	Jodhpur	90	65.4	16-165	5.89	7

Table 8 : Average plant density, number of species, above ground biomass and litter/m^2

Canopy cover	Plant population Pernnials (No.)	Annuals (No.)	No.of species occuring Total	Perennials (No.)	Annuals (No.)	Total	Above ground biomas(g)	Canopy Density	Litter (g)
1. Acacia senegal	53.2	169.3	222.5	4.7	14.4	19.1	128.9	0.4-0.8	30.3
2. Tecomella undulata	125.7	225.7	351.4	6.7	16.9	23. 6	192.5	0.3-0.6	39.2
3. Prosopis cineraria	112.5	245.6	358.1	6.7	19.4	26.1	234.8	0.5-0.7	68.0
4. Prosopis juliflora	52.9	102.7	132.7	3.9	11.7	15.6	117.7	0.4-0.6	23.0
5. Albizzia lebbeck	64.3	185.1	249.4	3.8	15.3	19.1	130.8	0.3-0.5	23.4

Table 9 : Mean height (cm) of forage species under various tree canopy

	Acacia senegal	Tecomella undulata	Prosopis cineraria	Prosopis juliflora	Albizzia lebbeck
1. Aristida sp.	52.8	54.6	66.8	34.9	47.9
2. Brachiaria ramosa	19.7	17.8	22.2	12.2	23.9
3. Chloris virgata	59.0	56.9	58.4	49.0	63.7
4. Dactyloctenium sindicum	50.6	48.8	59.3	38.7	57.3
5. Eleusine compressa	35.4	41.7	48.4	15.3	34.9
6. Cyperus sp.	33.2	32.6	34.2	14.4	35.3
7. Corchorus tridens	-	26.4	37.4	30.7	36.9
8. Digitaria adsendens	57.3	67.6	71.5	42.8	74.0

Grass production under Khejri tree

L.D. Ahuja

Introduction

Role of different trees for providing shade and top feed to animals and fuel and timber for inhabitants is well known. In an open forest, there is a close relationship between the trees and forage species (on the ground) which largely contribute for livestock production. The area in the arid tract is largely occupied by scrub forests. The forest area below 250 mm rainfall zone occupy 0.4% and 1.3% above 300 mm zone of the total land area. These figures are lower than the normal i.e. 10% of the total land area.

Plantation layout: In order to find out suitable techniques of afforestation of different useful tree species for this region, studies were undertaken in 1958 onward at this Institute. The technique comprised provenance trial of different tree species viz. Prosopis cineraria (Khejri) Tecomella undulata (Rohida), Albizzia lebbea (Siris) and Acacia senegal with different methods of sewing, soil working, age of planting etc. under different combinations. The layout of experiment was replicated in randomised block pattern.

To evaluate the contribution of forage species under different tree species study was undertaken, in the above said plantation of 14-18 years old, grouped in four different sets of silvicultural experiments given in tabular form:

Methods of Planting

Experiment	Establishment Year	Species tried	Replication	Treatment	Plot size m.	Forage yield recorded
I.	1958	Four	4	Planting method (2)	7x7	1972-76
II.	1959	Four	4	Soil working (5) method of sowing(2)	12x10	1972-75
III.	1959	Three	4	Seedling ages (3)	12x10	1972-76
IV.	1959	Four	4	Time of planting(3)	12x9	1972-77

Method of Study: Estimation of herbage production was carried out by laying Forage Estimation quardrts (FEQ) having the dimension of 1 x 10 m or 2x 5m depending upon the plot size of respective experiment. One FEQ was laid out under in each tree species plot. Herbage was harvested at ground level from FEQ during November each year (1972-77). It was air dried and weighed species wise. Every year the position of FEQ was changed.

Results: The data of six years forage production in each experiment has been given in table 10, which is self explanatory. The forage production under Prosopis cineraria(1.1 - 1.5 t/ha)in all the four experiment was higher than other tree species, whereas it was minimum under Acacia senegal (Kumut) (0.6 - 0.7 t/ha). In experiment IV though the plant population of Prosopis and Acacia on hectare basis were almost similar yet the forage production under Prosopis(Khejri) was on higher side. On the other hand, tree population of Albizzia lebbek (Siris) is sizeably less than Prosopis (Khejri) but the forage production was slightly higher with Prosopis only.

Table 10 : Average Forage Yield (t/ha) under different tree species

Experiment No. & Period of Observation	Particulars	Tree species			
		Prosopis cineraria	Teconella undulata	Albizzia Lebbek	Acacia senegal
Expt.I	1. Total forage production	* 1.5	* 1.5	* 1.4	0.6
	2. Contribution of perennial sp.	1.1	* 0.8	* 0.9	0.3
	3. Perennial grass species %	74.8	53.7	57.9	52.5
	4. Trees/ha	566.6	383.3	283.3	1516.6
Expt.II 1972-75	1. Total forage production	* 1.5	* 1.5	* 1.4	0.7
	2. Contribution of perennial sp.	* 1.2	+ 0.8	+ 0.9	0 4
	3. Perennial Grass species %	78.3	51.1	66.5	58.8
	4. Trees/ha	*1377.5	*942.8	* 688.8	3724.4
Expt.III 1972-76	1. Total forage production	* 1.2	..	* 1.1	0.7
	2. Contribution of perennial sp.	0.9	..	* 1,0	0.6
	3. Perennial grass species %	74.7	..	85.3	82.4
	4. Tree/ha	*1743.3	298	298.3	*1812.4
Expt.IV 1972-77	1. Total forage production	*1.1	* 1.1	0.9	0.7
	2. Contribution of Perennial sp.	*1.0	* 1.1	0.9	0.7
	3. Perennial grass species %	97.9	99.2	97.1	98.8
	4. Trees/ha	*1264.8	1111.1	362.0	*1280.5

* Values in a horizontal line do not differ significantly.

Table 11: Average Forage Yield in T/Ha Under Different tree species During Various Years

Experiment	1972	1973	1974	1975	1976	1977
I	0.4[x]	2.6	0.4[x]	0.6	1.0	-
II	0.4[x]	2.6	0.4[x]	0.6	-	-
III	0.7	1.6	0.3	1.2[x]	1.2[x]	-
IV	0.2[x]	1.8	0.2[x]	1.1	1.2	1.4
Rainfall (mm)	363.1	641.8	244.3	661.9	639.6	353.2
Rainy day	17	27	13	41	32	28

- = Not recorded

x = Values in horizontal line do not differ significantly.

The forage production under Teconella undulata stands second and was comparable with Prosopis, inspite of the fact that the tree population on hectare basis was less with T.undulata.

Contribution of perennial grass species under Khejri tree was as high as 78.3% and lowest with T. undulata (51.1%) in experiment No.I to III, whereas in experiment IV, the percentage contribution by grass species. did not differ much under all the trees/ This may be due to inherent site differences. During the period of six years study under various tree species it can be concluded that Khejri plantation provide higher forage production under its canopy with greater proportion of nutritional perennial grasses.

Yearwise forage production: Maximum forage production (1.6 - 2.6 t/ha) was obtained during 1973 with 27 rainy days (Table 11) following by 1.4 t/ha in 1977 with less rain but almost equal number of (28 days) rainy days. Data on forage production, under different tree species, had variation during each year, which may be perhaps, due to high variability in rainfall. During the year 1973, the rainfall was with a regular interval of nearly eight days and every time it was a soaking rain with bright sun light in between the two rainy period. During 1976 and 1975 the total rainfall was either similar or more, with more number of rainy days but the forage production was quite low. Cause of lower forage production can be attributed to two major factors which operated during monsoon period. There were heavy showers and flooding of the ground which resulted in the casuality of most of the annual species under water logged condition. Secondly there were more cloudy days during the peak growth period of the herbage. Thus higher forage production depend on rainfall distribution pattern, period of rainfall and sufficient bright light during growth period.

Physico-Chemical Status of Soils Under "Khejri" (Prosopis cineraria Linn.)

R.K. AGGARWAL

Introduction

Tree vegetation during the course of its establishment initiates a series of changes in ecological and soil physico-chemical characteristics. These changes in soil much depend on the type of vegetation, it supports. The rooting pattern, canopy, type and quantity of litter fall of the tree vegetation have directly and indirectly much greater influence on the soil fertility and moisture status of the soil. It is also stated that the influence of specific forest stand on the soil is greatest in regions climatically favourable for the development of that vegetation type.

The very fact that P.cineraria occurs and encouraged in all cultivated fields and village grazing grounds shows that its usefulness has been generally accepted by the land owners who have this strong conviction based on the observations that crop growth under "Khejri" tree is better than the adjoining areas under the same management conditions. Legris (1963) commented on how, in parts of Rajasthan, millets mustard and irrigated wheat are grown in the shade of P.cineraria. Blagovershensky (1968) relates how farmers "insisted that 'bajra' grow better around these trees." Contrary to this, the crop growth under P.juliflora tree is almost scanty. Both trees have small leaves and are not so dense as to produce a shadow effect on plant growth (Singh and Lal, 1969). Under such a situation one's attention is naturally drawn to know the probable reasons for good growth under P.cineraria and very poor growth under P.juliflora. One of the reasons might be their effect on the soil fertility and moisture status. Goor and Barney (1968) claims that "Because of long tap root of P.cineraria, it does not compete for moisture with crop plants and they may grow right upto the trunk of the tr

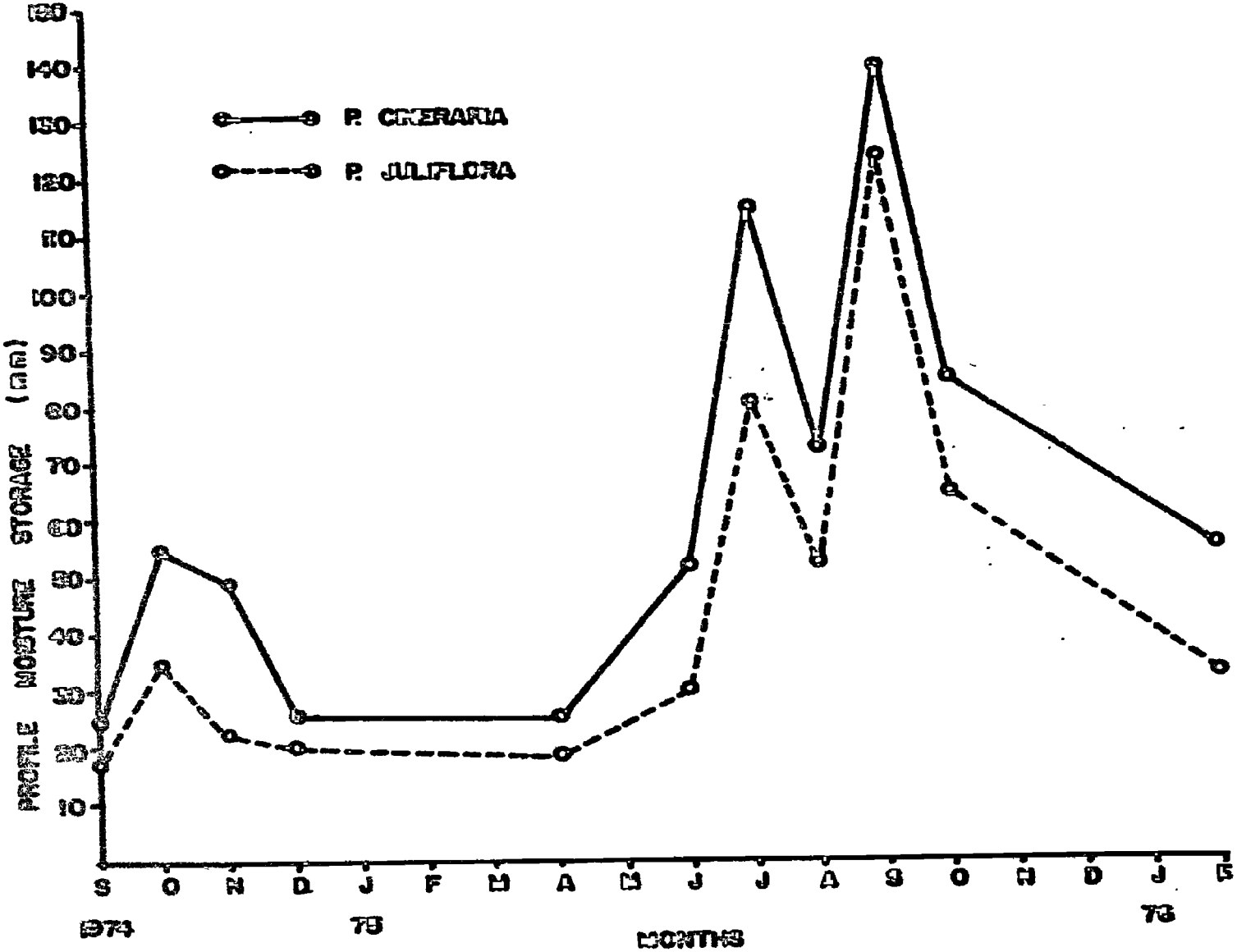


Fig-1 MOISTURE CHANGES IN SOIL UNDER DESERTIC TREE VEGETATION
(After Gupta and Saxena, 1970)

Though, some work on the influence of P.juliflora on soil properties have been reported elsewhere (Kearney and Peebles, 1960; Paulson, 1950, Tiedemann and Klemmedson, 1973), but the information on P.cineraria and its effect on soil fertility and moisture conditions in the arid areas of N.W.India is rather meagre. The results of the studies conducted on the soils under fourteen years old P.cineraria tree vegetations at C.R. Farm Jodhpur and elswhere have been presented and discussed in the following paragraphs taking P.juliflora and open filed conditions for comparison.

