Acacia tortilis

Knowing the Species

Establishment and growth of trees in arid region is very slow due to hostile environmental conditions such as, low and uncertain rainfall, extremes of temperature, high evapotranspiration, strong winds, loose sandy soils which are prone to wind erosion and are infertile having poor moisture holding capacity. The problem is further compounded by very large population of animals and human being which impede the growth of plantations by overbrowsing and felling. Obviously, forestry in such regions could be promoted only with species which not only thrive under these constraints, but are fast growing. *Acacia tortilis* is an important tree of arid region of many African and Asian countries, where its natural plantations are in abundance. It was introduced in Indian desert in 1958 from Israel and has been found a very promising species. It is particularly suitable for sand dune stabilization. The species, locally known as 'Israeli babul' has made Indian desert its natural home during last three decades.

Acacia tortilis, is native of Sudan, Ethiopia, Yemen, Somalia, part of Kenya, Tanzania, Arabia and Southern Israel. It is usually a medium size tree of 4 to 12 m height, sometimes a shrub or bush 1.5-18 m high, occasionally of 21 m. Bark on trunk usually rough and fissured, grey to black brown. Crown usually flat and spreading (parasol type) but sometimes (especially in sub sp. *raddiana*) rounded. Young branchlets densely to sparsely pubescent or glabrous to subglabrous. Spines paired; some short and hooked, up to about 5 mm long, others long straight, slender, whitish, 1.2-8(-10) cm long, never enlarged or inflated. Petiole usually with a gland. Pinnae 2-10, occasionally to 14 pairs on a short rachis up to 2 (-4) cm long, usually glandular between the top 1-3 and lowest 1-2 pairs of pinnae. Leaflets 6-20 pairs per pinna, glabrous to densely pubescent, 0.5-2.5(-6) mm long, 0.2-1(-1.5) mm wide. Flowers white or yellowish-white, scented, in round fluffy heads 0.5-1.1 cm in diameter, on axillary peduncles 0.4-2.5 cm long. Pods variable indehiscent or slowly dehiscent, contorted or spirally twisted, very rarely and abnormally (Kenya) pods straight or nearly so, glabrous, pubescent or tomentellous, rarely with spreading hairs. Seeds oblique or parallel to long axis of pods.

In general, *A. tortilis*, a member of family *Mimosoideae* is very distinctive and easily recognized with the characteristics mixture of long straight spines and shorter hooked ones combined with spirally twisted or contorted crown has given it the popular name of Umbrella Urorn; however the foliage is smaller than in many acacias, and the whitish flowers in small round heads are also characteristic, though this is a feature shared with other *Acacia* species. Under Indian arid conditions this species starts flowering and fruiting at 3 years of age. Flower buds appear in the first week of May and fruit setting commences from mid July. Fruits ripen during the period November to February. On an average, annually a tree yields 4 to 6 kg seeds at 6 to 8 years of age. Seeds of this species which are light brown in colour resemble those of *Acacia nilotica* sub sp. *indica* (babool) in size and the weight is approximately 85 g/1000 seeds.

General Distribution

Widespread in Africa, from South Africa northwards to Algeria and Egypt, extending in Asia to Israel and southern Arabia. *A. tortilis* is cultivated in India (sub sp. *raddiana)* and Pakistan. In India, plantations of *Acacia tortilis* occur in the districts of Barmer, Bikaner, Jaisalmer, Sri-Ganganagar, Jodhpur, Pali, Seekar, Churu, Jhunjhunu, Nagaur, etc. in western Rajasthan. It is also being planted in arid zones of Gujarat, Haryana, Punjab, Tamil Nadu, Andhra Pradesh and Karnataka. It is prominent on sand dunes of arid regions where it has good growth. In western Rajasthan, roadside plantations are predominantly of *Acacia tortilis*. In IGNP, stage I area there are old plantations of *Acacia tortilis* which have attained very good growth. Block plantations of *Acacia tortilis* have been raised in desert districts of western Rajasthan to meet fuel and fodder demands. *Acacia tortilis* has been planted in silvipastoral systems along with *Lasiurus sindicus* and *Cenchrus ciliaris* in arid regions. It also occurs on farm lands as boundary plantations. In Sudan it is found in the northern region where rainfall is 200 mm or below. In the drier parts, it is confined to water receiving sites, and is characteristic of erosion runnels in desert lay-gravel. The sub species *raddiana* was noted growing in fossil black clays and on rocky cliffs (Kordofan, Sudan), on deep sands (Abeche, Chad), on eroded 'reds' (Tin el Hasan, Morocco) and in red ferruginous soils on iron pans north of Kano, Nigeria. In Botswana, *Acacia tortilis* occurs in floodplain grasslands, parklands and tree savanna. In Somalia, *Acacia tortilis* occurs in wide range of soils which include saline and gypseous. In Abu Dhabi, it is generally confined to the heavy soils in the valley flats. In West Africa, occurrence of *Acacia tortilis* sp. *raddiana*, extends from Senegal to the Red sea and across the Sahara to Tunisia. The southern limit of the main distribution runs from Saint Louis in Senegal eastward to south of Lake Chad, a line which corresponds to the 500 isohyet and marks the edge of Sahel. In Wadi El-miyah, *Acacia tortilis* sp. *raddiana* occurs as a dominant of vegetation community type II, along with *Pergularia tomentosa*, *Panicum turgidum* and *Capparis decidua*. In Egyptian desert (tributary wadis in eastern part) *Acacia tortilis* dominates in association with *Leptadenia pyrotechnica, Maerva crassifolia* and *Solenostemma argel*. In the middle and southern regions, the associates are *Aerva persica, Cassia senna, Colocynthis vulgaris, Salsola baryosma, Balanites aegyptiaca and Morettia philaena*.