Soil Physical Conditions: The studies conducted by Singh and Lal (1969) on the mechanical composition of soils under P.cineraria have shown an increase in silt plus clay content upto 120 cm depth while in open field conditions this increase was upto 90 cm only. This differentiation in mechanical composition of soil with depth under P.cineraria may also lead t the variation in soil moisture status. Soil moisture studies conducted during May 1974 to February 1976 under different desertic tree species at this Institute (Aggarwal et al., 1975 and Gupta and Saxena, 1978) have shown higher soil moisture content under P.cineraria than in open field. The results presented in Fig. show that throughout the period of observation, the maximum amount of moisture was observed in the soil under P.cineraria and the minimum under P.juliflora. The soil moisture ranged from about 27 to 50 mm during the rainless period of November to June and 115 to 140 mm during the July to September under P.cineraria. During September 1975, the average depletion rate of 1.8 mm/day and 2.1mm/ day was observed from the soil under P.cineraria and P.juliflora respectively, indicating thereby a higher initial depletion by the latter type of vegetation. This probably leads to a higher moisture status of soil under P.cineraria. The moisture depletion pattern from different depths showed higher depletion of moisture from deeper layers under P. cineraria while it was higher from shallower depths under P.juliflora, thus higher moisture availability in the surface by higher density of above ground flora in P.cineraria. This shows that P.cineraria does not not compete with the perennial and annual flora under it canopy.

This is because of deep tap root system (Goor and Barney, 1968) of P.cineraria, but because of a lateral root system that perhaps spreads upto distances of 10 m or more (Kearney and Peebles, 1960) of P.juliflora which competes with perennial grass for moisture.

Soil Fertility Conditions

Organic matter and nitrogen content: Organic matter content is of prime importance in the development and maintenance of soil fertility. Organic matter, by affecting soil conditions, effectively help the aeration and moisture conservation in soil, thus providing optimum conditions for the micro-organism to flourish. It affects the reaction of the soil, and the viability of the microflora, especially the nitrifyingorganism. The nitrogen status is also closely associated with the level of organic matter.

The results on pH and electrical conductivity showed a slight reduction on pH (8.0) under P.cineraria in comparison to the open field conditions (pH 8.2) and also in EC values which was 0.01 mm hos/cm under P.cineraria while it was 0.22 mmhos/cm under P.juliflora and 0.20 mmhos/cm under open field conditions. Singh and Lal (1969) also reported decrease in pH under P.cineraria grown under high rainfall conditions of eastern region of Rajasthan. This reduction in pH values observed under P.cineraria may be attributed to the presence of higher content of organic matter, soluble calcium and comparatively lower content of $CaCo_3$. The results presented in Table-12 show the depthwise distribution of organic matter and nitrogen content in soils under P.cineraria, P.juliflora and open field conditions. The organic matter and total nitrogen contents were highest under P.cineraria over p.juliflora and open field particularly in surface soil. In general, the organic matter and nitrogen contents were higher in surface soil and decreased with depth. When the mean values of whole soil profile are taken, it has been observed that there was 45% increase in organic matter and totalnitrogen content in P.cineraria over open field conditions. However, the percent increase in surface soil (0-15 cm) was conspicous. There was an increase of about

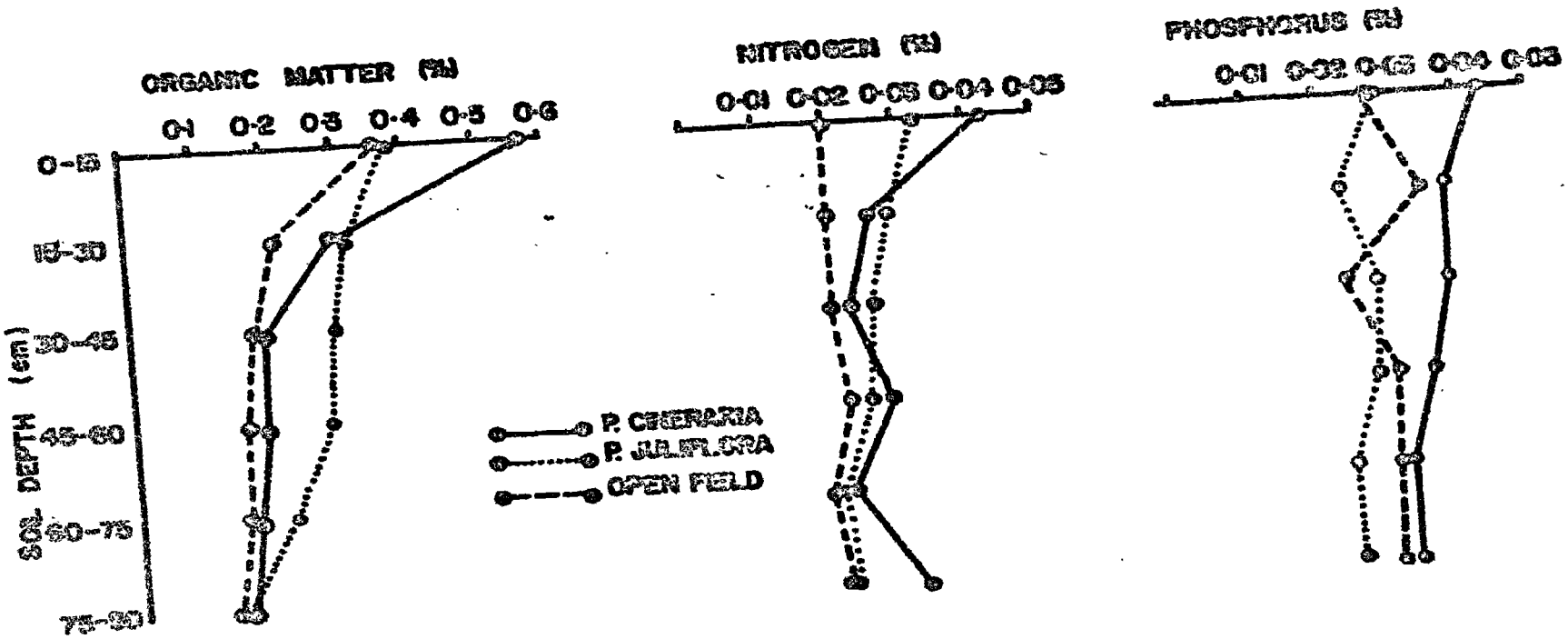


Fig- 2 DEPTH WISE DISTRIBUTION OF ORGANIC MATTER, NITROGEN AND PHOPHORUS IN SOIL

Table 12: Available macro and micronutrient contents in soils

Location	Depth (cm)	N	P	K	Zn	Mn	Cu	Fe
		(Kg/ha)			(ppm)			
P.cineraria	0-15	250	22.4	633	0.60	10.0	0.50	5.3
	15-30	193	10.3	325	2.28	11.7	1.28	2.4
P.juliflora	0-15	250	10.3	409	0.50	7.5	0.50	2.6
	15-30	212	4.5	258	1.30	11.2	0.67	4.0
Open field	0.15	203	7.7	370	0.20	6.9	0.26	3.0
	15-30	196	4.0	235	0.08	8.1	0.50	4.0

150% of organic matter in soils under P.cineraria over P.juliflora and open field conditions, while total nitrogen showed an increase of about 126% and 210% over P.juliflora and open field. Similar results have been reported by Singh & Lal (1969) and Sharma (1967). This increase in organic matter under P.cineraria appears to be because of higher litter fall (68 g/m^2 in comparison to 23 g/m^2 under P.juliflora) and belowground flora (Aggarwal et. al. 1975). and thereby also increasing nitrogen status of soil. Further studies conducted on the analysis of coarse (1.6 mm sieve) and finer litter (less than 0.5 mm sieve) of P.cineraria and P. juliflora revealed higher nitrogen content in the finer litter of P.cineraria (Table 13)

Total Phosphorus and Potassium : Singh and Lal (1969) reported increase in phosphorus and potassium contents in soils supporting growth of P. cineraria over P.juliflora and open field . The increase was more significant in surface soil while in lower depths the differences were marginal. Aggarwal et.al. (1975) also reported a higher content of phosphates in surface soils under P.cineraria. The results in figure 2 show that there was increase in phosphate content in all the depths of soil supporting P.cineraria over open field. However, the soils supporting P.juliflora showed the depletion of phosphates particularly in lower depths in compari to that of open field. The increased phosphate.level in soils under P. cineraria may be due to higher content of phosphorus in its fine litter (Table 14) and vigorous growth of vegetation which in turn leaves behind more of organic matter in form of roots, stubbles and dead leaves.

Available nutrients: The quantitative estimations of available nutrients of interest to the Silviculturist from several points of view. Such informations contribute to an understanding the influence of species composition on soil chemical characteristics. The status of available nutrients in soils much depends on the quantity and quality of organic matter added to soil by the tree species it supports and also on its rooti pattern.

Singh and Lal (1969) reported increase in levels of available phosphorus and potassium in surface soils under P.cineraria while under P.juliflora there was depletion in these nutrients over open field conditions. This was attributed to higher organic matter levels, above ground flora and deep tap root system of P.cineraria. The results presented in Table 12 as reported by Aggarwal et.al. (1975) showed a similar trend in available phosphorus and potassium content in the soils under P.cineraria grown on the sandy loam soils of desertic region. The data show about three times increase in available phosphorus in surface soil (10-15 cm) of P.cineraria over open-field conditions and two times increase over P.juliflora. The available phosphate level in sub-surface soil of P.cineraria was also high while there was no marked difference between P.juliflora and open field. On the basis of availability limits of soil test values, the soils supporting P.cineraria can be catagorised into high in available phosphorus which is of interest for crop production when the desertic soils in general are quite low in this content. Similarly, available potassium level is also quite high in surface soil under P.cineraria. However, there was slight increase in the available nitrogen content in soils under P.cineraria in comparison to that under open field conditions.

The data on available micronutrients showed an increase in Zn, Mn and Cu contents in both the soil depths while Fe content was higher in surface soil only under P.cineraria over the soils under P.juliflora and open field. Though, there does not seem to be much difference in the micronutrients contents in the litter of these two species, perhaps, the higher litter fall and above ground vegetation growth in P.cineraria has led to increase micronutrients status in soils under this tree species.

Fertility status of soil just below the litter: This layer under forest ecosystem assumes importance as this reflects the level of humified organic matter mixing with the mineral soil and in turn influence the fertility status of the mineral soil below. It was observed that the depth of this layer under P.cineraria was more than P.juliflora while it was absent under open field conditions.

Table 13: Chemical analyses of soils just below the litter of *P.cineraria* and *P.juliflora*.

Vegetation	pH	O.C. %	P. %	No_3-N (ppm)	NH_4-N (ppm)	Zn	Cu	Mn	Fe
						ppm			
P.cineraria	8.0	2.9	0.07	56.0	36.4	3.60	1.87	10.08	2.80
P.juliflora	8.3	2.1	0.05	50.0	36.4	1.82	1.05	8.58	3.70
LSD 0.05						0.42	0.26	0.60	0.28

Table 14: Chemical composition of litter of P.cineraria and P. juliflora

	Coarse litter (> 1.6 mm)						Fine litter (< 0.5 mm)					
	Zn	Mn	Cu	Fe	N	P	Zn	Mn	Cu	Fe	N	P
	Percent of dry wt. basis											
[illegible]a	0.73	0.86	1.20	15.68	1.55	0.15	0.46	1.35	0.20	20.17	1.91	0.21
[illegible]	0.71	1.12	0.95	17.47	1.61	0.15	0.42	2.15	0.25	38.55	1.60	0.18

The presence of this layer under tree species is perhaps due to lower temperature and higher soil moisture conditions which favour the accumulations of organic matter due to increased microbial activity.

The data presented in Table 13 show higher level of organic matter, phosphorus and nitrate nitrogen content in litter soils under P.cineraria, with a corresponding reduction in pH value. Available Zn, Cu and Mn contents were also higher in soils under P.cineraria while soils under P.Juliflora showed higher Fe content. This increase in Fe content under P.juliflora may be due to the higher Fe content contained in the litter of P. juliflora. (Table 14).

The results presented in this paper demonstrate a definite distribution pattern of soil properties within the zone of influence of P.cineraria. There is a strong indication that the P.cineraria trees are the casual agent of the patterns observed and that they function to improve soil conditions beneath their ~~ex~~ canopies in comparison to that under P.juliflora and open filed conditions. The improved soil physical conditions coupled with higher availability of nutrients under P.cineraria canopy explains better crop growth under this tree species. On the other hand, the growth of P.juliflora has hardly shown any improvement in soil physical and chemical conditions underneath its canopy. One of the factors assigned for this is the toxins present in its leaves (Lahiri and Gaur, 1969) which inhibit the growth of vegetation under P.juliflora canopy. This would appear to confirm traditional Hindu belief: for Vartak (1969) records that "Khejri" is sacred to Ganesh, while 'babul' is "a resort for demons".

Prosopis cineraria in relation to soil water and other conditions of its habitat

A.N. LAHIRI

Plants which are otherwise adapted to the harsh environment of the desert may surprisingly often lack the ability to grow in association with other plant species. Some desertic trees, such as Prosopis juliflora, do not allow establishment and growth of the groundccover of vegetation (Lahiri and Gaur, 1969). This aspect warrents special reckoning in the context of the importance of agro-forestry and silvi-pastoral enterprises in the arid and semi-arid regions. In this regard, Prosopis cineraria tree, which abounds in the sandy desert plains of Western Rajasthan, holds an unique position as it fosters the growth of ground cover of vegetation. Since the soil moisture and nutritional conditions are generally limiting in these areas, enquiries pertaining to this trait seems very meaningful. Attempts have been made here to relate some findings in this direction.

Soil-water condition in P. cineraria community

In order to gain an insight to the drifts in soil moisture within the community, moisture contents up to the depth of 2 metres were measured, during May to October, 1963 (Fig. 5) and also from November, 1963 to June, 1964 (Fig. 6). It was found that fluctuations in soil moisture due to showers (Fig. 5) were restricted only up to about 50 cm depth from the surface. At these depths, soil moisture was below 1.0 per cent from May to the middle of July. In general, moisture content varied between 1.0-2.0 per cent between the depth 50 cm to 100-150 cm and moisture level about 2.0 per cent only occurred below 100-150 cm.

Moisture content above 3.0 per cent was found only in small pockets around 175-200 cm with indications of higher soil moisture at greater depths. Again in Fig. 6, it may be observed that the moisture content, except on occasion of sporadic showers hardly ever executed 2.0 per cent up to the depth of 125 cm. The foregoing illustrations suggest that plants with limited root system can only grow during the favourable soil moisture conditions of the short rainy season which extend from July to September.

Moisture utilisation of P. cineraria

Despite the meagre moisture in the upper layers of soil during the months of March and April, different processes like shadding of old leaves, regeneration of new leaves, flowering and fruiting of P. cineraria take place during this period. These, as well as 70 to 80 per cent relative turgidity maintained by leaves during March to May (Lahiri, 1964), suggest that an established tree may not be subjected to moisture stress despite the low moisture status of the upper soil layers.

Determination of hourly rates of transpiration of P. cineraria tree (25.4 cm dia at breast height) from dawn to dusk, on two consecutive days of summer, winter and monsoon indicated (Lahiri and Kumar, 1967) that a high rate of water turnover was maintained in all the seasons. The trends of diurnal changes in transpiration rate (Fig. 7) indicate that the leaves in the sunny side maintained consistantly a slightly higher rate as compared to those in the shade side. In all cases, the rate gradually increased from the morning and declined towards the evening. During the active period of transpiration, there were two distinct peaks (more obvious in the transpiration of the sunny side), one in the forenoon and one in the afternoon with an intervening 'noon dry drop'. Such drop has variously been attributed to

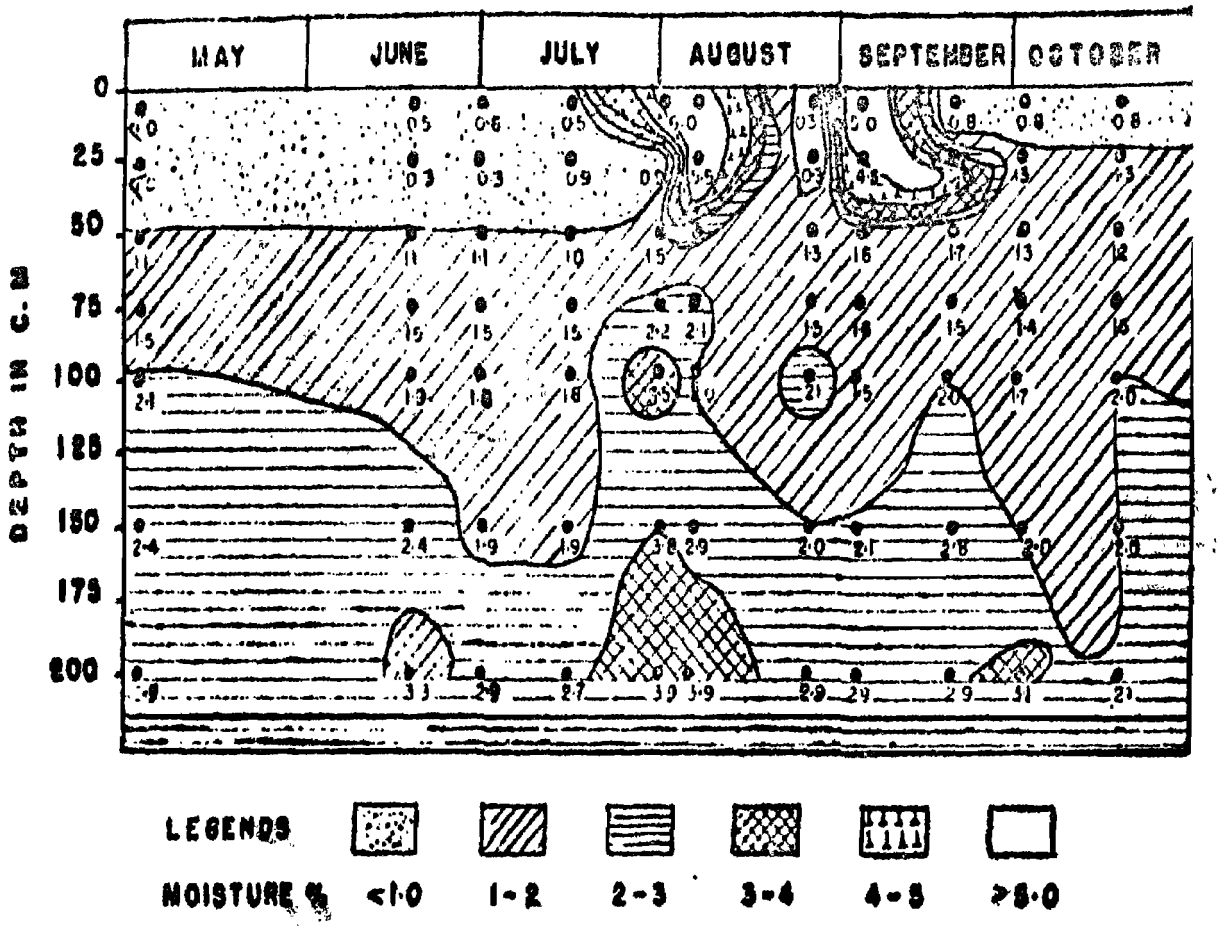


FIG. 5 Chrono-isoplets indicating the soil moisture status during the period between May to October, 1963.

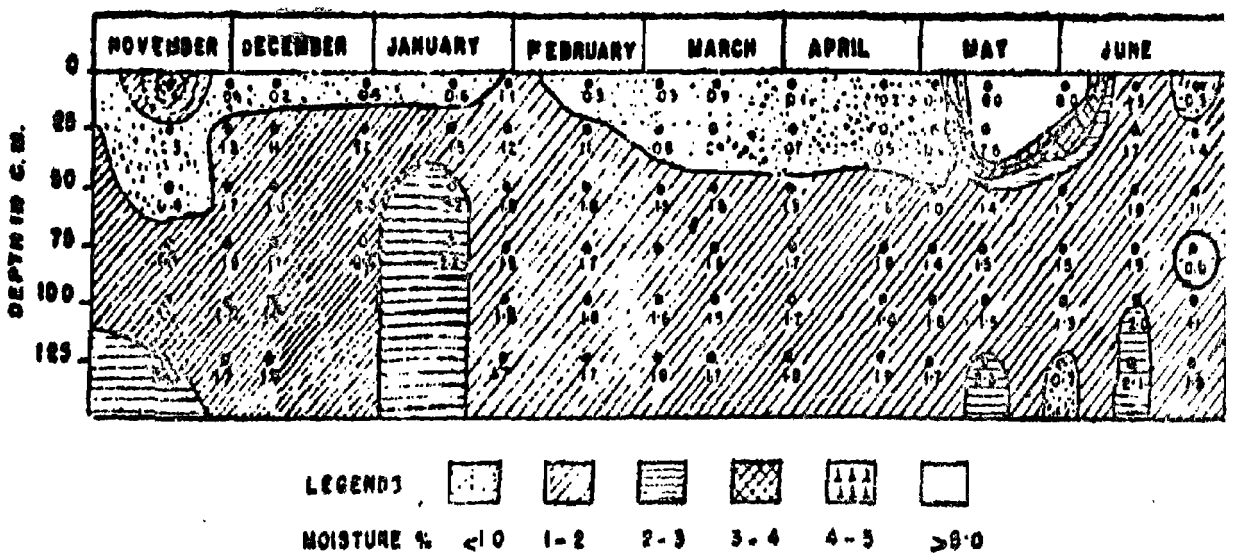


FIG. 6 Chrono-isoplets indicating the soil moisture status during the dry period extending from November, 1963 to June, 1964.

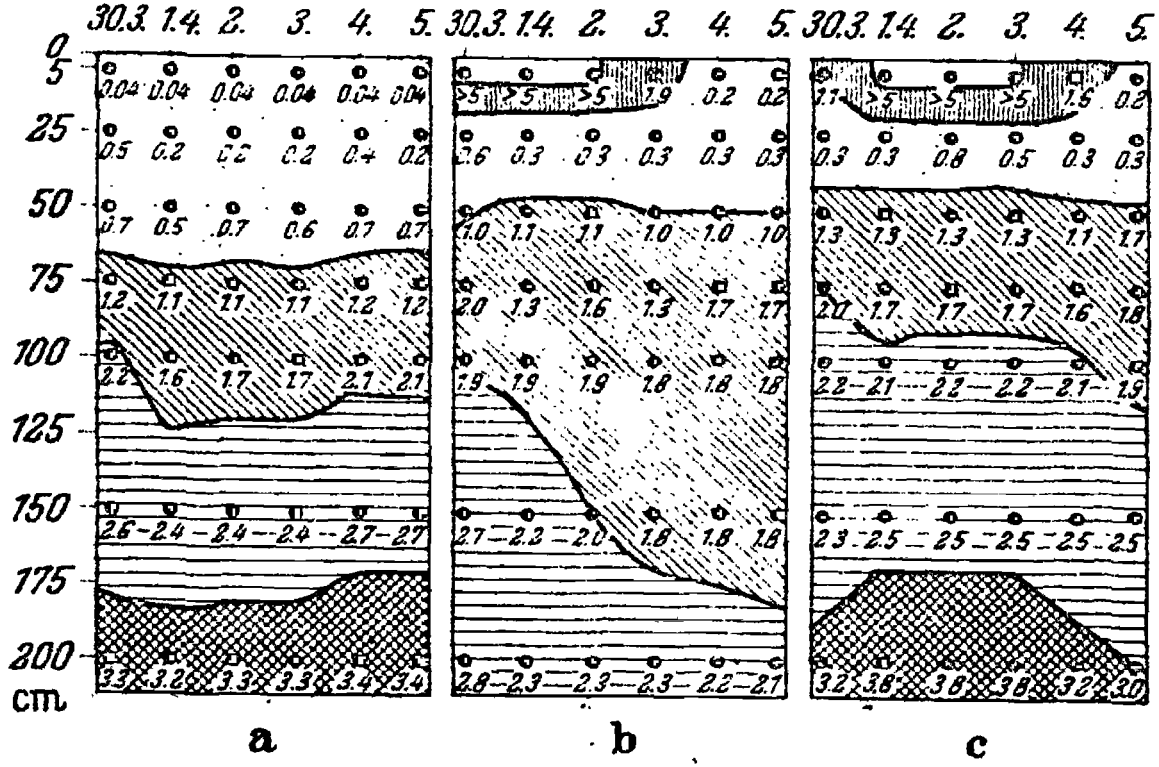


Fig. 1. Chrono-isoplets indicating distribution of moisture at various depths at positions (*a*) below the tree, (*b*) between two trees and (*c*) away from the tree grove. Solid circles indicate the positions of gypsum blocks and the figures against them indicate the moisture percentages. Ordinate: depth in cm, (0 =surface). Moisture: < 1.0 %, 1—2 %, 2—3 %, 3—4 %, 4—5 %, > 5.0 %

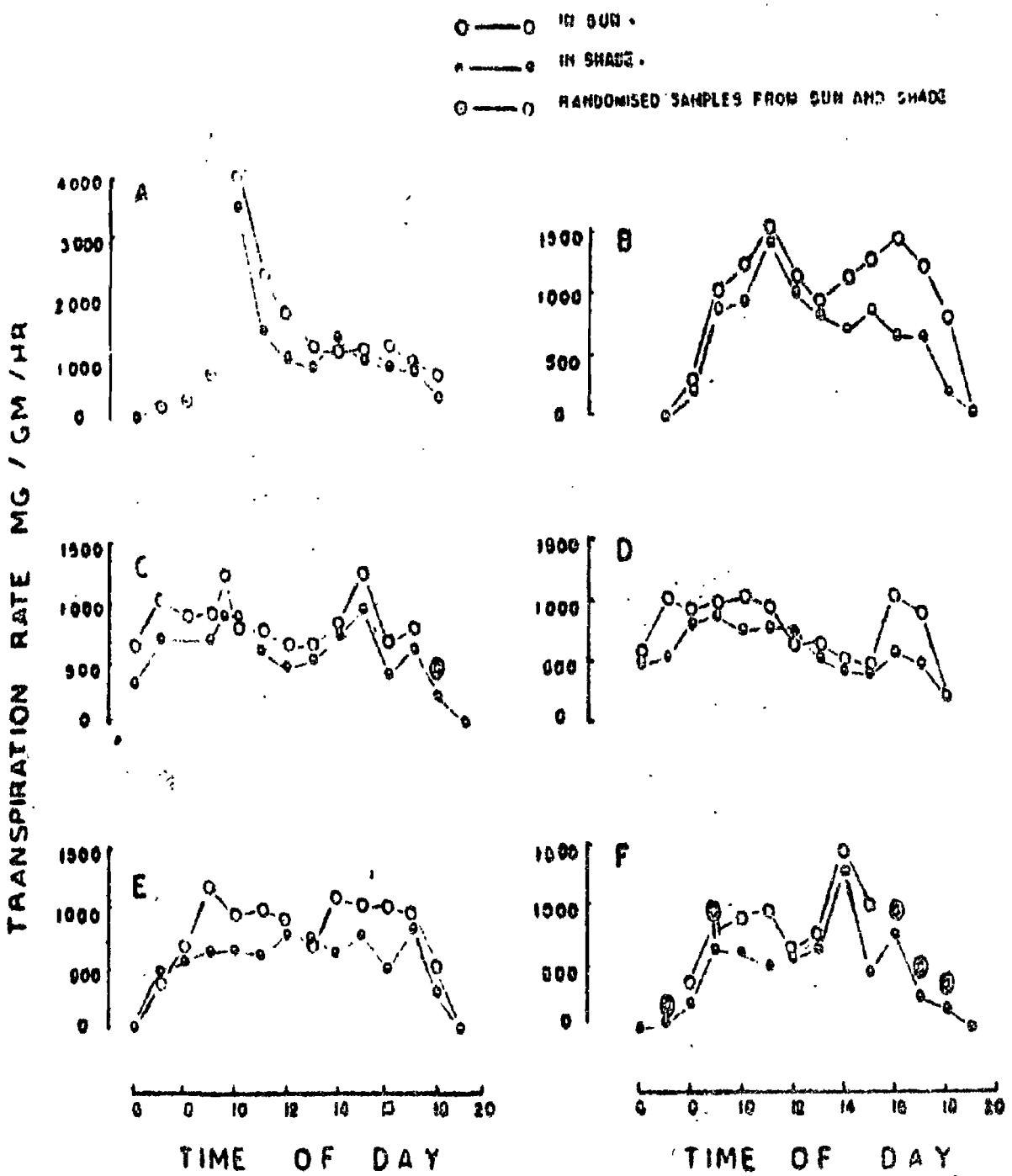


FIG 8 Diurnal variations in the transpiration rates in the sunny and shade sides of the *P. spicigera* tree in different seasons. A: 4.2.63; B: 5.2.63; C: 27.5.63; D: 28.5.63; E: 26.8.63; F: 27.8.63. At the time of cloudiness transpiration in the shade side has been noted and (c) indicates the hour when cloudiness was observed.

mid-day closure of stomata due to water stress or increase in incident radiation or temperature mediated rise in intercellular space carbon dioxide. However, seasonal changes did not alter the double peak character of the diurnal course of transpiration rate, although the magnitudes and positions of peaks changed on different occasions.