A. tortilis is widely occurring and variable species within which four sub species are recognized. Their geographical ranges are generally distinctive, though there is some overlap in sub species *tortilis* and sub species *raddiana*. The sub species are separated by the presence or absence of pubescence on the pods, their width and differences in the pubescence of the branchlet. The shape of the crown is distinctive is sub species *raddiana*.

Distribution of Sub Species

- ***Acacia tortilis* sub species *tortilis***

  Synonyms – *Mimosa tortilis* Forsk

  Sub species *tortilis* occurs in Somalia, Ethiopia, Sudan northwards to Egypt and Israel extending to the Yemen, Arab Republic, P.D.R. Yemen, Oman, Saudi Arabia, Abu-Dhabi and Qatar.

- ***Acacia tortilis* sub species *raddiana* (Savi) Benan var. *raddiana***

  Synonyms - *A. raddiana* Savi
  A. fasciculate Guill & Perr. non H. B.K.
  A. tortilis var. *lenticellosa* Chiov.
  A. tortilis forma *raddiana* (Savi) Roberty

Tree 1.2-10m high, with more or less rounded crown. Young branchlet and leaves glabrous or subglabrous. Pods 6-9 mm wide, glabrous glandulae.

Sub species *raddiana* var. *raddiana* occurs in northern Africa from the Senegal eastward to the Sudan, Somalia and Kenya. Its status (native or introduced) in Kenya is uncertain. It also extends through Egypt to Israel, Jordan and Saudi Arabia. It is widely planted in Indian arid zones, the maximum coverage being in western Rajasthan.

- ***Acacia tortilis* sub species *raddiana* var. *pubescens* A. Chev.**
  Synonyms - *A. fasciculata* var. *pubescens* (A. Chev.).
  A. tortilis var. *pubescens* Aylmer ex. Burtt Davy.
  A. raddiana var. *pubescens* (A. Chev.) A.F. Hill.

  Similar to var. *raddiana* but young branchlets shortly more or less pubescent and pods appressed – puberulous.

  The var. *pubescens* has been found in Mali, Algeria and Sudan. It will be noted that the features differentiating var. *pubescens* from var. *raddiana* are those that might be expected from hybridization between sub species *raddiana* and sub species *tortilis*.

  Trees in Israel "intermediate in some characters between *A. raddiana* and A. *tortilis*" considered hybrids. Similar trees were described as "*tortilis* (*raddiana* X *spirocarpa*)" in Tunisia near Bou Hedma. It was considered that the distinctions between *spirocarpa* and *raddiana* were not clear, though it was suggested (without reasons) that *raddiana* might be better reinstated as a species.

  The considerations such as these, together with the occurrence of glabrous pods in sub species *heteracantha* that *raddiana* has been placed sub species of *Acacia tortilis.*

- ***Acacia tortilis* sub species *spirocarpa* (Hochst ex. A Rich) Brenan var. *spirocarpa***
  Synonyms - *A. spirocarpa* Hochst ex. A. Rich
  A. petersiana Bolle.
  A. spirocarpa var. major Schweinf.
  A. spirocarpa forma *pubescens* Terracc probably
  *A. pappi*i Gandoger
  *A. tortili*s forma *spirocarpa* (Hochst ex. A. Rich) Roberty.

  Sub species *Spirocarpa* var. *spirocarpa* is restricted to eastern Africa, occurring in the Sudan, Ethiopia, Somalia, Uganda, Kenya Tanzania, Malawi, Mozambique, Zimbabwe and Botswana.

- ***Acacia tortilis* sub species *spirocarpa* var. *crinita* Chiov. The var. *crinita* has been found in Somalia, Kenya and Tanzania.**

  Some specimen at the Royal Botanic Gardens, Kew from the Yemen Arab Republic are very similar to var. *crinita* in their densely spreading hairy pods, but the pods lack glands. The evidence is insufficient for a certain opinion but it is possible that these specimens are sub species *tortilis* showing long hair on pods to var. *crinita*.

- ***Acacia tortilis* sub species *heteracantha* (Burch) Brenan**

Synonyms - *A. heteracantha* Burch.
A. litakunensis Burch.
A. spirocarpoides Engl.
A. maras Engl.

The sub species *heteracantha* occurs in Southern Angola, Namibia/S.W. Africa, Botswana, Zimbabwe, Mozambique, South Africa and Swaziland.

The occurrence of occasional intermediates between sub species *heteracantha* and sub species *spirocarpa* was observed but the vast majority of specimens can be placed without difficulty in one or the other sub species.

Utilization of the Species

Acacia tortilis is the most important species for sand dune stabilization. It plays a paramount role in Indian desert for wind erosion control. Shelter belts of *Acacia tortilis* are raised along roads, railway tracks and farms. It yields good fuel wood, leaves are lopped for fodder and fruits also form good fodder for the livestock. Twigs, branches and thorns are used as fencing materials. Bigger branches are used as poles for erecting fence around farms and plantations.

Wood Properties

Annual rings are observable in *Acacia tortilis* plantations in Africa (Senegal and Niger) but they are very irregular. The negative growth characteristics are diffuse porosity, banded parenchyma, false or disjointed rings, discontinuous rings and indistinct boundaries. Xylem vessels in *Acacia tortilis* are mostly solitary, but they also occur in radially, diagonally and even tangentially oriented multiples (2 to 4 vessels in multiples). The perforations were transverse or oblique or simple. Inter vascular pitting was predominantly alternate with linear apertures. Tyloses were not encountered, but the vessels had gummy deposits. Wood parenchyma was paratracheal of the aliform confluent type and formed narrow concentric bands with large starch grains in the cells. The broader bands of *A. raddiana* were the only difference that readily distinguished the two species. A frequently occurring feature was long vertical columns of cells containing rhomboidal crystals. These were most abundant in wood that was differentiated during weak cambial activity. Strength properties of the species are given in the following table.