It was estimated that about 222 mm of water is lost through transpiration annually from a community of 50 trees/ha in a hectare of land (Table 15). The quantity appears to be large particularly in reckoning with the average annual precipitation of about 366 mm of Jodhpur, where the experiment was conducted. However, it has been found (Mann and Lahiri, 1979) that most desert trees, excepting a few, generally use water at high rates all round the year and it has been suggested that many desert trees of this area behave like 'Phreotophyte' or 'Well plant' of Meinzer (1927), which habitually obtain their water supply from zone of saturation either directly or through capillary fringe. It is likely that P. cineraria falls in this category of trees as its moisture use is not restricted due to the low moisture regime of the upper layers of the soil, during the dry periods of the year.

Table 15. Approximate annual moisture loss from a stand of P. cineraria.

Season and dates	Moisture output per tree in kg per day	Mean	Mean annual moisture output per tree in kg	Annual water output in mm per hectare (50 trees)
A. WINTER				
a. 4.2.63	178.327			
b. 5.2.63	129.319			
B. SUMMER				
a. 27.5.63	112.111	121.356	44294.940	221.48
b. 28.5.63	111.091			
C. MONSOON				
a. 26.8.63	116.100			
b. 27.8.63	81.192			

Ability of this tree to tap water from great depths was proved through root excavation work of Late Prof. B.E. Nikolaevitch, UNESCO Expert at the Central Arid Zone Research Institute. It was found that roots with thick secondary growth extended far beyond 8-10 metres and in the course of the growth of the roots penetrated the Kankar layer.

Water use of ground cover of vegetation in P. cineraria community

It would thus appear that in a community of P. cineraria the established trees with deep root system hardly ever compete with the shallow rooted ground cover of vegetation. On the contrary, there are substantial evidences (Lahiri, 1977) to suggest that after a rainfall incidence soil moisture increases markedly beneath this tree and generally a higher soil moisture regime is maintained under this tree than under certain other species like P. juliflora, Albizzia lebbek and Acacia senegal.

Study of soil water balance undertaken during May to October, 1963 provided a fair idea of the consumptive use of moisture of ground cover of vegetation in P. cineraria community (Table 16). The ground cover consisted of Dactyloctenium sindicum, Cenchrus setigerus, Eleusine compressa, Crotalaria burhia, Aristida funiculata, Cenchrus biflorus, Cyperus rotundus, Gisekia phanaceoides, Brachiaria ramosa etc. It was assumed in the calculations of water balance that moisture above 102 mm in the 2 metre of the profile will go down as deep drainage. The data in Table 16 indicate that the water use of the ground cover was very low from May to beginning of July when grass cover was dry due to low soil moisture conditions. During this period, moisture in the profile varied between about 43 mm to 53 mm. Occasional negative evapotranspiration values indicated that the soil water increased probably by lateral or upward movement of moisture. In any case during the August and September when

Table 16. Soil water balance during the growth period of the ground cover.

Decads	Months	Initial soil moisture mm	Precipitation mm	Final soil moisture mm	Evapotranspiration mm	Deep drainage mm
I-II	May	53.25	0.0	53.09	0.16	0.0
II-III	May	53.09	0.8	52.49	1.4	0.0
III-IV	May-June	52.49	0.0	51.52	0.97	0.0
IV-V	June	51.52	0.0	51.37	0.15	0.0
V-VI	June	51.37	0.0	48.74	2.63	0.0
VI-VII	June-July	48.74	5.6	43.35	10.99	0.0
VII-VIII	July	43.35	0.0	47.40	-4.05	0.0
VIII-IX	July	47.40	0.0	70.87	-23.47	0.0
IX-X	July-August	70-87	10.1	89.12	-8.15	0.0
X-XI	August	89.12	44.8	75.66	26.34	31.92
XI-XII	August	75.60	17.8	52.96	40.50	0.0
XII-XIII	August-Sept.	52.96	42.9	58.04	37.82	0.0
XIII-XIV	September	58.04	32.9	74.84	16.1	0.0
XIV-XV	September	74.84	8.4	64.09	19.15	0.0
XV-XVI	Sept.-Oct.	64.09	0.0	50.55	13.54	0.0
XVI-XVII	October	50.55	0.0	43.04	7.51	0.0
XVII-XVIII	October	43.04	1.3	42.37	1.97	0.0

the soil moisture increased due to incidences of showers, consumptive use sharply increased with the inception of active growth of the ground cover. Both consumptive use and the growth of vegetation declined in October when the moisture in the upper layers of soil decreased.

It was found that during the growing period about 162.9 mm of moisture was utilised by the ground cover of vegetation where the rainfall was about 163.8 mm. It seems, therefore, that the moisture received through precipitation was fully utilised by the ground cover and the trees hardly imposed any competition for moisture. The tree thus seems to be idealy suited for silvi-pastoral and farm-forestry operations.

Influence of soil moisture on the growth of ground cover of vegetation in P. cineraria community

Unlike the P. cineraria, the growth of ground cover of vegetation is fully dependent on the moisture in the upper layers of soil invaded by their roots. The Table 17a indicates that under rain-fed conditions growth of grass cover was restricted only to the period when the soil moisture was favourable. But when the moisture stress was eliminated by irrigation during the dry months (January to May), the dry ground cover became green and showed marked growth which was more than that noted during the previous rainy season.

Foliar absorption of water

Ability of plant organs to absorb moisture from light showers or vapours or dew acquires importance in arid and semi-arid regions, as it often helps the plant to by-pass the rigours of soil moisture stress.

Between the 29th and 31st of March, 1963, there were showers (5.8 mm) in the experimental plot of "water balance study", in the Central Research Farm of this Institute at Jodhpur. Relative turgidity of leaf tissue sections was determined following the method of Slatyer and Melloroy (1961); on the 30th, after only 1.75 mm rain and also on six consecutive days after the end of shower (i.e. 1st to 6th April) in order to determine the changes in internal moisture balance of the tree due to this shower. Simultaneous measurement of soil moisture was carried out by determining resistances (corrected for temperature at 20° C) of gypsum blocks placed at various depths, below a tree, between two trees and away from the tree grove. The Table 17b shows that the low state of turgidity that was observed on the 30th of March, with only 1.75 mm rain, increased significantly after the completion of the rainy period on the 1st of April. Thereafter a gradual and significant lowering of relative turgidity was observed on each day. On the 6th April, relative turgidity percentage came down to a value almost similar to that observed at the onset of shower.

Fig. 8 showing the chrono-isoplets of soil moisture in the profiles at three positions indicates that only the top soil to a depth not exceeding 25 cm was wetted due to this shower at positions between two trees (Fig. 8b) and away from the tree grove (Fig. 8c). Below the tree (Fig. 8a), however, top soil remained dry and moisture content was below the wilting point (ca. 1.0%) up to the depth of approximately 60-64 cm. This could be due to the interception of rain by branches and foliage. Lack of soil moisture addition below the tree, thick secondary growth of roots in the upper layers of soil and the absence of any extending root systems in the wet portions (up to 25 cm depth) between two trees and away from the tree grove, suggested that the sudden change in the internal moisture balance due to this shower could not be mediated through absorption of water by roots. Direct absorption of moisture by the tree foliage could be the only other means by which the abrupt change in relative turgidity was brought about.

This interesting ability, among other traits, makes this tree well-adapted to desertic environment. Enrichment of soil moisture through stem flow etc, may thus occur only under conditions of heavy showers.

Soil-plant interaction within the community

However, it has been mentioned earlier that the general moisture regime remain more favourable under this tree as compared to certain other trees. This could be due to a number of factors, such as favourable generation of stem flow due to the growth pattern of the tree, wetting properties of above ground portions, root growth behaviour etc. This may be one of the reasons of better growth of ground cover below this tree as compared to that observed under other trees (Shankar et al., 1976). As a result of this accumulation of organic carbon and nitrogen contents of the soil were found to be more below this tree as compared to those found beneath P. juliflora, A. senegal, A. lebbek and T. undulata, or under pure cover of grasses like Lasiurus sindicus and Cenchrus ciliaris (Aggarwal and Lahiri, 1977). This important impact on the soil fertility makes this tree very suitable in agro-forestry and silvi-pastoral programme.

Better soil fertility beneath the P. cineraria tree suggests a higher growth and activity of soil micro-organisms which contribute towards building up of the fertility. Recent findings of the Soil Microbiology section of this Division, presented in the Table 17c

Table 17c. Population of soil micro-organism under different trees.

Sp.	Number of micro-organism per gm of soil			
	Bacteria x 10^5	Fungi x 10^3	Actino-mycetes	Nitrifying bacteria (MPN)
P. cineraria	32	29	16	1,100
A. lebbek	22	18	11	1,300
T. undulata	25	20	12	900
P. juliflora	20	16	10	700

unambiguously indicate that the population of bacteria, fungi and actinomycetes were markedly higher in the soil below the P. cineraria as compared to the other adapted tree species which grow in the desert. The population of nitrifying bacteria was also found to be fairly high. These evidences suggest that the whole system gets favourably geared to accommodate the ground cover of vegetation.

Studies on the nodulation behaviour of this tree (Basak and Goyal, 1975) again suggest its nitrogen fixing ability.

Concluding remarks

The facts which have emerged suggest that the observed improvement of plant growth beneath this tree may be due to the combined actions of a number of factors. The favourable influences of this tree are clearly discernible in the pearl millet (grown most extensively here under rainfed conditions) fields in sandy plains where these trees are found in abundance, as well as elsewhere, where the natural vegetation exists. The period during which this crop grows the trees have their foliage and thus lopping, which is undertaken after the cropping seasons, may not have any direct bearing on the crop improvement. Soil moisture being a serious limitation, its measurable improvement below this tree may be considered as a direct cause for the growth improvement. The stem-flow enrichment of moisture coupled with the lack of moisture exploitation by this tree from the upper soil layer in the unirrigated areas, and consequent luxuriant growth of other vegetation may contribute towards organic matter build up and fertility improvement below this tree over time. Shade effects coupled with microbial influences may hasten fertility build up and minimise losses, particularly of soil nitrogen. The contributions of bird droppings, leaf/pod fall, dung and urine of shade seeking livestock in this regard sound rather speculative in the absence of reliable data. But, such possibilities may not be completely ruled out.

Table 17a. Growth of grass cover under rainfed and under irrigated condition during the dry season in 20 cm x 20 cm portions of metre by metre quadrates.

	Months	1963 (rainfed) July	Aug.	Sept.	1964 (irrigated) Jan.	Feb.	March	April	May
1.	Dry weight of green leaves, gm	0.0	2.86	0.5	1.03	0.81	2.69	2.68	3.63
2.	Dry weight of green stem, gm	0.0	0.95	2.0	2.85	2.41	3.45	2.27	-
3.	Leaf area sq. cm	-	631.97	95.55	202.89	62.25	339.66	411.95	587.61

Table 17b. Changes in relative turgidity of the leaves after shower

1963 :	30.3.	1.4.	2.4.	3.4.	4.4.	5.4.	6.4.
(n)*)	A (5)	B (6)	C (5)	D (5)	E (6)	F (6)	G (6)
R. Turg. %	80.53 ±2.3	92.26 ±0.78	87.32 ±1.31	83.68 ±0.86	82.68 ±3.9	78.09 ±3.4	79.60 ±2.4

	B - A	B - C	B - D	B - E	B - F	B - G
diff. of means	11.73	4.94	8.58	9.58	14.17	12.66
t	4.88	3.18	7.15	2.15**	4.13	5.06

*) Number of observations. - **) significant at 5% level, in all other cases at 1% level.

The nutritive value and digestibility of Loong (P.cineraria (Khejri) leaves)

H.C. Bohra and P.K. Ghosh

Introduction

Top feeds, i.e. the leaves and pods of certain trees and shrubs, constitute a major source of nutrients for livestock in the desert, particularly during scarcity periods, In the arid zone of Rajasthan, the camel, goat, donkey and mule, which together make up about 40% of the approximately 19 million heads of livestock, are especially dependent on browsing to meet their nutrient requirements.

P.cineraria: the king of desert trees - occupies the most important position in this respect. Its contributions to the overall ecology of the region, and to the life pattern of the desert people are well known. The leaves of these plants, locally called "loong", are a palatable and nutritious top feed for all species of livestock. Its protein rich pods also provide considerable amount of moisture to the animals during the peak summer months of May and June.

Production of top feed - "Loong": Generally, Khejri trees are ready to provide animal feed from the 10th year onwards and may go on yielding "loon till their 200th year or so. A moderately grown tree yields nearly 25-30kg of dry leaf forage per year. Villagers lop their trees in the winter and allow the leaves to dry in the sun. In the green stage, the moisture content of the leaves may be as much as 60%. With gradual loss of moisture. the brittle leaves fall to the ground which are then preserved in suitable fodder storage chambers and used for stall feeding of the animals as and when required. The leaves, which are preserved in this manner, contain nearly 93.2% dry matter on fresh wt.basis and 92.1% organic matter and 16.8% crude protein on dry matter basis.

These partially dehydrated leaves are marketed as "loong". During usual grazing of the animals, and particularly during migration of livestock, the shepherds cut the branches of the Khejri trees on their way, and the freshly fallen leaves are relished by the moving animals. This is a common feature of desert animal husbandry. Preserved loong alongwith preserved Pala (the dry leaves of Zizyphus nummularia or bordi plant) are the mainstay of the rural as well as organised dairy sectors in western Rajasthan, involving both cattle and goats. The extremely slow growth rate of this species however, comes in the way of accruing as much benefits from the plant as it would have been otherwise possible.

Relative palatability and intake of leaves: Muthana and Shankaranarayanan (1978) reported that Khejri leaves rank second in terms of preference by domestic animals, the first position going to leaves of Acacia nilotica trees. However, considering the low productivity of top feed by Acacia nilotica, the overall first score may be assigned to the Khejri. As may be expected, the intake of Khejri leaves by goats is considerably more than that of by sheep. For example, CAZRI's studies (Table 18) have revealed average DM intakes of these leaves as 685 gm per day (or 1.88 kg per 100 kg. body weight per day) and 1606 gm per day (or 2.8 kg per 100 kg body weight per day) in sheep and goat, respectively. Mathur (1976) reported DMI of Khejri leaves for camel to be 1.38 kg per 100 kg body weight per day It is interesting to note that when maintained solely on fresh Khejri leaves, with their average water content of 61% about a 48% and 82%, respectively of the daily water requirements of sheep and goats may be met.

Chemical composition of leaves: Several studies have been carried out to determine the proximate composition of Khejri leaves, beginning with a report by Patel in 1961 and followed by those of Sen and Ray (1964), Ganguli et al. (1964), Gupta (1967) and Mathur (1976) (Table 19). The variations in chemical composition of the leaves as revealed by the data obtained by various workers is likely to be due to differences in the composition of the samples collected during different seasons.

Table 10. Dry matter intake and apparent digestibility of the nutrients of *Z. ginganea* leaves and nitrogen balance in sheep and goat.

Trait	Animal type		't' Value
	Sheep	Goat	
Intake			
Dry matter, g/day	685 ± 37.87	1306 ± 115.15	20.45***
Dry matter g/kg/day	18.8 ± 1.88	28.0 ± 2.18	12.78***
Organic matter g/day	621.9 ± 38.15	1185.5 ± 104.46	20.27***
Digestible energy Kcal/g, DMI	1.82 ± 0.207	2.13 ± 0.212	4.15**
Metabolizable energy Kcal/g, DMI	1.43 ± 0.205	1.76 ± 0.199	8.12**
Apparent digestibility (%)			
Dry matter	41.4 ± 3.66	48.8 ± 3.98	3.78 (N.S.)
Organic matter	42.9 ± 3.81	49.6 ± 3.73	1.25 (N.S.)
Crude protein	22.0 ± 5.50	38.9 ± 5.05	2.26*
Cell-wall constitutents	9.8 ± 5.35	21.9 ± 5.84	1.53 (N.S.)
Cell contents	67.8 ± 2.20	71.4 ± 1.72	0.64 (N.S.)
Acid-detergent fibre	-28.9 ± 8.64	-10.1 ± 5.37	1.82 (N.S.)
Hemicelluloses	74.2 ± 2.36	75.2 ± 5.87	0.15 (N.S.)
Cellulose	23.2 ± 4.31	36.1 ± 5.28	1.89 (N.S.)
Lignin	-163.2 ±32.73	-143.0 ±10.72	0.58 (N.S.)
Nitrogen balance g/day			
Nitrogen intake	15.75±0.972	30.23 ±1.716	28.96***
Faecal nitrogen	12.23±0.867	18.19 ±1.828	11.54**
Urinary nitrogen	1.42±0.117	1.99 ±0.180	10.77**
Total excretion	13.65±0.971	20.19 ±1.695	13.39***
Nitrogen balance	2.10±0.870	12.68 ±2.586	15.35***

Treatment differed significantly, *P<0.05; **P<0.01; ***P<0.001

Table 19: Percentage (on DM basis) proximate components of *P.cineraria* leaves

Trait/ Source	Patel (1961)	Sen & Ray (1964)	Ganguli et al(1964)	Gupta (1967)	Mathur (1976)
Crude protein	15.4	15.3	13.9	14.1	11.9
Ether extract	4.5	3.1	-	3.9	2.9
Crude fibre	13.4	17.5	20.3	15.6	17.5
Nitrogen free extract	56.8	54.1	59.2	54.8	43.5
Ash	-	9.9	6.5	11.5	8.1
Phosphorus	0.18	0.24	0.20	0.93	0.38
Calcium	1.92	2.65	1.50	2.50	2.10

The seasonal variations in the proximate components of this feed have been recently reported by Lahiri (1978). Crude protein (CP) has been found to be maximum in winter, ether extract (EE) and nitrogen free extract (NFE) are maximum in summer and crude fibre (CF) is maximum during the monsoon. Studies carried out by the Animal Studies Division of Central Arid Zone Research Institute have provided new information (unpublished) on cell-wall constitutents and micro nutrient contents of Khejri leaves. Cell-wall constitutents (CWC) make up about 45.5% of the dry matter (DM), while hemi celluloses constitute 17.1%, lignin 7.1%, cellulose 16.9% and silica 3.7% of the DM. The CAZRI's studies have revealed a tannin percentage of 11.6 on DM basis, while Gupta (1967) had reported a tannin concentration of 15% of the DM in Khejri leaves. The average sodium and potassium values, determined at the CAZRI, are of the order of 77 mg and 1.21 gm per 100 gm DM of the feed respectively, while th micro-nutrients iron, zinc, manganeze, and copper are, respectively, found to be 112, 1.16, 5.75 and 1.87 mg per 100 gm DM. The Na, K and Cu values found in Khejri leaves satisfy the US National Research Council's (1975) recommended requirements for sheep.

Evaluation of nutritive value of leaves: While a number of studies have been made on the chemical composition of Khejri leaves, there are very few reports on the results of actual metabolic trials on animals using this feed. Gupta (1967) on the basis of metabolic trials conducted by him on Magra sheep of Bikaner with winter-lopped Khejri leaves, recorded negative balances in respect of nitrogen, calcium and phosphorus. The DM digestibility of 38.9% and a digestible crude protein content (DCP) of 1.01% in Khejri leaves, as recorded by Gupta (1967) are lower than the correspondin values of 51.1% and 3.5% respectively for Pala (Zizyphus nummularia) leaves reported by Singh and Gupta (1977). Incidentally, the total digestible nutrients (TDN) were found to be the same in both of the feeds. Work done at Bikaner by Gupta (1967) on Magra sheep and by Mathur (1976) on the camel, provide a basis for comparing the two species with respect to the digestibility of different nutrients of Khejri leaves. It may be noted here that while the digestible energy of this feed for the camel was the lowest of all camel feeds analysed so far, viz. 1.36 kcal/g, DM,

Khejri leaves are still better utilized by the camel than by the sheep. The very low crude protein digestibility of khejri leaves has been reportedly increased by adding ferric chloride to this feed (Gupta, 1967).

The data presented in Tables 20 and 21 have been compiled from observations made at CAZRI. These indicate that there is no significant difference on the digestibility coefficients for dry matter, organic matter and cell-wall constituents of P.cineraria leaves in both sheep and goats. However, these values are generally higher in the goats than in sheep. Although, the feed contains appreciable amounts of crude proteins, the digestible crude protein values have been found to be rather low, viz. 3.1 and 5.5 per cent for sheep and goats, respectively. The digestibility of cellulose obtained from "loong" is of the order of 23 per cent, whereas the digestibility of cellulose from desert grasses like of Cehchrus ciliaris has been reported to be 57 per cent (Bohra and Ghosh, 1977). The low digestibility of crude proteins from P.cineraria leaves has also been reported by Gupta (1967), who postulated that this may be due to the high tannic acid content of this feed. The low digestibility of the cellulose may be due to the high lignin content in this feed. The tannins and lignin bind the proteins and the cellulose respectively, of P.cineraria leaves, and form undigestible complexes of protein-tannins and cellulose-lignin, thereby resulting in the low digestibility of these nutrients. Still, in contrast to the reports from Bikaner on 'loong' feeding (Gupta, 1967 and Mathur, 1976), the overall nitrogen balance recorded in the CAZRI studies has been positive in both sheep and goats.

The gross energy intake (kcal/100 kg body wt./day) on a 'loong' ration was about 50 per cent higher in goats than in sheep, but the total energy losses through faecesm urine and as methane (per 100 kcal intake) was higher by 13.0 per cent in goats than in sheep. The digestible and metabolizable energy intakes (kcal/100 kg body wt./day) in the sheep were 3.45 and 2.72 Mcal respectively and in goats 6.04 and 5.01 Mcal, respectively, when maintained on P.cineraria leaves (table 18 & 21)

Table 20: Digestibility and balances of different nutrients of winter-lopped P.cineraria leaves in sheep and camel

Trait/Type of Animals	SHEEP	CAMEL
A. Digestibility (%)		
Dry matter	38.9 ± 0.55	44.7 ± 1.62
Crude protein	7.2 ± 1.75	74.8 ± 1.93
Ether extract	31.5 ± 2.14	72.5 ± 0.69
Crude fibre	25.9 ± 1.19	49.3 ± 1.46
Nitrogen free extract	57.9 ± 1.38	60.6 ± 1.00
B. Nutrient balance, g/day		
Nitrogen balance	-0.57 ± 0.22	8.33± 0.06
Calcium balance	-0.27 ± 0.03	17.66± 1.01
Phosphorus balance	-0.22 ± 0.04	6.96± 0.67
C. Nutritive value (%)		
Digestible crude protein	1.01	8.93
Total digestible nutrients	39.83	48.66
Source:	Gupta (1967)	Mathur (1976)

At the end of a 17-day trial period with this feed the average body weight gains by the experimental sheep and goats were 0.5 kg. and 1.37 kg, respectively. Purohit and Mathur (1971) have observed that the rate of passage of khejri leaves through the intestine of Magra sheep is slower than that of Pala (Z.nummularia) leaves. In the opinion of these workers, the high tannic acid content of kehjri leaves may be the cause of their slower passage through the gut of the animal. Similarly, the relatively lower dry matter digestibility of khejri leaves (containing 10.7 per cent tannins) in comparison to that of pala leaves (containing 5.5% tannins) may also be due to the higher tannic acid content of the former feed.

On the strength of the evidences reported so far, it may be concluded that among the livestock species examined, the goat is the most efficient, followed by the camel and then the sheep, in utilizing the nutrients of Khejri leaves. It may also be concluded that the leaves which are collected in summer are somewhat better utlized by the livestock in comparison to the leaves collected during winter. In order that the Prosopis cineraria tree may serve the purpose of livestock husbandry of the desert areas in a more meaningful way, it is necessary to select and propagate fast growing strains of this tree and also to select trees with foliage having low tannic acid content.

Table 21: Energy balance in adult sheep and goat maintained on *Prosopis cineraria* leaves (values are means ± S.E.)

Trait	Sheep	Goat	't' Value
Gross energy intake (kcal)	3031.8 ± 543.70	6017.5 ± 530.68	15.06***
Gross energy output in faeces (kcal)	1898.3 ± 150.37 (62.6)	3209.8 ± 323.68 (53.3)	14.69***
Urine (kcal)	83.6 ± 8.11 (2.7)	73.5 ± 9.59 (1.2)	3.23*
Methane (kcal)	184.7 ± 13.17 (6.1)	404.6 ± 43.18 (6.7)	4.87**
Total energy output (kcal)	2167.3 ± 155.32 (71.5)	3687.9 ± 331.13 (61.3)	16.63***
Digestible energy (kcal)	1257.0 ± 157.10 (41.5)	2807.3 ± 435.57 (46.6)	13.38**
Metabolizable energy (kcal)	986.5 ± 152.27 (32.6)	2329.5 + 396.54 (38.7)	12.56**

Values in parentheses represent the percent of gross energy intake.

Treatments differed significantly, *P 0.05; **P 0.01; ***P 0.001.

Trace element concentrations in the foliage of "Khejri" (Prosopis cineraria)

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Introduction

Investigations over the years have shown the part that the trace elements play in a variety of metabolic processes in animals. These elements act as co-factors or catalysts in enzyme systems with roles ranging from relatively weak non-specific ion effects to highly specific associations in which the metal ion is firmly attached to th protein in a fixed number of atoms per molecule (Underwood, 1975). Therefore, presence of these elements in adequate level in diet is essential for optimum growth and productivity of the animal and to that extent knowledge of the amount of concentration in which these elements are present in animal feeds is a useful piece of information. Because of some limitations, it has been possible to analyse the material for iron, manganese, zinc and copper only and the results of the same are reported.

Methodology: Samples of the 'Khejri' foliage were collected at various locations in arid Rajasthan from well grown trees in the month of September (unless otherwise stated) i.e. the time when the harvesting of the foliage is about to start for its collection as a feed. The samples were thoroughly washed, digested in nitric acid-perchloric acid mixture and analysed using atomic absorption spectrophotometer.

Results.

(a) Iron: Results of analysis are reported in Table 22 It will be seen that iron content at the localities has a vast range of 134 to 638ppm. Nearly 50 per cent of the samples are in the range of 200 to 300 ppm and another 40 per cent over 300 ppm. Cursory analysis does not show any geographic consistency.

For example, the three samples at Research Farm, Jodhpur, show values between 227 to 460 ppm - a two fold variation. The reason for this variation needs to be ascertained. All the same the values do show fairly high concentration of this element. These appear comparable, possibly higher than those found in the vegetation of Mojave Desert (El-Ghonemy et al, 1978).

(b) Manganese: Like iron, the manganese concentration also shows a wide range with the extreme values of 17.5 and 117.5 ppm. Nearly 43, 35 and 16 per cent of the samples lie in the range of 20-30, 30 to 50 and over 50 ppm respectively. Above average values are associated with some localities in Bikaner, Jaisalmer and Nagaur district. Over all the values appear to be somewhat lower than these found in Mojave deserts. Though these are comparable to those of the mediterranian region of Egypt (El-Ghonemy et al, 1977).

(c) Zinc: As regards zinc over half the samples have values between 30 to 50 ppm and the rest of the population is distributed equally on either side of this middle range.

(d) Copper: Its concentration shows relatively less variation with 80 per cent of samples falling in 15 to 30 ppm range. Jodhpur material shows somewhat lower values whereas few isolated locality namely Didwana shows extraordinarily high value of 78.4 ppm. An analysis of 20 perennial species from Mojave Desert showed the values to range between 3 to 7.7 ppm only. Thus in comparison this arid Rajasthan tree is seen to have much higher value of copper.

Trace elements status as animal feed: The topic has been treated elaborately in other sections of this monograph. The brief discussion here is limited only to the trace elements concentration in Khejri foliage from view point of animal requirement. At present there is insuffici data on the dietary requirement of trace elements in common domestic animals of the arid zone.