Property	Condition	Value
Specific gravity	Green	0.66
	Oven dry	0.69
Weight	Green	1164 kg/m^3 at 76.3 per cent
	Oven dry	769 kg/m^3 at 12 per cent moisture content
Fibre stress	Green	335 kg/cm^2
At elastic limit	dry	461 kg/cm^2
Static bending	Modulus of rupture	green 608 kg/cm^2
		dry 806 kg/cm^2

	Modulus of elasticity	green	58000 kg/cm^2
		dry	71900 kg/cm^2
	Work to elastic limit	green	0.133 kg/cm^2
		dry	0.199 kg/cm^2
Impact bending	Izod value of work absorbed	green	160 kg/cm
		dry	105 kg/cm
Compression	Parallel to	green	344 kg/cm^2
		dry	416 kg/cm^2
	Perpendicular to grain	green	90 kg/cm^2
		dry	70 kg/cm^2
Surface hardness	Radial	green	615 kg
		dry	638 kg
	Tangential	green	614 kg
		dry	578 kg
Shear parallel to grain	Radial	green	114.2kg/cm^2
		dry	160 kg/cm^2
	Tangential	green	133.1 kg/cm^2
		dry	122.0 kg/cm^2

Fuel

There is fuel wood deficit situation in arid zones of Rajasthan, Gujarat, Harayana and other states. In Rajasthan the gap between the demand and supply is of the order of 1.65 m tones per annum. This calls for enhancing fuelwood yield. *Acacia tortilis* is a very good source of fuelwood, because of its fast growing habit and excellent coppicing behaviour. In Indian arid regions, it is the most important species planted on panchayat lands under 'village fuel wood plantation' scheme. On a panchayat land in Seekar district, *Acacia tortilis* planted for fuel wood was severly lopped leaving only the main stem and main branches. The plantation shows very good sprouting of new foliage. *Acacia tortilis* is found to be one of the 35 species chosen as particularly suitable for fuelwood in hot arid areas of Africa and middle east. Its dense 'red hard wood has high calorific value of 4400 K cal/kg making superior firewood and charcoal. The tree starts giving fuel wood at the age of 8 to 10 years at the rate of 50 kg/tree. Close planting at 3m x 3m yielded 54 tonnes/ha of fuel wood at 12th year of planting at Jodhpur. *Acacia tortilis* was found to be one of the commoner species for charcoal making in west Africa.

Fodder

Increase in livestock population and dwindling fodder resources of western Rajasthan leaves vast gap in demand and supply of fodder. This chronic deficiency of fodder needs to be corrected by stepping up fodder production from tree based land use system.

Acacia tortilis is one of the important sources of fodder for cattle in western India. West Africa, Somalia, Ethiopia, Sudan etc. Foliage and fruits of *Acacia tortilis* are important browse. A ten year old tree yields about 4 to 6 kg dry leaf and 10 to 12 kg pods per year. The foliage of *Acacia tortilis* is very much liked by sheep, goat, camel, cows and wildlife. The leaves are fed green as well as dry. The green foliage is fed during February to May. Whereas to store dry leaves, they are collected in the month of October. Fruits are preferred for stall fed animals. Like leaves, fruits are also collected and stored dry. However, the pods should be grinded and fed to make it more nutritious.

Leaves and pods of *Acacia tortilis* have been reported to be rich in proteins and other nutrients at par with *Acacia nilotica*, another important fodder species of semi-arid region. Crude protein and digestibility coefficient of *Acacia tortilis* has been reported to be 18% and 46.2%, respectively. Nutrient contents in the leaves have been reported to be, total N 14-18%, digestible N 11-12%, P 0.15-0.18% and net energy 5.552-6.212 mega joules/kg of dry matter. Pods of *Acacia tortilis* contain protein 18.8%, fat 2.4%, carbohydrate 46.2, minerals 5.1% and crude fibre 20.1%. Nutrient contents of the pods were, total N 14-18%; digestible N 9.8-14%; P 0.20-0.28%, net energy 4.141-5.522 mega jules/kg dry matter and digestible N per forage unit, 118-160 g.

Work under Indian conditions has shown that leaves of *Acacia tortilis* contain about 14.6% protein, 36% cell wall constituents, 10% hemi-cellulose, 25.9% acid detergent fibre and16.2 cellulose. These contents are at part with fodder from other tree species of arid region. More over water content of the fresh leaves of *Acacia tortilis* is about 60% which is helpful in partially meeting the water requirement of animals in this water deficit region of Thar desert. Some chemical ingredients interfere the digestion of fodder when fed to animals. They are present in lower proportion (within permissible limits), such as tannin 6.4% lignin 9.7% and cutin 0.4%.

Environmental Conservation/Amelioration

Sand movement is the spectacular feature of arid region which besides causing environmental hazards, pose serious problem such as siltation of canals and wells, engulfing the agricultural fields damaging crops, blocking railway and road transport, etc. Sand dune stabilization is the most important way of controlling wind eroded sand. *Acacia tortilis* has been found to be the most suitable and excellent species for planting on unstabilized sand dunes. Along roads and railways tracks and agricultural farms, it forms very effective shelterbelts. When raised with *Albizia lebbeck* as central row, *Acacia tortilis* reduced the wind velocity by 50 per cent upto the distance of twice the height of reduced the wind velocity by 50 per cent upto the distance of twice the height of shelterbelt, influencing the soil erosion and nutrient loss which were reduced to half. With the heavy biotic pressure, tree cover of Oran lands ('Dev Vans'), Gochars (grazing lands) and catchment areas have vanished, adversely affecting the microclimate of the surrounding habitats and influencing the water collection in the reservoirs which are the main source of drinking water for near by villages. The afforestation activities to regenerate such degraded common property land resources by Governmental and non-governmental agencies, include *Acacia tortilis* as an important plantation species. It's plantation on hill slopes and ravines prevents soil erosion from these sites and checks the siltation of water reservoirs.