Table 22: Trace element contents in Khejri (Prosopis cineraria) (on dry matter basis)

Locality	Trace element in ppm			
	Fe	Mn	Zn	Cu
		JHUNJHUNU DISTRICT		
Jhunjhunu	470	39.4	25.0	37.5
Jhunjhunu	545	50.0	46.0	28.1
		SIKAR DISTRICT		
Laxamangarh	291	30.0	61.7	29.6
Palsana	200	17.5	30.0	19.2
		CHURU DISTRICT		
Ratangarh	248	22.5	38.3	20.8
Churu	400	45.0	48.3	20.0
Sardar Shahar	253	21.3	35.0	16.0
Sardar Shahar	238	25.0	28.3	16.8
		NAGAUR DISTRICT		
Merta	638	42.5	58.5	32.0
Degana	324	30.0	31.6	24.8
Didwana	210	25.0	48.3	78.4
Banwasa	181	37.5	30.0	16.8
		PALI DISTRICT		
Jaitaran	333	55.0	41.7	24.0
		JODHPUR DISTRICT		
Jodhpur	460	46.2	30.9	14.1
Jodhpur	373	30.8	21.4	14.1
Jodhpur	226	32.7	25.0	9.0
Dhawa North	134	23.8	--	20.0
Dhawa West	162	20.0	--	16.0
Bap	333	17.5	30.0	14.4
Phalodi	362	47.5	33.3	19.2
Khara	257	20.0	29.2	16.0
Khara	305	20.0	23.4	27.2
		BIKANER DISTRICT		
Adasar	296	30.0	35.0	20.0
Beechwal	257	117.5	18.3	18.4
Shri Kolayat	286	37.5	48.3	18.4
Shri Kolayat	267	77.5	41.7	19.2
Baldu	248	32.5	32.5	17.6

Locality	Trace element in ppm			
	Fe	Mn	Zn	Cu
		JAISALMER DISTRICT		
Khetolai	324	31.3	65.0	27.2
Chandan	191	47.5	25.0	17.6
Jaisalmer	305	52.5	59.8	23.2
Larella west	172	27.5	30.4	16.0
Larella East	228	22.5	50.0	24.0
		BARMER DISTRICT		
Shiv	286	20.0	50.0	16.0
Chohtan	571	60.0	-	33.6
Sanverod	276	22.5	61.7	21.6
Takuberi	162	21.2	30.4	16.0

Therefore in evaluation of khejri foliage data on critical levels as available in the country or outside have been used. It is seen that iron content of 25 to 50 ppm in the feed is adequate to meet the requirement of cattle and sheep (Underwood, 1977; N.R.C. 1975). Judging from this standard, the iron content in Khejri (200 to 400 ppm) appears more than adequate. Likewise the managanese content in khejri (mostly 30-60 ppm) is much higher than the minimum requirement of 10 to 20 ppm in the feed. Concerning copper, pastures containing as low as 4-6 ppm of Cu are seen supporting healthy sheep and cattle. Compared to these Khejri is seen extraordinarily rich (15 - 30 ppm) in this element.

As regards zinc Mills et al (1967) have found that 15 ppm Zn in feed was necessary to maintain normal plasma Zn levels in sheep whereas Somers and Underwood(1969) found this to be insufficient for normal testicular growth and other metabolic functions. In case of cattle, the picture is not very clear. Whereas 8-9 ppm Zn in ration has been found adequate for young calves, responses have been obtained in growth of steers and young bulls in rations containing around 30 ppm Zn. Thus whereas 'Khejri' is seen to have by and large adequate levels of zinc, there may be certain situations of marginal deficiency.

INSECT PESTS OF KHEJRI (Prosopis cineraria)

D.R. Parihar

Introduction

Very little information is available about the insect pests attacking Khejri (Prosopis cineraria) plantations. Earlier reports from Rajasthan (Pal, 1977, Parihar, 1978, Yadava et al. 1978) indicated a number of pests have been recorded which are causing the devastation of Khejri trees. The following species are observed as pests of Khejri trees.

1. Chaffer beetles (White grubs) (Plate - Fig. 9 a & b)

The beetles (Holotrachia spp.) are nocturnal feeders. During day they remain buried in the soil. The beetles are observed after good premonsoon shower. They emerge from soil leaving behind a round hole between 8.00 AM to 9.00 PM and immediately fly to their host plant Khejri almost in a swarm and start feeding on the foliage. The congregation of beetles start from the top of the tree and move downwards with the result that the defoliation of host also take place in the same manner. Khejri are sometimes completely defoliated. The beetle leave the host plants between 5.00 AM to 5.30 AM next day and go back to the soil. High wind valocity and rain at the time of emergence, delay the emergence of th beetles (Anonymous, 1970).

The species, responsible for foliar devastation are Holotrachia spp., Schizonycha reficollin F and S. fuscesens, Aserica sp., Serica assemensis Br.(Pal. 1977)

Control: During the emergence of beetles, the trees may be sprayed with carbaryl 50 W.P. @ 0.15% to 0.2% OR Fenitrothion @ 0.05% OR B.H.C. EC @ 0.2% OR DDT 50% WP @ 0.1%/0.2%

Use of light trap or patromax or lantern (June-July) : The use of Light Trap during beetle flight-period offers an excellent mode of preventing the build up of a large scale incidence of the post.

The light trap of petromax-lantern may be employed collectively in the field near Khejri trees at 8 p.m. - 9 a.m. daily for 7-10 days. The collected beetles may be killed by dipping them in kerosinized water.

The adult beetle may also be collected by vigorous shaking of trees from 8.30 P.M. onwards and killing the adult beetles thus collected by drowning them in kerosinzed water.

2. Desert locust, Schistocerca gregaria (Forskal)

It is well known that in the past, locust devastations had deteriorated the desert ecosystem of several parts of Rajasthan (Pruthi 1969). During plague or swarming period, locust (adults) are known to prefer Khejri (Prosopis cineraria) trees. The swarms rest on the Khejri during night time and it eat the leaves and sometimes even bark of the trees (Bhanotor, 1975).

Control: Locust swarm resting on the trees can be destroyed by following methods.

1. Dustings : Gregarious adults, when congregated on trees are dusted with aldrin or BHC @ 20-25 kg/ha.

2. Spraying : Aldrin emulsion sprays on the trees @ 40-200 gms of aldrin in 1,140 litres of water per hectare by high volume sprayer or 90-110 litres per hectare by low volume sprayed.

3. Termites: Khejri is attacked by termite, Odontotermes obesus (Rambur). The casuality of trees is 18.7 per cent (Parihar, 1978). The infestation was observed on the roots, stem and bark of the trees. In the seedling stage, the attack is more on the roots, while the stem is unaffected. Termites nibble the tap root. Because of the destruction of the tap root, the upper plant gets no nutrition and as a result, leaves become yellowish and when the root system is completely devoured the plant ultimately died.

In the older trees, colonies of termites orginate at the base of the trunk, later penetrate into trunk which is followed by an extensive hollowing out of the heart wood (Plate 2, Fig. 10). Sometime trees fall away due to severe attack on roots and base of the main trunk (Fig.10.c).

The galleries of the termites are observed on the trunk upto 90-240 cms and sometimes even on the branches of trees.

Controls: For the control of termites following methods can be adopted.

Dusting: 5-10 gms aldrin 5% dust should be applied in shallow channels which are excavated in ground around each tree after clearing the galleries on the trees.

Spraying: The emulsion concentrators of .03% aldrin or 0.04% chlordane should be applied @ one litre per tree basis in a shallow pit in ground around the base of trunk. Both the treatments provide two years protection to trees:

Gall-fly (Lasioptera sp.) : The most important pest attacking the tree is gall-fly. The fly causes galls, mostly along the branches and rachis of leaves. The gall appears as a rounded or oval thickening and extend in size from 1-2 cm in length and 5-10 mm in width depending upon the stage of development of the gall. The galls are green and tender at the time of formation and gradually turn brown and harden. When these galls are cut open, maggots of the flay are found developing in it. Each gall carries 1-3 maggots. The adult escapes from the gall by making a minute pin hole. Pal (1971) recorded Eurytoma sp. (Eurytomidae: Hymenoptera) to be associated with gall formation in Prosopis cineraria (Plate 3, Fig 11)

Control: Gall fly are predated on the host plants by ant.Doryllus labiatus thus reducing the pest population. Two or three application of Garbaryll and endosulfan @ .05% to .08% at intervals of 7 days afford protection.

EXPLANATION

PLATE 1

Fig. 9a White grub beetle, Holotrachia consanguinea Bl.
Fig. 9b White grub beetle. Schizonycha ruficollis F.

PLATE 2

Fig 10a Here the extensive damage to the heart wood of the 100 year old Prosopis cineraria trees followed by Odontotermes obesus

Fig 10b Bark of trunk of Prosopis cineraria is damaged by Odontotermes obesus

PLATE 3

Fig 10c Here Prosopis cineraria has fallen away as a result of attac on roots of an old tree by O. obesus

Fig 10d A portion of the base of trunk showing the complete desertruction of taproot.

Fig 11 A branch of Prosopis cineraria showing insect galls on rachis of leaves.

Socio-economic dimensions of Khejri (Prosopis cineraria (Linn.) Macbride).

M.L. Purohit and Wajid Khan

Introduction

Prosopis cineraria has been one of the evergreen, longlasting friend of the arid dwellers even in the period of scarcity such as droughts and famines since times immemorial. It is said to be 'Kulp Taru' of the arid region due to its virtue by increasing soil fertility, providing fuel, timber, and vegetables to human beings, green fodder to animals, shade to all creatures during scorching heat in extreme summer. It provides greenary in acute dry periods, soothing effect to eyes and has a more aesthetic value among all the trees of the region. Therefore, by its own worth, it has become a crucial plant of the desertic terrain. It also named as 'Pride of Desert' by Kaul & Ganguli (1964). Its economical, cultural and socio-religious values in performing many of the rituals and rites in various sections of the arid society has been noticed. Almost all the parts of this tree i.e. from apex to root tip and even its bark is used in one form or the other and cater the services to human needs.

Importance to society: It planted on farm bund, ordinarily serves as fence between two plots and also as shelterbelt in desert prone areas. Generally it has been observed that this tree grows in fields as natural and little efforts have been done to plant in definite manner. In chronically drought affected areas agricultural land gets sanded periodically by the dry winds, it causes excessive surface evoporation thus creating moisture stress against the agricultural crops. The trees of Prosopis cineraria if judiciously planted to serve as wind breakers, save the land from degradation and better soil moisture and fertility.

The population of the Prosopis cineraria varies from village to village and depends upon bio-physical unit, sub-surface condition and socio-religious traditions of the villages.

Some communities in the arid zone abhor cutting of the trees. This tree is held sacred by "Bishnoies" an agricultural community of the region. Inspite of poor soil conditions the trees are green profuse vegetative growth during summer months. For the distribution of it one of the proverbs prove that,

"Gaon Gaon Gogo ne Gaon Gaon Khejri"

It means every village has shrine of Gogaji (snake God) under the Khejri, being a shady tree.

In the extreme desertic area in summers the travellers sit under this tree for taking rest while going on foot from one village to another. Water huts used to make under its shade for travellers and passer by. The camp of Barat (marriage party) stay under its shade. Almost all animals stay under its shade in summer and got protection from glaring sunshine and loo ie (hot winds which blow during summer). Before discussing the socio economic dimensions of this tree it would be better to describe its other economic associates in its own society, among which it exists in the arid areas. The bawal, (Acacia nilotica) bawali (Acacia jacquemontii benth) provide fuel and timber while its counter part Rohida (Tecomella undulata) (marwari teak) use for timber. Kumbat (Acacia Senegal wild)provides seeds and fuel, while kair (Capparis decidua) only fruits for vegetable and Phog (Calligonum polygonoides) gives fuel and flowers used for wet cury in curd. In compact settlement Neem (Azadirachta indica A.Juss.) Peepal (Ficus religiosa Linn.) become its associates and provide shade only.
Economical importance: It is one of the most common tree species growing on sandy plains throughout the area, often forming gregarious patches. Large insect galls upto 4 cm diameter have generally been observed on some trees (Bhandari, 1978). It has been recognised not merely as an attractive tree but as a major economical species among arid flora. Lot of efforts have been made by forest department to artificially grow these trees but ordinarily it grows under natural conditions due to regeneration of seeds. In tender age sheep and goats are the main enemies of this tree.

Sheep cause damage to the base of the seedlings by nipping, while goats damage at younger stage by browsing the branches and leaves, therefore, it must be protected from its enemies. It is the only tree which provides protection to the animals and birds in arid areas. Cats climb on it and get protected from dogs and other animals. Many large birds which act as predetors get shelter and make their nests on this tree such as kites, hawkes, vultures etc. in days and owls and bats in night. These birds kill small ⁂ animals like rats, rodents and rabits those damage the crop by biting and loosening of the soil by making burrows. Being small leaved plant it provides less protection to herbivore birds which damage crop during grain formation

The potential of this tree can be judged as it fulfill the needs of rural masses by utilizing each and every part of the tree. It boosts the rural economy without impairing the quantity and quality of the normal yields from the fields. The major dimension which favour Khejri among other trees are its wood, leaves, infloresences, pods, fruits, trunk, branches, roots, gums, etc. Its diverse benefits to the rural masses are as follows:

Providing Fire Wood: In this region it is one of the major source of fuel, because fuel is one of the most important constituents of family needs and is partly fulfilled by this tree. The branches, twigs and other parts after lopping the tree are used as fuel wood. But fuel wood high calorific value (sap wood 5003 cal; 9007 B.TU) and is used for making charcoal (Anon, 1969). The firewood makes a better charcoal among local plants of the arid zone and this charcoal gives better heat and energy. The wood ash, which contains 31 per cent of soluble potassium salts may be used as source of potash.* Even small thorny twigs are used for the fencing of fields to save the crop from animals. The shelter provided by trees can be utilized for cattle sheds, tractor sheds etc. in arid areas.

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* Chowdhary and Ghosh, Indian Forest Research N.S. Abid, 1946 4(3)17.

(b) Pods - The pods are used as fodder for livestock before they are ripe, they are rich in a sweetish farinaceous pulp which is consumed as food. The pods are eaten green or dried after boiling and serves as green and dry vegetable for rural masses. It is one of the constituents of famous dry curry 'Panchkuta'*. The wet curry of these pods with in bajra or gram flour is most famous. The preservative capacity of these pods are very long. A lot of local proverbs, couplets and literature available to prove the importance of these pods, i.e. locally known as 'Sangari' or sangar as follows:

"Sangari Phog, Thali ko - mewo"

Pod of the Khejri and flowers of the phog (Calligonus Polygonoides Linn.) are considered to be dry fruits in the extreme arid areas (locally known as Thali) of western Rajasthan.