Other Uses

The thicker branches of *Acacia tortilis* are used as poles for erecting fencing. It's wood is used as small timber in house construction and making agricultural implements. Roots of *Acacia tortilis* are made into spear shaft in Senegal, stems into fish spears at Lake chad and flexible roots are used for nomadic huts by the Fulani. The bark is used as vermifuge and as a dusting powder for skin diseases in Guinea.

Acacia tortilis has been found to provide a source of surplus honey in Botsvana, Oman and Yemen. The honey yield is estimated at 2-3 kg per colony per season. *Acacia tortilis* is useful in treating several ailments in African countries. In Egypt, Libya, Tunisia, Algeria and Morocco, gum of *Acacia tortilis* is used to treat ocular infections, jaundice and pulmonary

diseases. The dried powdered bark is used as a disinfectant in healing wounds, and the seeds are taken asan antidiarrhoeic. In Somalia, the stem bark is used in treatment against asthma. In Oman, young shoots of *Acacia tortilis* are used for treating mastitis. In Senegal, the bark which contains a high concentration of tannin is used as an anthelmintic. Its powder is used for treating skin disorders. Spear shafts are made from roots.

Natural Regeneration

Acacia tortilis is a plantation species in arid and semi arid regions of India. There are no natural stands of *Acacia tortilis* in India. In western Rajasthan, there are older plantations of 25 to 30 years. Natural regeneration has not been significant in these plantations. Various reasons for lack of natural regeneration in *Acacia tortilis* are as follows:

- Its seed coat is very hard and under the arid land conditions, where top soil dries rapidly, seeds fail to germinate owing to lack of sufficient moisture. In older plantations where canopy closure has taken place, like one in Jati Bhandu (Jodhpur forest division), fallen seed fail to germinate due to inadequate solar radiations and unfavourable temperature conditions. Lower proportion of established seedlings was observed under canopies compared with open areas. Studies conducted in controlled environmental condition by varying the photon flux density (PFD), showed that biomass of seedlings declined with decreasing PFD.
- The plantations in arid region are largely accessible to grazing by animals. Whatever little number of seeds germinate, the young seedlings are browsed by animals which have large population in Indian arid zone. The seeds which are left in excreta of animals, grazing in *Acacia tortilis* plantations and eating their pods, give rise to good germination. But such tender seedlings are either trampled or browsed by animals or they wilt in dry hot environment of arid regions. On sand dunes such seedlings are buried by moving sand. The influence of browsing in natural stands of *Acacia tortilis* in Tanzania was found alarming. When browsed by giraffe, it took 36 years to reach 5.75 m height whereas, in absence of browsing this height was attained in 13 years.
- *Acacia tortilis* has been found to be a good coppicer. Coppice shoots of 2 year old trees were reported to have mean height of 384 cm. To attain this mean height of 2 year old coppice shoots, seedlings initially transplanted took 4 years. Each stump produced on an average 3 to 4 coppice shoots and 100 per cent shoot emergence was recorded from the felled trees of 12 year old plantation. In a coppicing trial the multi stemmed *Acacia tortilis* didn't produce adventitious shoots if left uncut, but cutting some or all of the stems resulted in sprouting from the cut stumps .Shots vigour and numbers per stump were not influenced by stem diameter or height, but both increased with the number of stems cut. All aspects of shoot development were adversely affected if the trees were in poor health, and the number of trees producing shoots showed a marked decline on poor sites. Indeed, plantations of *Acacia tortilis* in India are largely on poor sites which may be the cause of its not so good coppicing in field conditions. The time of cutting also affects the coppice growth. Studies in Sudan indicated that *Acacia tortilis* of less than 25 cm diameter coppiced if cut before the rain.

Nursery Practices and Its Calendar

Nursery Site

Site selection for raising nursery plays an important role in raising the seedlings. The location of nursery should be near the area where plantation is proposed to be undertaken. It will reduce the damage of seedlings and avoid dislocation during transportation over long distances and also cut down the expense of transport. The site should be near the metal road to facilitate easy transport of seedlings. Good quality water should be available in plenty for irrigation. Supply of labour should be adequate in the area. The site should be free from insect and disease hazards and from harmful fungi and nematodes. The nursery site should be level and should not be prone to flooding during monsoon. It should be protected against the wind by raising shelter trees and an exposure which is excessively hot in afternoon should be avoided.

Seed Collection and Storage

Seed should be collected from a tree which is matured, healthy and has good growth. Seeds should be collected from the right kind of provenance of selected seed production area. Under Indian arid conditions, flower buds appear in the first week of May and fruit setting commences from mid July in *Acacia tortilis*. Fruits ripen from mid November to end of February. Seeds should be collected at right maturity time. Maturity of seeds is usually indicated by the cracking of dark coloured pods containing seeds that are hard coated and dark in colour. Collection of green Acacia seeds has been advocated as a means of arresting severe bruchid attack and avoiding the need for presowing treatment. Two simple field tests used in combination can be employed to judge the degree of maturity of 'green' crops:

- take a sample of pods and leave them to dry in the sun for a day or so. If seed remains swollen in the pod and is turning dark in colour, it is usually sufficiently mature to collect. If, on the other hand, the seed loses moisture and contracts it would be unwise to collect it.
- Make transverse cuts through several seeds. The embryo should be firm and swollen whilst the seed coat should not collapse when cut.