'Sangar ghanhu, Kair til, Aak gana capas,
phogas photiya Bhadli, Bandho Samay - ki Aas.

If the growth of these pods are profuse the next wheat crop will be better, if kair (Capparis decidua (Forsk) Edgew) are good than til (Sesumum) is better, if Aak (Calotropis procera (Ait) R.Br.) is better than possibilities of Capas (cotton) is more. If Phog (Calligdnum polygonoides Linn.) blooms then there is a possibility of good time. These type of predications for crops associated with local flora in proverbs narrated the whole theme in simple couplets.

"Samvat sangri Kaal Chagda"

When the growth of the pods of Khejri is good there will be good crop year, and if the growth of bor (fruit of Zizyphus numularia Burm.f.) is more it is said to be a bad crop year.

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* Panchkuta is a dry curry contains five ingridients viz. pods of Khejri (Prosopis cineraria), seed of Kumbat (Acacia senegal) dry fruit of Kair (Capparis Decidua fors K.Edg. Amchur (dry green mango slices), and dry mirch (chillies) it can be preserved for longer time as vegetables.

"Hal bhavata, Hakim Huya Ghar me gali beer
Marwar me nipaje, bor, sangri ne kair

This shows the erstwhile administration that uneducated ploughman became judges on the whim of rulers, and to maintain their prestige had a kept wife, and Marwar (erstwhile name of Jodhpur division before Independence) was famous for three things Ber (fruit of Zizyphus), Sangari (Pods of Khejri) and Kair (fruit of Capparis decidus (Forsk) Edgew. All these proverbs indicated that the importance of pods of the Prosopis cineraria in folklore of the area.

After repening these pods became sweetish and pulp is more sweeter with pale brown colour. These pods then known as Khoka and are to be considered as Marwari mewa i.e. dry fruits of arid zone. These are even fed to milch cattle and one tree of Khejri gives at least 5 to 10 kg. of these Khokas (ripen pods). The dry pods reduce the quest of water in summer month and generally farmers eat in dry periods. Children are fond of these ripen pods and climb on the trees for the same. They used to keep these ripen pods in their pockets of shirts and kneecovers while even going to school and considered it more nutritive and sweet dry fruits as sweet as appricot. The boiled dry pods after frying in sweet oil and sprinkle with salt and red chillies are used for entertaining the guest as salty dishes in the area.

(c) Leaves and inflorescences - The leaves of Khejri provide nutritive green fodder throughout the year and dry leaves are also liked by animals especially goats, camel and sheep (Muthana & Shankaranarayan, 1978). The dry leaves locally known as loong or loom. These are sometimes fed to cattles after boiling in water in the form of "Bantta." The lopping procedure in low density region of Khejri is different. The leaves are collected by wiping the branches with leather gloves. This process does not damage the twigs and remove 75% leaves for fodder purposes. Lopping of khejri either by axe or lopper takes place in regions with high tree density.

After lopping the Khejri, the branches, twigs and leaves are collected at one place and after a weeks time leaves are automatically separated from twigs, and kept as a fodder for animals. Twigs and branches used as fencing material or as fuel. The dry leaves fetch good market but in drought and famine period these sell like hotcakes. Mostly in towns goat keepers purchase these dry leaves @ Rs 30-35 per/40kgs. Apart from dry leaves (loong) small slender green twigs with leaves sell in the market in the form of bundle i.e. (Pulli). The weight of this pulli is about 1/2 kg. and cost Rs 0.50. The Butchars who raise the he-goats for meat and especially on Bakara Id. fetch very good prices of the he-goats as high as Rs 500/- Generally they fed to the he-goats loong as well as pulli of Khejri. The semi-nomads and migrants used to feed their animals while on the way, the leaves and twigs of Khejri. They used to keep a lopping equipment locally known as Tadi. With this they clip the twigs with green leaves and feed their cattle, goats, sheep and camel.

The inflorescences i.e. flower of this tree is very good as a blood purifier and have pale yellow colour. These seem as a mulburry i.e. catkin type of inflorescences. These are used after grinding and mixing with sugar in water for cooling effect and blood purifier in rural areas. By using this mixture as tonic in case of the skin disease and boils and it is said that with in a couple of days all these troubles vanished. The flowers mixed with sugar and administered to prevent miscarriage. Patutrim, a flavone glycoside (M.P.252° - 53°) has been isolated from the flower (Anon 1969). At Saruna, in Jhalawar, the flowers are pounded and mixed with sugar and eaten by women during pregnancy to safeguard them against miscarriage.

(d) Bark of trunk - The bark is locally known as 'Choda' has a sweetish taste. It is reported that during the severe famine of Rajputana (formerly name of greater Rajasthan) in year 1868-69 many lives were saved by the use of bark as a source of food. It is grounded into flour and made into cakes.

The barks as well as galls formed on the leaves are used for tanning. The bark is used in the form of power for boils etc. in the summer season as local medicine.

The bark is dry, acrid, bitter with a sharp taste, cooling, anthelomintic, tonic, cures leprosy, dysentery, bronchitis, asthma, leucoderma, piles, tremors of the muscles and wandering of the mind. It is also used in the Madhya Pradesh as a remedy for rheumatism. The bark is even perscribed for scorpion biting. The plant is recommended for treatment of snakes bite (Kirtikar and Basu 1935).

(e) Roots - It has a deep tap root and side roots spread beneath the ground at 2-3'. The villagers sometimes dig and out the roots and used for making cot frames, handle for agricultural implements. Because it is stronger than stem and less affected by insect in comparison of its wood. The slender long and straight roots are used in making butter churning sticks (Jerna) and horn of rakes (Jeyi). The deep roots are used for upper parts of the bullock cart which last for longer life. It has been observed during the flood periods that the Khejris are less affected due to its deep and long roots. Many persons during this mishap saved their lives by climbing or hanging on it. The bark of root is also used in leather tanning.

(f) Gum from 'Khejri' - The tree exudes a gum, which resembles the mesquite gum from the cut oends of branches. The gum occurs in small angular, fariable yellow fragments or sometimes in large avoid tears about 5 cms long. The tears have frosted appearance and are internally amber coloured, cracking to pressure because of the presence of numerous minute cracks. (Anon 1969). This form with water a dark coloured tasteless mucilage of about the same viscocity as that of gum arabic. The gum oozes out in February and March and is collected by local masses. It is very good in taste and used by the rural folk with sweetballs at the time of delivery and considered more nutritive.

(g) Seeds - There is a possibilities to explore oil from the seeds and this may be useful for the domestic as well as other purposes. Almost all the parts of this tree are used for benefit of man kind and prove its title "Kulp taru" of arid zone.

Besides increasing fertility it acts as a soil binder and lower down the speed of hot winds in extreme summer. It provides extra source of revenue in droughts and builds up farmers balanced economy and self sufficiency. A average big tree provides green fodder worth of Rs 10/- twigs of about Rs 8/- (in form of fencing and fuel material), and Rs 2/- as vegetable. The total additional income from one tree is about Rs 20/- alongwith non-monetary indirect benefits. In dry region atleast 30-40 trees are found in a hectare and yield Rs 600.00 - 800.00 as an additional income per annum. The number of trees in a field increases its value.

If the farmers do the job carefully in planting the trees at a distance of 12 meter in row to row and tree to tree by digging pits. Then he may earn at least Rs 2500/- per annum as an additional revenue. He can make Khejri trees grow to suit his own economy. Its needless to say that Khejri trees are cash crops with a distinct advantage over the traditional agricultural crops, the product is not perishable. If at any time the owner does not get the expected price he need not to harvest these trees, the trees will put on valuable growth and owner can always sell them when the market conditions are favourable. As against tree crops in this case of agricultural cash crops the farmer has no alternative but to harvest them irrespective of the market conditions.

Importance of the tree in socio-cultural purview

The description of the tree is in one of the couplets, spoken during the marriage time. When bridegroom comes to his father-in-law's house on the horse for marriage, then a following couplet is used by the bridegroom. He recites that in one of the Brahmin communities in the arid region.

"Anti tutti Khejri, Panofullan Chayi"
Shabash mara sasuji they latkan beti jayee.

"It describes tree and its irregular shape with bloom of flowers and leaves, bridegroom thanks mother-in-law for bearing a beautiful girl and offering him in marriage." At the time of marriage in number of caste the pillar that is like cross staff, fixed at the place of Chanwari (marriage performing encloser) made up of Khejri wood

and considered to be better among all trees. Some times in a few communities the rites is to show green leaves with green twigs but in remote arid areas Khejri leaves and twigs are to be shown at father-in-law's house.

At the time of Mossar (death feast) the villagers some times hang a wheel of his cart on Khejri tree and locally this phenomenan is known as 'peyda chandhana.' It means whosoever will pass from this route and under this tree, he is invited to attend that feast. It is said to be prestige point and for boosting purposes that he did at the death of his father or grand father even invite persons who passed from the way of his village.

In some of the folklore the description of the tree has been provided as one of the most greenary trees in arid region.

Man Bhawan aur suhavana mor khejri ro paid
Hariya Hariya Jad nipaje, Chare uont, bakeri ne bher

'Oh! my beatiful and attractive tree of Khejri' When you provide green leaves then camel, goats and sheep get nutritive fodder in this dry region.'

After coming from pilgrimage (A sacred the river, Ganga) villagers used to receive holy water of Ganga in a big procession and they put leaves of Khejri in vessels and loaded on heads of their women. In March and April there is a local festival of Gudla and Lotiyan, Khejri leaves and small twigs put inside the pot and move from deer to deer in rural areas. They consider Khejri as holy tree and to be worshipped. In Havana and Yagavas Khejri wood is considered to be next to peepal (Ficus religioisa Linn.) and known as Sami ahooti in yagayas. In old literature Dhanvantri who is known as lord of medicine, told that in a country where sami (Prosopis cineraria) neem (Azadircta indica A.Juss) and Aak (Calotropis procera Ait.) are available the diseases never occur. It shows the importance of Khejri.

Any tall person is given the similie of Khejri because of its unique tallness in the arid areas.

'Lumbe-Kedo-Hoyu Jesay Khejere hoyujenu'

It means one has become as tall as Khejri in arid areas.

The shrine of the Gogaji, Ramdeoji, Pabuji, Mahastimato, Seteelamata and Bhomiaji (All are local Gods) are generally beneath the khejri. At these shrines of local gods and goddesses cutting, lopping of these trees is strictly prohibited and these trees are to be considered sacred and damaging them is antireligious deed. Lord Rama at the time of marching his army to kill Rawana considered this tree as the goddess of Power and this worship is now known as Samipuja. Similar type of Pujan is usually performed at the time of Dessura by Gowsami of vallabhkul Sampardya. (The workship of the Khejri considered the workship of goddess of Sakti (power) at Chopasni. After killing Rawana every person plucks the leaves, twigs of the Khejri tree and considers as Laxmi (i.e. goddess of wealth and good fortune). People keep the dry leaves in homes or boxes for longer period. The infloresences are used as flower in arid zone for worshipping of seteelamata (goddess of small pox) in march after Holi festival. The punchkuta dry curry is also prepared on that day because all the mothers eat stale meal at least for three days to protect their children from effect of small pox, chicken pox and measles respectively.

There is a common belief associated with this tree among rural folk that the Khejri is the residential place of Ghosts and Ghostesses, especially on bigger and older trees. It is suggested to people that they should not pass by thatway and go under that tree at mid day, evening and midnight, other wise the ghost soul would onter in his body. Number of blind beliefs are attached to this tree in tract of western Rajasthan while in semi-arid tract of Rajasthan the Khejri is to be considered a sacred tree only.

The witch craft is also associated with this tree, if some child has fallen sick or having cough he has to be passed under the roots of this tree atleast seven times. If roots are not above the grounds. People dig the roots and make a suitable space under these roots and pass the child. This is considered to be a remedy in rural areas. Some Bhopa or Ozha (sorcerer) cure the upset stomach or anyother disease by chanting mantras and putting a big nail inside Khejri tree they believe that the dislocation of stomach and disease is set right in this way.

If somebody is affected by paralysis in rural areas this is considered to be effect of some Maiaji or majisa (local goddesses) and at such times people suggest that a copper vessel full of water should be moved over his head seven times anticlockwise and be poured at the roots of Khejri he would be cured within seven days time. This phenomena is locally known as Pani-verna. On Igiyras and Amasya (11th moon day and night without moon) some ladies poured water at Khejri and consider sacred.

Opinion Survey: The opinion poll of the local masses also confirmed the better crop growth under this tree. This phenomenon was explained by young and old respondents during field surveys that falling of the leaves and bird droppings increases soil fertility by adding humus, heal their look of crop under this tree is due to shade and this shade provides shelter to cattle in summer adds manure. Even in rains the water drops from leaves after rain stops. These points prove the logic of increasing better growth under tree and it would be further reinforced these facts by number of studies conducted (Singh and Lal 1969, Agarwal et.al. 1976, Shanker et al. 1976) to prove these facts. Due to above socio-economic dimensions the Khejri proves itself as a 'KULP TARU' of the arid areas of north west India.

SALIENT FEATURES OF KHEJRI

H.S.MANN

Prosopis cineraria (Linn.) Mac Bride (Syn. P.spicigera Linn.) vern, Khejri, is a moderate sized tree found on almost all the habitats of N.W.India except the hills and saline depressions. It holds an increasingly important place in the economy of India Desert and it dominates the vegetation of the region and forms the climax vegetation. Density of Khejri increases from the western region (100 - 200 mm. rainfall) to the north western part of western Rajasthan (200-500 mm). Optimum density expression can be seen in 300-400 mm rainfall areas on alluvial plains. Its distribution is discontinuous and it occurs in Rajasthan, Haryana, Gujrat, Karnataka and part of Madhya Pradesh.

There are two distinct ecotype of Khejri tree found in the desert. One with the spineless drooping twigs with comparatively acute angle of branching giving a close and compact canopy look, whereas the other one with spined non-drooping branches with slightly wider branching angle and comparatively with open crown.

Flat younger and older alluvial plains with sandy loam to sandy clay loam soils are invariably dominated by Prosopis. The prevalent plant community on sandy loam soil is Prosopis cineraria - Zizyphus nummularia - Cappari s decidus whereas sandy clay loam soils supports Salvadera olevides - Prosopis cineraria community. The land alongwith the river course are occupied by Acacia nilotica - Prosopis cineraria. Its association on piedmont and pediment plains is mostly with Acacia senegal and Euphortria caducifolia. Old stabilised longitudinal and coalasced parabolic dunes of 300-400 mm rainfall zone support Prosopis with Saccharum bengalene . Chief dominating plant of interdunal tract is Prosopis only where its main associate is Tecomella undulata. Thus distinctive communities are found on various habitats. The succession proceeds in different series depending on edaphic conditions but finally converge to climax community of P.cineraria.

Khejri tree puts up new growth with onset of spring season and continue to flower and fruit during hot months i.e. March to June, when most of the desert tree are leafless. Normally fully grown trees are lopped during the month of November and December. The shekhawati region (Churu-Jhunjhunu-Sikar-Nagaur) has systematic lopping system while in other regions it is irregular due to which, some time, much injury is caused to the lopped trees. Initially Khejri is slow in above ground growth but once assumed a full crown (10-20 years), its growth can be compared with other fast growing exotic trees. It has a very deep root system which enables it to tap the water from moist kankarpan and down below. The cut stump coppice well and assume 1.5 m high growth with 5-12 new shoots forming a dense bushy structure. Under continuous grazing stress it spreads horizontally instead of vertically. Such tree spread provide continuous browse to sheep and other animals, Khejri has a high seed germination percentage (80).

Khejri wood is hard but not so durable. The proportion of sapwood is more while heartwood in scanty. The wood is suitable for interior construction work such as column of huts, roofs, doors and windows etc. Wood is also used for agricultural hand tools. 40-70 kg. fuel wood per tree can be obtained from 20th to 30th year of age group plant. 25 years felling period is suitable in 350-400 mm. rainfall zone. It fullfil the needs of rural masses by utilizing each and every part of this tree. In this desert it is one of the major source of fuel. Small branches and twigs after lopping are used as fuel wood which has high calorific value (9007 B.T.U.) . It is also used in making charcoal. Green pods "Sangri" are used as fodder. It also serves as dry vegetable after drying and boiling. Ripe pods "Khokha" are eatem by children for its sweetish pulp. The inflorescence is largely utilized as a blood purifier and safeguarding the pregnancy against miscarriage. During severe famine in the past (1968-69) even the bark of this tree was consumed as food. Root and shoot bark is used for tanning purposes and the powdered bark used to cure several ailments. Khejri produces small quantity of gum which is generally utilized for local use.

A fully grown tree produces 25-30 kg of air dried leaves, 5 kg of pods and one kg of seeds in 300 - 400 mm rainfall zone. Air dried leaves of Khejri are called "Loong" which are fed to milch animals. Leaves contain 11.9 to 15.4% crude protein, 1.4 - 2.3% crude fibre, 0.18 - 11.93% phosphorous, 1.5 - 2.6% Calcium and 0.5% magnesium. Palatability of Khejri leaves have indicated that the dry matter intake of leave was 685 gm/day (or 1.88 kg per 100 kg. body weight/day) in sheep and goat respectively. Dry matter intake of Khejri leaves by camel comes to 1.38 kg per 100 kg. body weight/day. Micronutrient status of leaves for iron, zinc, manganese and copper are, respectively, found to be 112, 1.16, 5.75 and 1.87 mg/100 gm dry matter. Cell wall constituents of leaves make up 45.5% of dry matter while hemi-cellulose constitute 17.1%, Lignin 7.1%, cellulose 16.9%, silica 3.7% and tanin 11.6% of dry matter. Average sodium, potassium values are of the order of 77 mg and 1.21 mg per 100 gm dry matter. Among the livestock goat is the most efficient followed by camel and sheep in utilizing the nutrients of Khejri leaves. The leaves collected during summer period are better utilized by the live stock in comparison to the leaves collected during winter.

In the experiments at CAZRI, it was found that the Khejri tree support high number of forage species (19.1), their biomass (234.8 g/m^2) and plants per unit area (35.81/m^2) as compared with other desert tree species like Tecomella undulata (Rohida), Albizzia lebbek (siris) and P.juliflora (vilayti babool). The litter was also highest (68.0 g/m^2) under its canopy. The contribution of perennial grass species was as high as 78.3% where as it was lowest (51.1%) with T.undulata. Maximum amount of moisture was observed under its soil and minimum under P.juliflora. Higher moisture availability in the surface layer allows more density of ground flora. There was a slight decrease of pH (8.0) and EC. (0.01 mmhos/cm) under Khejri than open area.

There was 45% increase of organic matter and nitrogen contents under this tree over open field conditions. The surface soil was found to contain higher nitrogen, phosphorous and potassium contents which reflected better growth and vegetative biomass.

Soil micronutrient status under Khejri have shown an increase in Zn, Mn and Cu contents in whole profile where as Fe content was higher in surface soils only. The litter present under Khejri also showed higher level of organic matter, phosphorous, nitrate nitrogen contents and the micronutrients status over open area and Prosopis juliflora.

Studies on diurnal variation in transpiration indicated that irrespective of the season, rate of moisture output increase from sun rise and declined in the evening with an intervening "Moon day drop." During the peak hours the rate of transpiration increased to 1000 - 15000 mg/gm/hr. The estimates on moisture expenditure have shown that a stand of 50 trees/ha losses a moisture of 221.5 mm/year whereas the mean annual rainfall is 366 mm. The left over 144 mm of moisture is generally consumed by herbage growth. Physiological studies have shown that the foliage directly absorbs the rain water.

Nodulation studies have shown higher number of root nodules on lateral roots than on the tap root of the tree when the seedlings were raised in Delhi soil. The rhizobia present on tree were akin to cow pea group.

Some important pest of Khejri which destroy the leaves and produce the gall formation during flowering time are white grub (chaffer beetle), Desert locust (Shistocarica gregaria), Termite (Odonto teomen obesus) and gall fly (Goccidomylid galli)

In view of the desirable characteristics and its adaptability it is no surprise, that the people in the desert propagate and protect this tree.

Agro-forestry, bajra in Khejri trees is a long standing tradition in the arid region of India. There is even talk of the culture sustained by Khejri.

As would appear from the material in these pages considerable scientific in sight has been gained about this important desert tree. It is hoped that with the renewed interest in agro-forestry and silvi-pastoral systems further studies will be undertaken so that land use and management practices are evolved for higher sustainable levels for coming generations.

Role of Khejri in Agro-forestry

H.S. Mann and S.K. Saxena

National Commission of Agriculture in its interim report (1973) on social forestry has emphasized the role of social and agroforestry. It envisages a crash programme of plantation during plan periods, which fulfils the objectives like, (i) Fuel-wood supply to rural areas and replacement of cow-dung, (ii) Supply of small timber, (iii) Fodder supply and (iv) Protection of agricultural field against wind blast.

Agro-forestry may be defined as practising agriculture and forestry together. Tree plantation in agricultural fields ameliorates the microclimate and increase productivity of agricultural lands. It maintains soil mantle, checks wind erosion and purify the air.

Agro-forestry has been in practice since decades in Indian humid Tropics and dry deciduous forest under different terminologies. Taungya in north and north east India and Kumri in south India (Paroda & Muthana 1979). In this system, the agricultural crops like ragi and groundnut etc are taken in the new plantations in between the tree rows for 2-3 years and then shifted to new plantation sites. The farmers take care of the tree seedlings by weeding around the plant and protect them from livestock. The crops provide micro-climatic conditions to the saplings. The crop residue enrich the soils especially when legume crops are taken. But in Indian desert this practice is altogether different. In certain tracts food and forage crops are taken in a naturally established tree land (wood-land) of Khejri trees or Khejri-Babool trees. During droughts the top feed/'loong' and tender twigs of Khejri trees during summer serve as the only resource of fodder to livestock.

Desert condition

High density of human population (48/sq.km) and live-stock (18.10 m) population exerts pressure on the existing vegetal cover for their daily requirement of fuel wood. Small timber for agricultural implements and house construction are extracted either from their own field, community land or government lands. Due to high demand and negligible replacement fewer tree exist on some of the farm land. Historically, cultivation of crops like millet (bajra), legume has been practised between the standing trees of Khejri. In some of the areas described in the following paras, this system is systematically followed, whereas in other part this practice has been abused.

Agro-forestry in Indian Desert

The farmers of western Rajasthan know the value of Khejri tree. Ordinarily a cultivator hesitates to cut a Khejri tree on his own field for fuel and thus one can find various tree density on the cultivated field. The alluvial plains with sandy loam soils invariably support number of Khejri tree. In Nagaur, Sikar and Ganganagar district there is exceptionally high Khejri density.

Flat alluvial plains having deep to very deep soils (100-150 cm) in 350-450 mm rainfall zone with sandy loam to sandy clay loam soils underlain by an indurated kankar pan support Prosopis-Zizyphus community. Here Khejri tree density varies from 20-40/ha with 4-10% crown cover.

Sandy undulating older alluvial plains of Nagaur and Ganganagar district and some part of Sikar district was covered with deep to very deep (2-4 m) sand deposition where hummocks are generally found along the field boundaries. These plains

are invariably dominated by Khejri where the plant density ranges from 40-120/ha. Better tree growth and higher plant population are correlated with an increase in soil depth.

Agro-forestry practices : In a well developed tree land on the alluvial soils all the trees are lopped for foliage "loong" in a systematic manner, without causing any injury to the tree (Photo) in the month of November and December each year. In case of rabi cropping, especially for wheat, the lopping is generally completed by the end of October or mid of November. The lopped trees remain dormant upto middle of February. The plant sprout well with several new twigs. The tender twigs are once again cut (10-30%) during May-June for livestock feeding. All this keeps the crown cover with less foliage and uneffective for checking sun-light. In June-July the sown kharif crops and the tree crown cover develop simultaneously. A Khejri tree acquires a fully developed crown by the month of October when the kharif crops mature. The crops and tree do not have any competition amongst each other. Annual crops draw their moisture and nutrients from first 50-60 cm of soil whereas the effective root system of tree is below this depth.

Aggarwal et al (1976), Shanker et. al 1977 and Singh and Lal (1969) have shown that the forage species produce higher biomass production under Khejri tree canopy due to high fertility status. Paroda and Muthana (1979) tried to follow Agro-forestry practice under Acacia tortilis plantation. Cowpea (Vigna sinensis), Jowar (Sorghum vulgare) and Guar (Cyamopsis tetragonoloba) were sown between interspaces (4 x 4 m) of twelve years old plantation. Significantly higher green forage yield was produced by cowpea followed by Sorghum as compared to open field.

In another integrated land use pattern 50% A. tortilis plantation was lopped and remaining half was left unlopped and grain crops of Guar and Moong (Vigna radiatus) were sown to see the lopping effect by the same authors. The grain and fodder of sown crops under the lopped trees was significantly higher than the unlopped trees.

Name of species	Yield in kg/ha	
	Unlopped	Lopped
Moong (grain)	5.8	35.6
Moong (fodder)	28.0	183.0
Guar (Grain)	29.1	81.2
Guar (Fodder)	29.1	70.0

Source : (After Paroda and Muthana)

However, the height and growth of tree was not effected by the cultivation of these legumes. This integrated landuse system not only give higher income but helps in checking the soil erosion and maintain the fertility status. Lopping practice in A. tortilis, an exotic, confirms the locally followed practice in Khejri woodlands.

Agro-forestry development programme

In rural areas woody and shrubby growth on uncultivable wastelands, fallows or agricultural fields are mostly the source of fuel wood. In order to increase fuel and timber, Agroforestry programme through Khejri plantation could be adopted on a large scale. This practice will ensure the balanced economy of wood-lot for the rural areas. Agro-forestry programme should be implemented through forest department/State Agricultural department/Agricultural Universities/Panchayat and extension

agencies of Central Government department. The programme should be carried out with a sense of urgency. It should be time bound and target oriented.

Khejri tree, though initially slow growing compensate the initial handicap by providing continuous supply of fodder, fuel, timber and vegetable even in drought years. There is a need for careful selection of comparatively fast growing Khejri germ plasm for arid to semi arid tract like district Nagaur. Seed of such plant should be collected, tested and supplied to various seedling raising agencies/department.

Raising of nursery

Sandy loam soil mixed with 1/5 part of farm yard manure should be filled in polythene tube of 10 x 30 cm (200 gauge) and G.I. tube (18-21 gauge) of same size in the month of September-October. Few holes may be created in the lower side of the polythene tube by a punching machine. One to two healthy seeds should be sown after acid scarification for 15-30 minutes. The seed should be sown at 3-5 mm soil depth. Watering of tubes may be carried out by a water-can fitted with a showering hose. Till germination is complete, mild watering may be carried out daily. Generally germination is complete in 10-15 days. In a months time only one healthy seedling in each tube should be retained. October sown seedlings are ready in about 9 months for monsoon planting. Weeding, decrusting of surface layer and watering should be carried out periodically. Care should be taken to keep the sapling unbranched and erect. Root growth may be regulated by periodic cutting of excessive root growth at the base of the tube.

Planting : Prior to transplanting, pits of 60 x 60 cm should be dug and refilled after mixing small quantity of farm-yard manure (one kg to 2 kg/pit) and 5-10 gm of aldrex powder.

In a given field of alluvial flats, the sapling should be transplanted at 10 x 10 m apart (row to row and plant to plant).

After care : The farmers should protect the seedling from animal browsing, disease and pest attack. In case of mortality gap filling should be carried out in the same season. At least one effective weeding and two soil working in a year around the sapling will help in better growth. For a better establishment if possible summer watering in the first year of planting should be done. In case of any insect attack insecticide spray may be carried out. 0.1% of solution of Aldrex 30% EC may also be applied in the soil at six months interval (February and October) for checking the termite attack.

Habitat suiting for Khejri plantation : Younger alluvial plains (double cropped area), older alluvial flats, sandy undulating plains, interdunal plains and swale of stabilised dunes are the ideal habitats for raising Khejri woodlands for Agro-forestry practices. This practice may also be followed in Rajasthan canal command area where the growth shall be faster.

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