These seeds need to be stored safely with proper measures like fumigation, dusting, cold storage, etc. until it is required for sowing. *Acacia tortilis* seeds retain their viability for many years and present few storage problems by virtue of their hard seed coat which restricts moisture exchange and loss of stored reserves through respiration. Generally it is advised to store them dry, in moisture-proof airtight containers. Glass or plastic bottles and tin containers are suitable. They should be as full as possible to reduce the amount of included air. Treating with insecticidal powder (Phostoxin used in Israel malathion, pyrethrin and benezene hexachloride based insecticides) and fumigation (carbon disulphide) will protect the seeds against insect pests. A new method known as preservation by carbon dioxide exchange is being advocated by the Division of Forest Research, CSIRO, which is cheap and easy. The seeds remain viable for a period 7-8 years under protected conditions.

Sowing

Seeds of *Acacia tortilis* have hard seed coat which is impervious to water which causes seed dormancy and the germination may extend over months or years. To ensure a high germination percentage which is rapid and uniform, pre-sowing treatment is necessary. The successful treatments are of two major classes.

Wet
Use of boiling or hot water, acids, organic solvents and alcohols.

Dry
Use of dry heat, microwave energy, impaction, percussion, and manual or mechanical scarification.

Several studies on seed treatment indicate that maximum germination in shortest time could be achieved by soaking the seeds in concentrated sulphuric acid. The time of treatment varied from 20 to 60 minutes depending upon seed size and age.

Use of suitable potting mixture is essential for raising healthy seedling stock. To raise nursery stock of *Acacia tortilis* in arid region, practice in vogue is to mix sand, clay soil and farmyard manure in 1:1:1 ratio. Mixing of only 20% tank silt + 6% FYM was found to nearly double the height (from 21 cm in pure sand to 39 cm) of *Acacia tortilis* seedlings. The potting mixture is filled in polythene bags of about 20-30 cm length and 5-8 cm width. Perforations are made in the bottom of the bags to facilitate better drainage.

Treated seeds are sown directly into polythene containers at about 1 to 2 cm depth. Two seeds are usually sown in each container and surplus germinant picked out to empty ones. Sowing is generally done in the month of February. Seedlings from these sowing attain, on an average, 30 to 40 cm height by early July. Now they are ready for transplant.

Regular supply of good water is essential for good germination and healthy growth of seedlings. Nutrient concentration has no effect on germination and radicle length. In case of non-availability of good water, the waters of EC 4 to 6 m mhos/cm and SAR upto 15 can be used for *Acacia tortilis*. No fertilization is required for nursery plants of *Acacia tortilis*. Watering should be given every day either by sprinklers or garden canes. Weeds from nursery bags should be removed.

Acacia tortilis is mainly raised from seeds. Vegetative propagation tried indicates that rooting ability of leafy 2-node cutting of *Acacia tortilis* was good in the summer, though, there were large clonal variations.

Planting Practices for the Species Including Calendar

Site Preparation
Acacia tortilis is suitable for deep sandy soils of arid region. It was particularly found a suitable species for sand dunes and sandy plains. It is also being planted on degraded sites such as shallow soils of low fertility, low hills, ravines etc. It thrives well in extremely arid climate of less than 200 mm rainfall and, extreme temperatures of as high as 50^0C and as low as 0^0C. Western Rajasthan has virtually become its natural habitat.

Plantations of *Acacia tortilis* are raised as block plantations, road side or canal side plantations in rows and as shelterbelts along farm boundaries. The plantations are primarily raised from nursery grown seedlings. *Acacia tortilis* could be raised by seed

sowing also. Site preparation for planting *Acacia tortilis* will vary depending upon soil and topographic conditions. They are discussed in following lines.

Sand Dunes

To raise *Acacia tortilis* on sand dunes, the site is to be prepared as follows. Protect the planting site by erecting suitable barbedwire fencing before planting. Erect micro-wind breaks (about 2' height) of locally available shrubs or other plant material at 5 m spacing across the prevailing wind direction in parallel strips or in checker boards design at 5 m x 5 m spacing. The material used for micro-wind breaks is usually the shrubs of *Aerva psuedotomentosa* or *Crotolaria burhia*. In the first year of planting seeds of *Lasiurus sindicus* may be sown along the strips to obtain live fencing. This is completed by the mid of June. With the onset of monsoon, pits of size 60 cm x 60 cm x 60 cm are dug at 5 m x 5 m spacing and seedlings are planted. The pit soil is refilled after mixing farmyard manure.

Deep Sandy Soils

Pits of size 50cm x 50cm x 50cm are dug before commencement of rains. At the time of planting weathered soil along with farm yard manure is refilled. It is advisable to make saucer shaped depressions around each tree immediately after planting for better harvest of rain water. Saucers of 1.5 m diameter have been found very effective in conserving rain water and better tree growth in arid regions.

Shallow Sandy Loam Soils Overlying Hard Calcareous Pan

The hard pan on such sites hinders root growth and consequently the tree establishment. Therefore, deeper pits of size 90 cm deep and 60 cm diameter are dug and refilled with a mixture of weathered soil and farm yard manure in equal proportion. Thereafter, saucers of 1.5 m diameter are prepared around each tree.

Rocky and Semi Rocky Terrain with Scattered Soil Pockets

Wherever soil pockets or accumulations of soil exist, pits of 45 cm x 45 cm are dug. Half the soil is refilled and remaining half is made into crescent shape ridge of 15 cm high across the local slopes to harvest the runoff. Wherever slope is more, slanted trench ridge system of planting is very effective. For raising *Acacia tortilis* on ravine lands trench and pit method of soil working is suggested.

Acacia tortilis plantations are raised as block plantations as well as row plantations in the form of shelter belts along roads, canals, farms etc. In block plantations espacement is 3m x 3m on sandy plains, 5m x 5m on sand dunes and at 3m x 3m interval in shelterbelt plantations. In agroforestry and silvipastoral system different spacings have been tried. It was plantedat 4m x 4m spacing when intercropped with sorghum, pigeon pea and castor. In a silvipastural system with *Cenchrus ciliaris* as the inter crop, *Acacia tortilis*, at 5m x 10m spacing, produced the maximum biomass.

In arid regions, planting at a suitable depth (deeper planting) helps faster establishment of trees. Higher survival of deep planted seedlings of *Acacia tortilis* was reported. The seedlings raised in 30 cm deep tubes survived better than those raised in 18 cm deep tubes.

Acacia tortilis, though grows on poor sites and has low maintenance requirement, responds to better management of moisture and nutrients. Under rainfed conditions use of moisture harvesting and conservation practices such as micro-catchment approach, mulching, weeding,

etc. are essential for better establishment and growth of trees. It was reported that circular water catchments in combination with application of pond sediment and farmyard manure caused significantly better growth of trees. Run off collection by making inter row slopes of 20 per cent or bigger saucers of 1.5 m diameter have been found to increase tree growth dramatically in Indian arid region. Petroleum mulches have been found beneficial in raising *Acacia tortilis* on sand dunes in Iran. Rainfall in arid region is highly uncertain. Sometimes there are long dry spells resulting in heavy mortality of seedlings in the year of establishment. Therefore, supplemental waterings, are essential for the first two years. Three to four waterings per year are beneficial. It requires repeated waterings in first year of establishment. *Acacia tortilis* could be raised by irrigation with saline water of EC 4 to 6 m mhos/cm and SAR upto 15. In very adverse conditions like Lakhara Velara area of Kachchh in Gujarat (sea salinity coupled with aridity), use of drip irrigation is done in the simple form .Fertilizer application is not advised in *Acacia tortilis* plantations in arid regions. Fertilizer application under moisture stress conditions has detrimental effect on tree growth. However, when watering is ensured, trees may respond to fertilizer applications. It was reported that P is the most limiting nutrient in Savanna because of the strong translocation from the leaves to the twigs before leaf abscission.

Use of biofertilizers has tremendous potential in *Acacia tortilis*. The *Acacia tortilis* could be inoculated with fast growing strains of rhizobia. Seedlings of *Acacia tortilis* were found to develop rhizobial nodules 8 nodules/plant were observed when *Acacia tortilis* seedlings were inoculated with native rhizobia. Use of VA mycorrhizal fungus *Glomus mosseae* increased the seedling weight of *Acacia tortilis* by 170%. Root weight was also increased, and the indication was that mycorrhizae enhanced the drought tolerance.

Cultural Operations and Its Calendar

Weeding

Moisture plays a very crucial role in arid zone forestry. Six to eight weeks after planting, weeds are usually large enough to compete for water with the newly planted seedlings. It is therefore advisable to start weeding about 6 to 8 weeks after planting by using a hoe. In this operation weeds are dug out by roots. If necessary it is advised to go for second hoeing preferably before the weeds produce seeds so as to eradicate weeds from the area. Hoeing helps in preventing moisture loss through cracks formed especially in heavy soils where aeration is also improved. Weeding some times also helps avoiding the danger of fire.

Thinning

Trees need space, both for their crows and roots. They compete for root space soon after planted, first with weeds, later with the trees planted near them. The roots of the remaining trees spread further and can secure a larger supply of water and mineral nutrients, if some of the near by trees are removed. Density of the planting and the rate of thinning depends on the quality of site, rainfall and the extent and method of cultivation.

Pruning

Acacia tortilis is recommended to be lopped once a year for sustained production. The guidelines include not to lope tree of less than 2m or branches with a diameter greater than 7.5 cm, only lopping mature leaves, and always leaving the top third of the tree unlopped. The influence of pruning on the growth of *Acacia tortilis* was studied in N. Transvaal (South

Africa). Trees were tolerant of pruning and increased in size when all current season's shoots were removed. Shoot production increased after winter pruning and decreased after summer pruning.

Pests and Diseases

Numerous insect pests and diseases attack *Acacia tortilis* right from seed collection to plantation stage. Some important insects pests and their control measures are being described here.

Pests of Seeds

Four main groups of insects feed upon the seeds of *Acacia tortilis* in arid and semi-arid zones. These are Coleoptera (beetles), Hemiptera (plant Bugs) Lepidoptera (moth and butterflies) and Hymenoptera (phytophagus wasps). The Coleoptera (beetles) is the most important group of insects causing damage.

The larvae stage of Coleoptera, Lepidoptera and Hymenoptera cause damage by boring into the seed from an egg laid on the pod or in the pod tissue. Hemiptera (plant bugs) feed externally in the larvae and adult stages by inserting sucking mouth parts into pod tissue.

The Bruchidae beetles exert tremendous influence on the leguminous trees in tropics. Bruchidae are small insects. They are oval-shaped but appear slightly truncated at both ends. Most species have large compound eyes with a deep U-shaped cleft opening towards the front. The antennae arise from this cleft. Most bruchids have flattened scale like hairs covering the thorax and elytra.

Majority of bruchid species infesting the tree, lay eggs on the surface of the developing pods. Egg development takes 5-10 days from ovi-position. The larva's first priority on emergence is to gain access to the seed. Larvae first form a tunnel within the seed and then enlarge this to make a cell. During the period of growth, which may take 3-4 weeks or as many months, depending on prevailing climatic conditions, the larvae moult 4 times and then pupate. Before this happens preparation is made for the emergence of the adults. The area of the cell nearest to the out-side is cleared and enlarged and only a thin layer of testa is left which forms a circular window of semi-translucent material. On emergence the adults bite their way out leaving circular holes.

Control Measures

- **Preventive measures**
  The trees selected for seed production can have individual branches covered with sleaves or pollination bags made from woven glass fibre material to exclude the pest species.

- **Chemical control**
  Insecticides like Endosulphan and Tetrachlorvinphos are effective against bruchids.

- **Biological control**

Some parasites and predators can be successfully used to control the bruchids. Parasites attack on egg, larvae and pupal stages.

- **Egg parasitoids**
  Bruchid eggs, because of their position on the out side of a pod, are easily located by parasitoids. *Uscana* sumifumipennis has been reported be a group of egg parasitoids associated with bruchids.

- **Predators**
  Bruchids fall to complete their life cycle in presence of mites (Acarina) of the genus Pymotes. They feed on egg, larvae pupae and adults of bruchids. *Pymotis boylei* is most probably the species which attacks on bruchids.

Pests of Trees

Julodis sp. is the important pest of adult trees which causes severe defoliation.

Acacia tortilis is also susceptible to root knot nematode species, *Meloidogune javanica* and *M. incognita*.

Eriophyids cause gall formation on the leaflets and pinnules and in place of axillary buds. An out growth is created due to hyperplasia.

Powder pest beetles (*Sinoxylon anale* and *Sinoxylon crassum*) are the most important pests of timber which reduce felled timber to dust in weeks. These beetles can be effectively controlled by applying 1.5% linolane/endosulphan water emulsion on timbers.

The insect pests of *Acacia tortilis* and their nature of damage are given in the table below.

Insect	Damage	Family	Order
Baralade similes	Leaf defoliator	Lasiocampidae	Lepidoptera
Cryptothlea Crameri	-do-	Physchidae	-do-
Indarbela quadrinotata	Bark feeding caterpillar	Indarbelidae	-do-
Oxyrhachis tarandus	Sap sucker	Membracidae	Hemiptera
Caryedon gonagra	Attack pods and seeds	Bruchidae	Coleptera
Acmaeodera aurifera	Shoot and root borer	Buprestidae	-do-
Sinoxylon anale	Attack felled timber	Bostrychidae	-do-
Sinoxylon crassum	-do-	-do-	-do-
Stromatium barbatum	Attack dry logs	Cerambycidae	-do-
Lyctus africans	Attack sawn timber	Lyctidae	-do-

Arid region has menacing population of rodents causing heavy damage to the plantations by debarking and slicing of stem and roots. Trunks of *Acacia tortilis* have been observed to be

completely sliced by rodents. The important rodent species involved are *Gerbillus gleadowi* and *Meriones hurrianae*. Losses to the tune of 4.5-10 per cent in a period of two months have been reported in *Acacia tortilis* plantations in Nagaur district. To control rodent attack on plantations following measures should be undertaken. The active burrow should be checked and prebaiting (one kg bajra grain and 30 g groundnut/sesame oil) is suggested for two days. On the fifth day, 2 per cent zinc phosphide should be added to the bait (1 kg pearlmillet + 20 g vegetable oil + 20 g zinc phosphide) and rolled deep into the active burrows at the rate of 6 g per burrow. After 8-10 days of operation, Bromadiolone (0.005 per cent) ready to use loose bait or wax cakes should be rolled deep in the freshly opened burrows for managing the residual population of rodents.

Diseases

A number of pathogens attack *Acacia tortilis* right from seedling stage to established plantations and also during storage of seeds. Diseases such as seed rot, wilt and collar rot attack seedlings of *Acacia tortilis*. Tip dying of growing shoots is encountered both in nursery and in young plantations. Old plantations of *Acacia tortilis* were found to suffer from ganoderma root rot, heart rot (Fomes sp.) and die back in Pushkar (Ajmer) and in other localities. Various diseases of *Acacia tortilis* and their control measures are discussed.

- **Seed rot**

  Seed rot commonly occurs in storage when immature or cracked seeds are stored in high moisture conditions. The genera belonging to fungi imperfecti i.e. *Aspergillus niger*, *A. flavus*, *Penicillium* sp. and *Alternaria* sp. attack the cracked areas of seed and cause rot which spoils the seed in storage. Treatment with mercury based fungicides i.e., Emisan -6 @ 0.1% or Captan @ 0.2% was found effective in checking the fungal infection during storage. Keeping moisture free conditions and isolation of damaged seeds, reduce the chances of infection.

- **Tip dying**

  Tip dying incited by *Botrydiplodia theobromae* causes dying of young shoots in nurseries and in young plantations of *Acacia tortilis*. The pathogen in fact acts as a secondary invader after attack of tip borer. Combination of fungicide and insecticide (Blitox @ 2% + Metasystox @ 0.05%) applied as foliar spray controls the disease.

- **Fusarium wilt**

  Yellowing and early defoliation of leaves are the characteristic symptoms of fusarium wilt followed by death of seedlings. Water logging and high moisture conditions favour the infection of wilt in nursery plants. Avoiding water logging conditions and soil drenching with Bavistin @ 0.1% or Dithane Z-78 @ 2% prevent the disease infection.

- **Collar rot**

  Macrophomina phaseolina, the casual organism of collar rot infects young seedlings of *Acacia tortilis*. Hot and dry climatic conditions favour the occurrence of disease. Soil drenching with Bavistin (0.1%) or Dithane M-45 (0.2%) controls the disease attack.

- **Ganoderma root rot**

  Ganoderma root rot which is caused by *Ganoderma lucidum* attacks old plantations of *Acacia tortilis*. The disease occurs throughout Rajasthan and Gujrat. The old infected

stumps and roots act as source of infection. Spread of disease takes place through root to root contact. Hot and dry climate favours the spread of disease. The disease can be minimized by avoiding pure plantations and raisisng resistant provenances.

- **Heart rot**
  Heart rot is caused by *Fomes* sp. It is a wound parasite which enters through the mechanically damaged branches or hole made by the borers. Sporophores are perennial and dark to light brown in colour. The disease can be minimized by avoiding untimely lopping and mechanical injury.

- **Die back**
  Die back caused by *Irpex flavus*, attack on the broken branches in *Acacia tortilis* plantations. Light yellow coloured, sessile fruiting bodies of fungus are generally observed in the lower surface of the branch. Disease can be managed by pruning of infected portions and applying Chaubattia paste.

- **Bark canker**
  Bark canker caused by *Botryodiplodia theobromae*, has been reported on old plantations at Pushkar, Ajmer. Sun scorch causes splitting of bark and then the fungus enters through these cracked portions and spoils sap wood. Sometimes attack of borer and termites is also reported.

- **Leaf rust**
  Leaf rust caused by *Ravenelia acaciae* is characterized by early defoliation in nurseries and young plantations. The disease can be controlled by spray of copper based fungicides at monthly intervals.

Yield and Management of the Species

Acacia tortilis has been found to be the fast growing species in arid conditions. However, its growth varies depending on site conditions and management practices. Three year old plantation of *Acacia tortilis* at Jodhpur attained mean ht of 4.5m and collar diameter 12.3 cm at 3 year of age. However, on a shallow sandy loam soil overlying a hard calcareous pan at Pali, they were only 1.6 m tall and had 4.1 cm collar diameter. Growth studies at different site conditions in Indian arid zone indicated that *Acacia tortilis* registered a mean annual increment of 61, 56.1, 44, 57.5 and 55.5 cm on deep sandy soils, shifting sand dunes, rocky and semi rocky refractory sites, sandy loam shallow soils overlying hard calcareous pan beneath, respectively (shown in the table). Mean annual height and D.B.H. increments of *Acacia tortilis* were reported to be 78 cm and 1.1 cm, respectively, over 8 years at Jodhpur. At 10 years of age *Acacia tortilis* attained a height of 641 cm and D.B.H. 14.1 cm which increased to 785 cm and 20 cm, respectively at 14 years of age. Trees raised from transplanted seedlings exhibited better growth than by sowing. Height of 5 year old trees under two situations was 312 cm and 182 cm, respectively. At a site having 350 mm rainfall in Pakistan, *Acacia tortilis* attained a height of 3.1 m at 3 year of age.

When raised as shelterbelt at Jodhpur, *Acacia tortilis* attained a height more than six metres after seven years of planting.

In Indira Gandhi Nahar Project area of Indian desert, *Acacia tortilis* raised on sand dunes with limited irrigation at 3m x 3m spacing attained a height of 3.60m and G.B.H. 10cm at 3 years of age. The M.A.I. of 6 m^3/ha was reported.

Performance of *Acacia tortilis* under different site conditions in arid region (Western Rajasthan).

Location	Mean annual rainfall (mm)	Soil type	Age of plantation (years)	Mean growth (cm)	Survival (%) (Ht.)	(DBH.)
Jodhpur	320	Deep sandy soil	9	599	13.2	100
Pali	440	Shallow sandy loam overlying hard calcareous pan below 22 cm	9	547	10.8	98
Kailana (Jodhpur distt.)	320	Rocky site with scattered soil pockets	6	304	7.5	100
Beriganga (Jodhpur distt.)	320	Semi Rocky site with accumulation of transported soil	5	320	8.0	100
Barmer	275	Shifting sand dunes	5	306	7.3	98
Jhunjhunu	445	-do-	6	460	7.6	100
Bikaner	265	-do-	9	480	8.0	90

Source: Technical Bulletin No.5 (1979), CAZRI, Jodhpur.

In an average plantation, on a 10 year rotation, the yield per tree was estimated to be 80-100 kg fuel, 100 kg fodder, and 20-25 kg of thorny twigs and branches for fencing. Fuel yield per hectare after 10 years is estimated to be 30 tonnes or an average of 3 tonnes/ha/year. Higher yields upto 5 tonnes per hectare could be obtained by planting at closer spacings and in good soils or with higher moisture.

Full grown tree of *Acacia tortilis* gives, on average, 10-12 kg leaf and 4-6 kg pod yield in western Rajasthan. In Harayana, about 15 to 20 kg of green fodder has been reported from *Acacia tortilis. Acacia tortilis* yields small wood which is used for fence posts and for small implements. The bole and branch wood production of 363.6 kg per tree (93.14 t/ha) under wider tree spacing has been reported.

Economics of Planting the Species

Comparative studies on economics of planting different tree species in western Rajasthan, indicate that on a 10 year felling cycle, *Acacia tortilis* proved to be most economic with a net cost benefit ratio of 29% per hectare, whereas the other species had negative cost benefit ratio. A cost benefit ratio of 1:2 from 10 year rotation of *Acacia tortilis* planted at 5m x 5m spacing at Jodhpur was reported.

Planting *Acacia tortilis* in a silvipastoral system has been found more remunerative than its pure plantation. Estimates of total revenue from fuel wood and fodder over the 7 year period showed that a combination of trees (5 x 10 m spacing) with grass (*Cenchrus ciliaris*) produced greater income than trees or grasses alone.

Source Institutions for Detailed Information

1. Principal Chief Conservator of Forests, Van Bhawan, Jaipur (Rajasthan).
2. Conservator of Forests, Jodhpur Circle, Jodhpur (Rajasthan).
3. Forest Research Institute (ICFRE), New Forest, Dehradun (Uttranchal).
4. Arid Forest Research Institute, Jodhpur (Rajasthan).

Source: Indian Council of Forestry Research and Education, Dehradun. *Acacia tortilis*. Dehradun, Forest Research Institute. 20p.